Surveyor Pro Project Cost Estimate Created October 5

WBS Items	# Units/Hrs.	Cost/Unit/Hr.	Subtotals	WBS Level 2 Totals	% of Total
1. Project Management				**$306,300**	**20%**
Project manager	960	$100	$96,000		
Project team members	1920	$75	$144,000		
Contractors (10% of software development and testing)			$66,300		
2. Hardware				**$76,000**	**5%**
2.1 Handheld devices	100	$600	$60,000		
2.2 Servers	4	$4,000	$16,000		
3. Software				**$614,000**	**40%**
3.1 Licensed software	100	$200	$20,000		
3.2 Software development*			$594,000		
4. Testing (10% of total hardware and software costs)			$69,000	**$69,000**	**5%**
5. Training and Support				**$202,400**	**13%**
Trainee cost	100	$500	$50,000		
Travel cost	12	$700	$8,400		
Project team members	1920	$75	$144,000		
Subtotal			$1,267,700		
6. Reserves (20% of total estimate)			$253,540	**$253,540**	**17%**
Total project cost estimate				**$1,521,240**	

*See software development estimate.

FIGURE 7-2 Surveyor Pro project cost estimate

Surveyor Pro Software Development Estimate Created October 5

1. Labor Estimate	# Units/Hrs.	Cost/Unit/Hr.	Subtotals	**Calculations**
Contractor labor estimate	3000	$150	$450,000	3000*150
Project team member estimate	1920	$75	$144,000	1920*75
Total labor estimate			**$594,000**	Sum above two values
2. Function point estimate	Quantity	Conversion Factor	Function Points	**Calculations**
External inputs	10	4	40	10*4
External interface files	3	7	21	3*7
External outputs	4	5	20	4*5
External queries	6	4	24	6*4
Logical internal tables	7	10	70	7*10
Total function points			**175**	Sum above function point values
Java 2 language equivalency value			46	Assumed value from reference
Source lines of code (SLOC) estimate			8,050	175*46
Productivity×KSLOC^Penalty (in months)			29.28	3.13*8.05^1.072 (see reference)
Total labor hours (27 hours/function point)*			4,725	27*175
Cost/labor hour ($120/hour)			$120	Assumed value from budget expert
Total function point estimate			**$567,000**	4,725*120

* Based on historical data

FIGURE 7-3 Surveyor Pro software development estimate

BEST PRACTICE

Software expert and author Alvin Alexander shared his knowledge on the challenging topic of estimating software development costs in several presentations and a book called *Cost Estimating in an Agile Development Environment* (2015). Alexander describes how to use Function Point Analysis (FPA) techniques based on his personal experience working on a multimillion dollar software project over five years. (Recall that function points are a means of measuring software size in terms that are meaningful to end users.) The project initially used a more traditional, waterfall approach but later moved to a more agile approach.

Alexander explained that at the beginning of the project, when requirements documents were very long and detailed, the programming work took about three times the amount of time that was required to create the requirements (a ratio of 3:1). Later in the project, after their client trusted them more and actually knew the developers by name, the requirements were much shorter (more like user stories), and the ratio of programming work to requirements work was much higher—6:1 to 9.5:1. User stories describe what users do or need to do as part of their job function, focusing on the "who," "what," and "why" of a requirement in a simple, concise way. Developers can analyze user stories to estimate the number of internal logical files (ILFs)—a group of logically related data that resides entirely within the application boundary and is maintained through external inputs. You can then use the ILFs to approximate the number of function points, and then multiply by a certain number of hours/function point to estimate the person-hours needed to develop the software.[16]

World class organizations take about half as long as average organizations (19 versus 35 hours) to develop one function point. They use consistent documentation (for requirements, analysis, and use cases), they follow consistent processes for developing software, and their technical staff focus on business instead of technology. "It is impossible to separate world-class organizations from world-class metrics organizations."[17]

It is very important to have several people review the project cost estimate. It is also helpful to analyze the total dollar value as well as the percentage of the total amount for each major WBS category. For example, a senior executive could quickly look at the Surveyor Pro project cost estimate and decide if the numbers are reasonable and the assumptions are well documented. In this case, the government had budgeted $1.5 million for the project, so the estimate was in line with that amount. The WBS Level 2 items, such as project management, hardware, software, and testing, also seemed to be at appropriate percentages of the total cost based on similar past projects. In some cases, a project team might also be asked to provide a range estimate for each item instead of one discrete amount. For example, the team might estimate that the testing costs will be between $60,000 and $80,000 and document their assumptions in determining those values. It is also important to update cost estimates, especially if any major changes occur on a project.

