2. *Hardware*
   - 2.1 *Handheld devices*: 100 devices estimated by contractor at $600 per unit.
   - 2.2 *Servers*: Four servers estimated at $4,000 each, based on recent server purchases.
3. *Software*
   - 3.1 *Licensed software:* License costs will be negotiated with each supplier. Because there is a strong probability of large future contracts and great publicity if the system works well, costs are expected to be lower than usual. A cost of $200/handheld device will be used.
   - 3.2 *Software development:* This estimate will include two approaches: a labor estimate and a function point estimate. The higher estimate will be used. If the estimates differ by more than 20 percent, the project will require a third estimation approach. The supplier who developed the proof of concept project will provide the labor estimate input, and local technical experts will make the function point estimates.
4. *Testing*: Based on similar projects, testing will be estimated as 10 percent of the total hardware and software cost.
5. *Training and support*: Based on similar projects, training will be estimated on a per-trainee basis, plus travel costs. The cost per trainee (100 total) will be $500, and travel will cost $700/day/person for the instructors and project team members. The team estimates that the project will require a total of 12 travel days. Labor costs for the project team members will be added to this estimate because they will assist in training and providing support after the training. The labor hours estimate for team members is 1,920 hours total.
6. *Reserves*: As directed, reserves will be estimated at 20 percent of the total estimate.

The project team then develops a cost model using the preceding information. Figure 7-2 shows a spreadsheet that summarizes the costs by WBS item. Notice that the WBS items are listed in the first column, and some are broken down into more detail based on how the costs are estimated. For example, the project management category is broken down into three subcategories because the project manager, team members, and contractors will each perform project management activities that must be accounted for in the costs. Also notice the columns for entering the number of units or hours and the cost per unit or hour. Several items are estimated using this approach. The estimate includes some short comments, such as reserves being 20 percent of the total estimate. Also notice that you can easily change several input variables, such as number of hours or cost per hour, to revise the estimate.

The asterisk by the software development item in Figure 7-2 provides reference for detailed information on how this more complicated estimate was made. Recall the assumption that software development must be estimated using two approaches, and that the higher estimate would be used as long as both estimates differed by no more than 20 percent. The labor estimate was used in this case because it was slightly higher than the function point estimate ($594,000 versus $567,000). Figure 7-3 shows how the function point estimate was made, and the Best Practice feature provides more information on function point estimates. As you can see, many assumptions were made in producing the function point estimate. By putting the information into a cost model, you can easily change several inputs to adjust the estimate.

the cost rate is estimated to be $600 per unit. The project will require four additional servers to run the software required for the devices and for managing the project.

- The project requires purchased software licenses for accessing the GPS and three other external systems. Software development includes developing a graphical user interface for the devices, an online help system, and a new module for tracking surveyor performance using the device.
- Testing costs should be low due to the success of the prototype project. An estimate based on multiplying the total hardware and software estimates by 10 percent should be sufficient.
- Training will include instructor-led classes in five different locations. The project team believes it will be best to outsource most of the training, including developing course materials, holding the sessions, and providing help desk support for three months as the surveyors start using their devices in the field.
- Because several risks are related to this project, include 20 percent of the total estimate as reserves.
- You must develop a computer model for the estimate so that you can easily change several inputs, such as the number of labor hours for various activities or labor rates.

Fortunately, the project team can easily access cost estimates and actual information from similar projects. A great deal of information is available from the proof of concept project, and the team can also talk to contractors from the past project to help them develop the estimate. Computer models are also available, such as a software-estimating tool based on function points. **Function points** are a means of measuring software size based on what the software does for end users. Function points are comprised of inputs, outputs, inquiries, internal data, and external interface data. Allen Albrecht initially defined this metric in the 1970s, and today it is the international standard used to measure software size. It is the most commonly used software size metric, followed by lines of code.[15]

Because the estimate must be provided by WBS and by month, the team first reviews a draft of the project schedule. The team decides to begin by estimating the cost of each WBS item and then determine when the work will be performed, even though costs may be incurred at different times than when the work is performed. The team's budget expert has approved this approach for the estimate. The team has further assumptions and information for estimating the costs for each WBS category:

