7

PROJECT COST MANAGEMENT

Project Cost Management includes the processes involved in planning, estimating, budgeting, financing, funding, managing, and controlling costs so that the project can be completed within the approved budget. The Project Cost Management processes are:

7.1 Plan Cost Management—The process of defining how the project costs will be estimated, budgeted, managed, monitored, and controlled.

7.2 Estimate Costs—The process of developing an approximation of the monetary resources needed to complete project work.

7.3 Determine Budget—The process of aggregating the estimated costs of individual activities or work packages to establish an authorized cost baseline.

7.4 Control Costs—The process of monitoring the status of the project to update the project costs and manage changes to the cost baseline.

Figure 7-1 provides an overview of the Project Cost Management processes. The Project Cost Management processes are presented as discrete processes with defined interfaces, while in practice they overlap and interact in ways that cannot be completely detailed in the *PMBOK® Guide*. These processes interact with each other and with processes in other Knowledge Areas.

On some projects, especially those of smaller scope, cost estimating and cost budgeting are tightly linked and can be viewed as a single process that can be performed by a single person over a relatively short period of time. They are presented here as distinct processes because the tools and techniques for each are different. The ability to influence cost is greatest at the early stages of the project, making early scope definition critical (see Section 5.3).

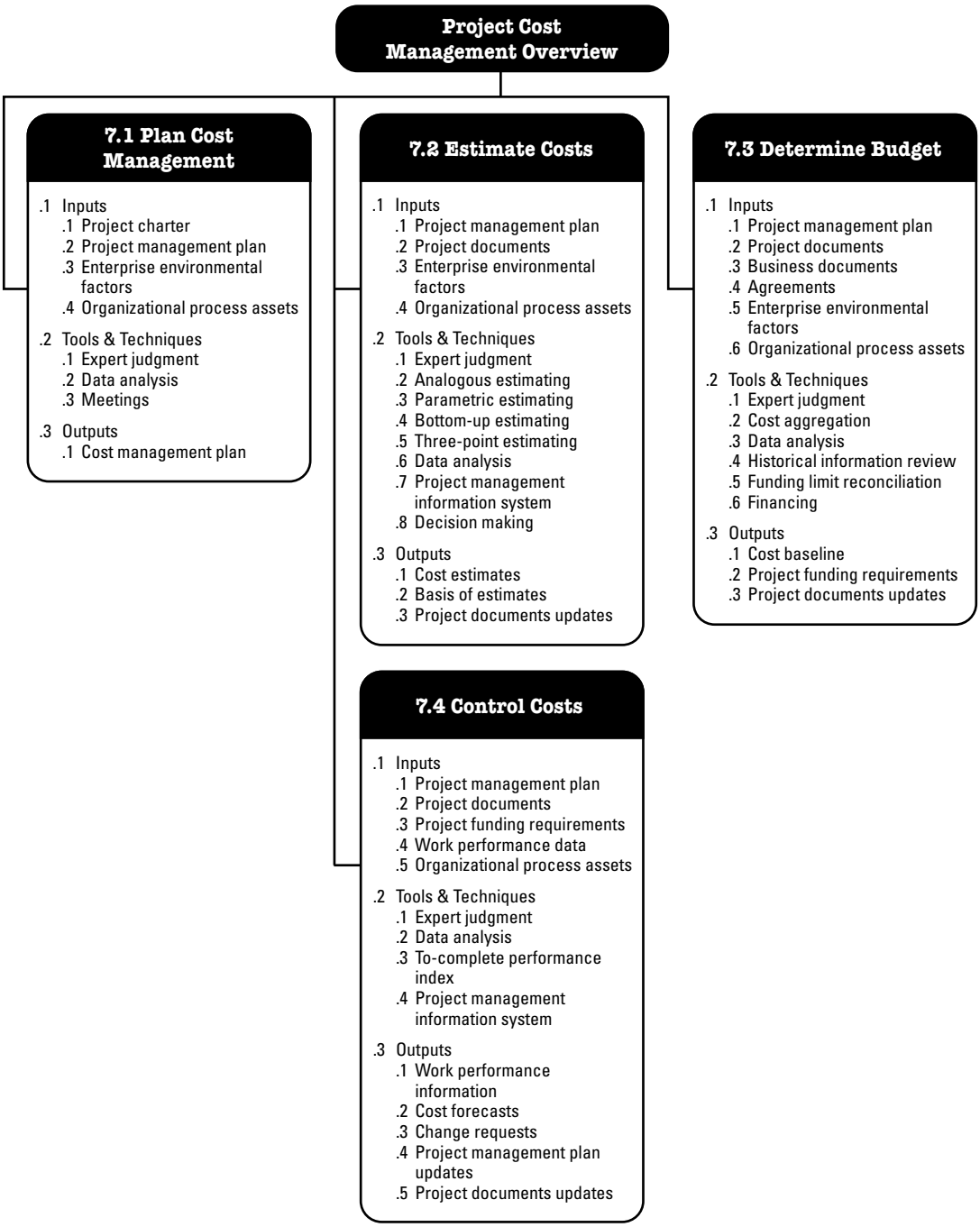

Figure 7-1. Project Cost Management Overview

KEY CONCEPTS FOR PROJECT COST MANAGEMENT

Project Cost Management is primarily concerned with the cost of the resources needed to complete project activities. Project Cost Management should consider the effect of project decisions on the subsequent recurring cost of using, maintaining, and supporting the product, service, or result of the project. For example, limiting the number of design reviews can reduce the cost of the project but could increase the resulting product's operating costs.

Another aspect of cost management is recognizing that different stakeholders measure project costs in different ways and at different times. For example, the cost of an acquired item may be measured when the acquisition decision is made or committed, the order is placed, the item is delivered, or the actual cost is incurred or recorded for project accounting purposes. In many organizations, predicting and analyzing the prospective financial performance of the project's product is performed outside of the project. In others, such as a capital facilities project, Project Cost Management can include this work. When such predictions and analyses are included, Project Cost Management may address additional processes and numerous general financial management techniques such as return on investment, discounted cash flow, and investment payback analysis.