After the total cost estimate is approved, the team can then allocate costs for each month based on the project schedule and when costs will be incurred. Many organizations also require that the estimated costs be allocated into certain budget categories, as described in the next section.

7.5 DETERMINING THE BUDGET

Determining the budget involves allocating the project cost estimate to individual material resources or work items over time. These material resources or work items are based on the activities in the work breakdown structure for the project. The cost management plan, scope baseline, activity cost estimates, basis of estimates, project schedule, resource calendars, risk register, agreements, and organizational process assets are all inputs for determining the budget. The main goal of the cost budgeting process is to produce a cost baseline for measuring project performance and to determine project funding requirements. The process may also result in project documents updates, such as items being added, removed, or modified in the scope statement or project schedule.

The Surveyor Pro project team would use the cost estimate from Figure 7-2 along with the project schedule and other information to allocate costs for each month. Figure 7-4 provides an example of a cost baseline for this project. A **cost baseline** is a time-phased budget that project managers use to measure and monitor cost performance. Again, it's important for team members to document assumptions they made when developing the cost baseline and have several experts review it.

Most organizations have a well-established process for preparing budgets. For example, many organizations require budget estimates to include the number of FTE for each month of the project. One FTE normally means 40 hours of work. One person could be assigned full-time to a project to provide one FTE, or two people could be assigned half-time to provide one FTE. This number provides the basis for estimating total compensation costs each year. Many organizations also want to know the amount of money projected to be paid to suppliers for their labor costs or other purchased goods and services. Other common budget categories include travel, depreciation, rents and leases, and other supplies and expenses. It is important to understand these budget categories before developing an estimate to make sure data is collected accordingly. Organizations use this information to track costs across projects and non-project work and to look for ways to reduce costs. They also use the information for legal and tax purposes.

Surveyor Pro Project Cost Baseline Created October 10*

	Months												
WBS Items	1	2	3	4	5	6	7	8	9	10	11	12	Totals
1. Project Management													
1.1 Project manager	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	96,000
1.2 Project team members	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	144,000
1.3 Contractors		6,027	6,027	6,027	6,027	6,027	6,027	6,027	6,027	6,027	6,027	6,027	66,300
2. Hardware													
2.1 Handheld devices				30,000	30,000								60,000
2.2 Servers				8,000	8,000								16,000
3. Software													
3.1 Licensed software				10,000	10,000								20,000
3.2 Software development		60,000	60,000	80,000	127,000	127,000	90,000	50,000					594,000
4. Testing			6,000	8,000	12,000	15,000	15,000	13,000					69,000
5. Training and Support													
5.1 Trainee cost									50,000				50,000
5.2 Travel cost									8,400				8,400
5.3 Project team members							24,000	24,000	24,000	24,000	24,000	24,000	144,000
6. Reserves				10,000	10,000	30,000	30,000	60,000	40,000	40,000	30,000	3,540	253,540
Totals	20,000	86,027	92,027	172,027	223,027	198,027	185,027	173,027	148,427	90,027	80,027	53,567	1,521,240

*See the lecture slides for this chapter on the companion website for a larger view of this and other figures in this chapter. Numbers are rounded, so some totals appear to be off.

FIGURE 7-4 Surveyor Pro project cost baseline

In addition to providing a cost baseline, estimating costs for each major project activity over time provides project managers and top management with a foundation for project cost control, as described in the next section. Cost budgeting, as well as requested changes or clarifications, may result in updates to the cost management plan, which is a subsidiary part of the project management plan. See Appendix A for information on using Project 2013 for cost control.