1. *Project management*: Estimate based on compensation for the part-time project manager and 25 percent of the four team members' time. The budget expert for this project suggested using a labor rate of $100/hour for the project manager and $75/hour for each team member, based on working an average of 160 hours per month, full time. Therefore, the total hours for the project manager under this category are 960 (160/2 * 12 = 960). Costs are also included for the four project team members who are each working 25 percent of their time: a total of 160 hours per month for all project personnel (160 * 12 = 1920). An additional amount for all contracted labor is estimated by multiplying 10 percent of the total estimates for software development and testing costs (10% * ($594,000 + $69,000)).

simpler than a real cost estimate, but it illustrates a process to follow and uses several of the tools and techniques described earlier.

Before beginning a cost estimate, you must gather as much information as possible about the project and ask how the organization plans to use the cost estimate. If the cost estimate will be the basis for contract awards and performance reporting, it should be a definitive estimate and as accurate as possible, as described earlier.

It is also important to clarify the ground rules and assumptions for the estimate. The Surveyor Pro project cost estimate includes the following ground rules and assumptions:

- This project was preceded by a detailed study and proof of concept to show that it was possible to develop the hardware and software needed by surveyors and link the new devices to existing information systems. The proof of concept project produced a prototype handheld device and much of the software to provide basic functionality and link to the Global Positioning System (GPS) and other government databases used by surveyors. Some data is available to help estimate future labor costs, especially for the software development, and to help estimate the cost of the handheld devices.
- The main goal of this project is to produce 100 handheld devices, continue developing the software (especially the user interface), test the new system in the field, and train 100 surveyors in selected cities to use the new system. A follow-up contract is expected for a much larger number of devices based on the success of this project.
- The project has the following WBS:
  1. Project management
  2. Hardware
     - 2.1 Handheld devices
     - 2.2 Servers
  3. Software
     - 3.1 Licensed software
     - 3.2 Software development
  4. Testing
  5. Training and support
  6. Reserves
- Costs must be estimated by WBS and by month. The project manager will report progress on the project using earned value analysis, which requires this type of estimate.
- Costs will be provided in U.S. dollars. Because the project length is one year, inflation will not be included.
- The project will be managed by the government's project office. The project will require a part-time project manager and four team members. The team members will help manage various parts of the project and provide their expertise in the areas of software development, training, and support. Their total hours will be allocated as follows: 25 percent to project management, 25 percent to software development, 25 percent to training and support, and 25 percent to non-project work.
- The project involves purchasing the handheld devices from the same company that developed the prototype device. Based on producing 100 devices,

- *Estimates are done too quickly*. Developing an estimate for a large software project is a complex task that requires significant effort. Many estimates must be done quickly and before clear system requirements have been produced. For example, the Surveyor Pro project described in the opening case involves a lot of complex software development. Before fully understanding what information surveyors need in the system, someone would have to create a ROM estimate and budgetary estimates for this project. Rarely are the more precise, later cost estimates less than the earlier estimates for IT projects. It is important to remember that estimates are done at various stages of the project, and project managers need to explain the rationale for each estimate.
- *People lack estimating experience*. The people who develop software cost estimates often do not have much experience with cost estimation, especially for large projects. They also do not have enough accurate, reliable project data on which to base estimates. If an organization uses good project management techniques and develops a history of keeping reliable project information, including estimates, the organization's estimates should improve. Enabling IT people to receive training and mentoring on cost estimating will also improve cost estimates.
- *Human beings are biased toward underestimation*. For example, senior IT professionals or project managers might make estimates based on their own abilities and forget that many younger people will be working on a project. Estimators might also forget to allow for extra costs needed for integration and testing on large IT projects. It is important for project managers and top management to review estimates and ask important questions to make sure the estimates are not biased.
- *Management desires accuracy*. Management might ask for an estimate but really want a more accurate number to help them create a bid to win a major contract or get internal funding. This problem is similar to the situation discussed in Chapter 6, Project Time Management, in which top managers or other stakeholders want project schedules to be shorter than the estimates. It is important for project managers to help develop good cost and schedule estimates and to use their leadership and negotiation skills to stand by those estimates.