Cost budgeting also provides information for project funding requirements. Some projects have all funds available when the project begins, but others must rely on periodic funding to avoid cash flow problems. If the cost baseline shows that more funds are required in certain months than are expected to be available, the organization must make adjustments to avoid financial problems.

7.6 CONTROLLING COSTS

Controlling project costs includes monitoring cost performance, ensuring that only appropriate project changes are included in a revised cost baseline, and informing project stakeholders of authorized changes to the project that will affect costs. The project management plan, project funding requirements, work performance data, and organizational process assets are inputs for controlling costs. Outputs of this process are work performance information, cost forecasts, change requests, project management plan updates, project documents updates, and organizational process asset updates.

Several tools and techniques assist in project cost control. As shown in Appendix A, Project 2013 has many cost management features to help you enter budgeted costs, set a baseline, enter actuals, calculate variances, and run various cost reports.

In addition to using software, however, you need a change control system to define procedures for changing the cost baseline. This cost control change system is part of the integrated change control system described in Chapter 4, Project Integration Management. Because many projects do not progress exactly as planned, new or revised cost estimates are often required, as are estimates to evaluate alternate courses of action.

Performance review meetings can be a powerful tool for helping to control project costs. People often perform better when they know they must report on their progress. Another very important tool for cost control is performance measurement. Although many general accounting approaches are available for measuring cost performance, earned value management (EVM) is a powerful cost control technique that is unique to the field of project management.

7.6a Earned Value Management

Earned value management (EVM) is a project performance measurement technique that integrates scope, time, and cost data. Given a cost performance baseline, project managers and their teams can determine how well the project is meeting scope, time, and cost goals by entering actual information and then comparing it to the baseline. A **baseline** is the budget figure in the original project plan plus approved changes. Actual information includes whether or not a WBS item was completed, approximately how much of the work was completed, when the work actually started and ended, and how much the completed work actually cost.

In the past, earned value management was used primarily on large government projects. Today, however, more and more companies are realizing the value of using this tool

to help control costs. Moreover, a discussion by several academic experts in earned value management and a real practitioner revealed the need to clarify how to calculate earned value. Brenda Taylor, a senior project manager for P2 Project Management Solutions in Johannesburg, South Africa, questioned the accuracy of calculating earned value simply by multiplying the planned value to date by a percentage complete value. She suggested using the rate of performance instead, as described below.

Earned value management involves calculating three values for each activity or summary activity from a project's WBS.

1. The **planned value (PV)**, also called the budget, is the portion of the approved total cost estimate planned to be spent on an activity during a given period. Table 7-3 shows an example of earned value calculations. Suppose that a project included a summary activity of purchasing and installing a new web server. Suppose further that, according to the plan, it would take one week and cost a total of $10,000 for the labor hours, hardware, and software. Therefore, the planned value (PV) for the activity that week is $10,000.
2. The **actual cost (AC)** is the total direct and indirect costs incurred in accomplishing work on an activity during a given period. For example, suppose that it actually took two weeks and cost $20,000 to purchase and install the new web server. Assume that $15,000 of these actual costs were incurred during Week 1 and $5,000 was incurred during Week 2. These amounts are the actual cost (AC) for the activity each week.
3. The **earned value (EV)** is an estimate of the value of the physical work actually completed. EV is based on the original planned costs for the project or activity and the rate at which the team is completing work on the project or activity to date. The **rate of performance (RP)** is the ratio of actual work completed to the percentage of work planned to have been completed at any given time during the life of the project or activity. For example, suppose that the server installation was halfway completed by the end of Week 1. The rate of performance would be 50 percent because by the end of Week 1, the planned schedule reflects that the task should be complete but only 50 percent of the work has been completed. In Table 7-3, the earned value estimate after one week is therefore $5,000.[18]

TABLE 7-3 Earned value calculations for one activity after Week 1

Activity	Week 1
Earned value (EV)	5,000
Planned value (PV)	10,000
Actual cost (AC)	15,000
Cost variance (CV)	−10,000
Schedule variance (SV)	−5,000
Cost performance index (CPI)	33%
Schedule performance index (SPI)	50%