It is also important to be cautious with initial estimates. Top management never forgets the first estimate and rarely, if ever, remembers how approved changes affect the estimate. It is a never-ending and crucial process to keep top management informed about revised cost estimates. It should be a formal process, albeit a possibly painful one.

7.4d How to Develop a Cost Estimate

One of the best ways to learn how the cost estimating process works is by studying sample cost estimates. Every cost estimate is unique, just as every project is unique. You can see a short sample cost estimate in Chapter 3 for JWD Consulting's project management intranet site project. You can also view the ResNet cost estimate on the companion website for this text.

This section includes a step-by-step approach for developing a cost estimate for the Surveyor Pro project described in the opening case. Of course, it is much shorter and

preparing cost estimates must have the needed expertise to determine whether certain parts of the project will be more or less expensive than analogous projects. For example, estimators often try to find a similar project and then customize or modify it for known differences. However, if the project to be estimated involves a new programming language or working with a new type of hardware or network, the analogous estimate technique could easily result in too low an estimate.

Bottom-up estimates involve estimating the costs of individual work items or activities and summing them to get a project total. This approach is sometimes referred to as activity-based costing. The size of the individual work items and the experience of the estimators drive the accuracy of the estimates. If a detailed WBS is available for a project, the project manager could require each person who is responsible for a work package to develop a cost estimate for that work package, or at least an estimate of the amount of resources required. Someone in the financial area of an organization often provides resource cost rates, such as labor rates or costs per pound of materials, which can be entered into project management software to calculate costs. The software automatically calculates information to create cost estimates for each level of the WBS and finally for the entire project. Using smaller work items increases the accuracy of the cost estimate because the people assigned to do the work develop the cost estimate instead of someone unfamiliar with the work. The drawback with bottom-up estimates is that they are usually time-intensive and therefore expensive to develop.

Three-point estimates involve estimating the most likely, optimistic, and pessimistic costs for items. You can use a formula like the PERT weighted average described in Chapter 6, Project Time Management, to calculate cost estimates or use a Monte Carlo simulation, described in Chapter 11, Project Risk Management.

Parametric estimating uses project characteristics (parameters) in a mathematical model to estimate project costs. For example, a parametric model might provide an estimate of $50 per line of code for a software development project based on the programming language the project is using, the level of expertise of the programmers, the size and complexity of the data involved, and so on. Parametric models are most reliable when the historical information used to create the model is accurate, the parameters are readily quantifiable, and the model is flexible in terms of the project's size. Many projects involving building construction use parametric estimates based on cost per square foot. The costs vary based on the quality of construction, location, materials, and other factors. In practice, many people find that using a combination or hybrid approach with analogous, bottom-up, three-point, and parametric estimating provides the best cost estimates.

Other considerations when preparing cost estimates are how much to include in reserves, as described earlier; the cost of quality, as described in Chapter 8, Project Quality Management; and other cost estimating methods such as vendor bid analysis, as described in Chapter 12, Project Procurement Management. Using software to assist in cost estimating is described later in this chapter.

7.4c Typical Problems with IT Cost Estimates

Although many tools and techniques can assist in creating project cost estimates, many IT project cost estimates are still very inaccurate, especially those for new technologies or software development. Tom DeMarco, a well-known author on software development, suggests four reasons for these inaccuracies and some ways to overcome them.[14]

TABLE 7-2 Maximum FTE by department by year

Department	Year 1	Year 2	Year 3	Year 4	Year 5	Totals
Information systems	24	31	35	13	13	116
Marketing systems	3	3	3	3	3	15
Reservations	12	29	33	9	7	90
Contractors	2	3	1	0	0	6
Totals	41	66	72	25	23	227

The number and type of cost estimates vary by application area. For example, the Association for the Advancement of Cost Engineering (AACE) International identifies five types of cost estimates for construction projects: order of magnitude, conceptual, preliminary, definitive, and control. The main point is that estimates are usually done at various stages of a project and should become more accurate as time progresses.