TABLE 7-4 Earned value formulas

Term	Formula
Earned value (EV)	EV = PV to date * BP
Cost variance (CV)	CV = EV − AC
Schedule variance (SV)	SV = EV − PV
Cost performance index (CPI)	CPI = EV/AC
Schedule performance index (SPI)	SPI = EV/PV
Estimate at completion (EAC)	EAC = BAC/CPI
Estimated time to complete	Original time estimate/SPI

The earned value calculations in Table 7-4 are carried out as follows:

$$EV = 10{,}000 * 50\% = 5{,}000$$
$$CV = 5{,}000 - 15{,}000 = -10{,}000$$
$$SV = 5{,}000 - 10{,}000 = -5{,}000$$
$$CPI = 5{,}000/15{,}000 = 33\%$$
$$SPI = 5{,}000/10{,}000 = 50\%$$

Table 7-4 summarizes the formulas used in earned value management. Note that the formulas for variances and indexes start with EV, the earned value. Variances are calculated by subtracting the actual cost or planned value from EV, and indexes are calculated by dividing EV by the actual cost or planned value. After you total the EV, AC, and PV data for all activities on a project, you can use the CPI and SPI to project how much it will cost and how long it will take to finish the project based on performance to date. Given the budget at completion and original time estimate, you can divide by the appropriate index to calculate the estimate at completion (EAC) and estimated time to complete, assuming that performance remains the same. There are no standard acronyms for the terms *estimated time to complete* or *original time estimate*.

Cost variance (CV) is the earned value minus the actual cost. If cost variance is a negative number, it means that performing the work cost more than planned. If cost variance is a positive number, performing the work cost less than planned.

Schedule variance (SV) is the earned value minus the planned value. A negative schedule variance means that it took longer than planned to perform the work, and a positive schedule variance means that the work took less time than planned.

The **cost performance index (CPI)** is the ratio of earned value to actual cost; it can be used to estimate the projected cost of completing the project. If the CPI is equal to one, or 100 percent, then the planned and actual costs are equal—the costs are exactly as budgeted. If the CPI is less than one or less than 100 percent, the project is over budget. If the CPI is greater than one or more than 100 percent, the project is under budget.

The **schedule performance index (SPI)** is the ratio of earned value to planned value; it can be used to estimate the projected time to complete the project. Similar to the cost performance index, an SPI of one, or 100 percent, means the project is on schedule. If the SPI is greater than one or 100 percent, then the project is ahead of schedule. If the SPI is less than one or 100 percent, the project is behind schedule.

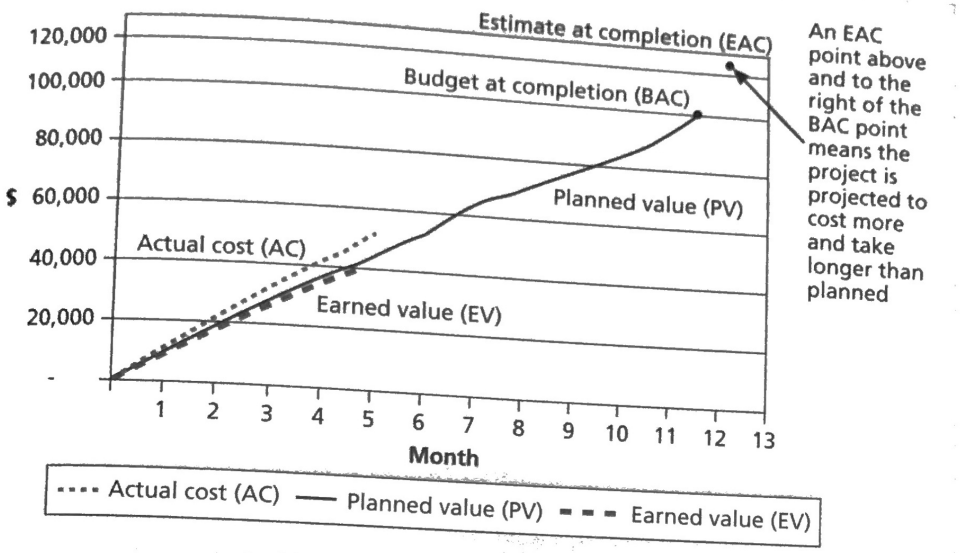

FIGURE 7-5 Earned value chart for project after five months

Note that in general, *negative numbers for cost and schedule variance indicate problems in those areas*. Negative numbers mean the project is costing more than planned or taking longer than planned. Likewise, *a CPI and SPI of less than one or less than 100 percent also indicate problems*.

The cost performance index can be used to calculate the **estimate at completion (EAC)**—an estimated cost of completing a project based on performance to date. Similarly, the schedule performance index can be used to calculate an estimated time to complete the project.

You can graph earned value information to track project performance. Figure 7-5 shows an earned value chart for a one-year project after five months. Note that the actual cost and earned value lines end at five months because the data was collected or estimated at that point. The chart includes three lines and two points, as follows:

- Planned value (PV), the cumulative planned amounts for all activities by month. Note that the planned value line extends for the estimated length of the project and ends at the BAC point.
- Actual cost (AC), the cumulative actual amounts for all activities by month.
- Earned value (EV), the cumulative earned value amounts for all activities by month.
- **Budget at completion (BAC)**, the original total budget for the project, or $100,000 in this example. The BAC point is plotted on the chart at the original time estimate of 12 months.
- Estimate at completion (EAC), estimated to be $122,308 in this example. This number is calculated by taking the BAC, or $100,000 in this case, and dividing by the CPI, which was 81.761 percent. This EAC point is plotted on the chart at the estimated time to complete of 12.74 months. This number

is calculated by taking the original time estimate, or 12 months in this case, and dividing by the SPI, which in this example was 94.203 percent.

Viewing earned value information in chart form helps you visualize how the project is performing. For example, you can see the planned performance by looking at the planned value line. If the project goes as planned, it will finish in 12 months and cost $100,000. Notice in the example in Figure 7-5 that the actual cost line is always on or above the earned value line, which indicates that costs are equal to or more than planned. The planned value line is close to the earned value line and is slightly higher in the last month. This relationship means that the project has been on schedule until the last month, when the project fell behind schedule.

Top managers who oversee multiple projects often like to see performance information in a graphical form, such as the earned value chart in Figure 7-5. For example, in the opening case, the government officials were reviewing earned value charts and EACs for several different projects. Earned value charts allow you to see quickly how projects are performing. If there are serious cost and schedule performance problems, top management may decide to terminate projects or take other corrective action. The EACs are important inputs to budget decisions, especially if total funds are limited. Earned value management is an important technique when used effectively, because it helps top management and project managers evaluate progress and make sound management decisions. Consult the *PMBOK® Guide* and other resources for more information and calculations about earned value.

If earned value management is such a powerful cost control tool, then why doesn't every organization use it? Why do many government projects require it, but many commercial projects don't? Two reasons are EVM's focus on tracking actual performance versus planned performance and the importance of percentage completion data in making calculations. Many projects, particularly IT projects, do not have good planning information, so tracking performance against a plan might produce misleading information. Several cost estimates are usually made on IT projects, and keeping track of the most recent cost estimate and the associated actual costs could be cumbersome. In addition, estimating percentage completion of tasks might produce misleading information. What does it mean to say that a task is actually 75 percent complete after three months? Such a statement is often not synonymous with saying the task will be finished in one more month or after spending an additional 25 percent of the planned budget.

To make earned value management simpler to use, organizations can modify the level of detail and still reap the benefits of the technique. For example, you can use percentage completion data such as 0 percent for items not yet started, 50 percent for items in progress, and 100 percent for completed tasks. As long as the project is defined in enough detail, this simplified percentage completion data should provide enough summary information to allow managers to see how well a project is doing overall. You can get very accurate total project performance information using these simple percentage complete amounts. For example, using simplified percentage complete amounts for a one-year project with weekly reporting and an average task size of one week, you can expect about a 1 percent error rate.[19]

You can enter and collect earned value data only at summary levels of the WBS. Quentin Fleming, author of the book *Earned Value Project Management*,[20] often gives presentations about earned value management. Many people express their frustration in trying to collect such detailed information. Fleming explains that you do not have to collect information at the work package level to use earned value management. It is most important to have a deliverable-oriented WBS, and many WBS items can summarize several