In addition to creating cost estimates for the entire project and activity cost estimates, it is also important to provide supporting details for the estimates and updates to project documents. The supporting details include the ground rules and assumptions used in creating the estimate, a description of the project (such as scope statement and WBS) used as a basis for the estimate, and details on the cost estimation tools and techniques used to create the estimate. These supporting details should make it easier to prepare an updated estimate or similar estimate as needed.

Another important consideration in preparing cost estimates is labor costs, because a large percentage of total project costs are often labor costs. Many organizations estimate the number of people or hours they need by department or skill over the life cycle of a project. For example, when Northwest Airlines developed initial cost estimates for its reservation system project, ResNet, it determined the maximum number of full-time equivalent (FTE) staff it could assign to the project each year by department. Table 7-2 shows this information. Note the small number of contractors that Northwest Airlines planned to use. Labor costs are often much higher for contractors, so it is important to distinguish between internal and external resources. (See the companion website for this text to read the detailed case study on ResNet, including cost estimates.)

7.4b Cost Estimation Tools and Techniques

As you can imagine, developing a good cost estimate is difficult. Fortunately, several tools and techniques are available to assist in creating one. These tools and techniques include expert judgment, analogous cost estimating, bottom-up estimating, three-point estimating, parametric estimating, the cost of quality, project management estimating software, vendor bid analysis, and reserve analysis.

Analogous estimates, also called **top-down estimates**, use the actual cost of a previous, similar project as the basis for estimating the cost of the current project. This technique requires a good deal of expert judgment and is generally less costly than other techniques, but it is also less accurate. Analogous estimates are most reliable when the previous projects are similar in fact, not just in appearance. In addition, the groups

- A **rough order of magnitude (ROM) estimate** provides an estimate of what a project will cost. A ROM estimate can also be referred to as a ballpark estimate, a guesstimate, a swag, or a broad gauge. This type of estimate is done very early in a project or even before a project is officially started. Project managers and top management use this estimate to help make project selection decisions. The time frame for this type of estimate is often three or more years prior to project completion. A ROM estimate's accuracy is typically −50 percent to +100 percent, meaning the project's actual costs could be 50 percent below the ROM estimate or 100 percent above. For example, the actual cost for a project with a ROM estimate of $100,000 could range from $50,000 to $200,000. For IT project estimates, this accuracy range is often much wider. Many IT professionals automatically double estimates for software development because of the history of cost overruns on IT projects.
- A **budgetary estimate** is used to allocate money into an organization's budget. Many organizations develop budgets at least two years into the future. Budgetary estimates are made one to two years prior to project completion. The accuracy of budgetary estimates is typically −10 percent to +25 percent, meaning the actual costs could be 10 percent less or 25 percent more than the budgetary estimate. For example, the actual cost for a project with a budgetary estimate of $100,000 could range from $90,000 to $125,000.
- A **definitive estimate** provides an accurate estimate of project costs. Definitive estimates are used for making many purchasing decisions for which accurate estimates are required and for estimating final project costs. For example, if a project involves purchasing 1,000 personal computers from an outside supplier in the next three months, a definitive estimate would be required to aid in evaluating supplier proposals and allocating the funds to pay the chosen supplier. Definitive estimates are made one year or less prior to project completion. A definitive estimate should be the most accurate of the three types of estimates. The accuracy of this type of estimate is normally –5 percent to +10 percent, meaning the actual costs could be 5 percent less or 10 percent more than the definitive estimate. For example, the actual cost for a project with a definitive estimate of $100,000 could range from $95,000 to $110,000. Table 7-1 summarizes the three basic types of cost estimates.

TABLE 7-1 Types of cost estimates

Type of Estimate	When Done	Why Done	How Accurate
Rough order of magnitude (ROM)	Very early in the project life cycle, often 3–5 years before project completion	Provides estimate of cost for selection decisions	−50% to +100%
Budgetary	Early, 1–2 years out	Puts dollars in the budget plans	−10% to +25%
Definitive	Later in the project, less than 1 year out	Provides details for purchases, estimates actual costs	−5% to +10%