TRENDS AND EMERGING PRACTICES IN PROJECT COST MANAGEMENT

Within the practice of Project Cost Management, trends include the expansion of earned value management (EVM) to include the concept of earned schedule (ES).

ES is an extension to the theory and practice of EVM. Earned schedule theory replaces the schedule variance measures used in traditional EVM (earned value – planned value) with ES and actual time (AT). Using the alternate equation for calculating schedule variance ES – AT, if the amount of earned schedule is greater than 0, then the project is considered ahead of schedule. In other words, the project earned more than planned at a given point in time. The schedule performance index (SPI) using earned schedule metrics is ES/AT. This indicates the efficiency with which work is being accomplished. Earned schedule theory also provides formulas for forecasting the project completion date, using earned schedule, actual time, and estimated duration.

TAILORING CONSIDERATIONS

Because each project is unique, the project manager may need to tailor the way Project Cost Management processes are applied. Considerations for tailoring include but are not limited to:

- **Knowledge management.** Does the organization have a formal knowledge management and financial database repository that a project manager is required to use and that is readily accessible?
- **Estimating and budgeting.** Does the organization have existing formal or informal cost estimating and budgeting-related policies, procedures, and guidelines?
- **Earned value management.** Does the organization use earned value management in managing projects?
- **Use of agile approach.** Does the organization use agile methodologies in managing projects? How does this impact cost estimating?
- **Governance.** Does the organization have formal or informal audit and governance policies, procedures, and guidelines?

CONSIDERATIONS FOR AGILE/ADAPTIVE ENVIRONMENTS

Projects with high degrees of uncertainty or those where the scope is not yet fully defined may not benefit from detailed cost calculations due to frequent changes. Instead, lightweight estimation methods can be used to generate a fast, high-level forecast of project labor costs, which can then be easily adjusted as changes arise. Detailed estimates are reserved for short-term planning horizons in a just-in-time fashion.

In cases where high-variability projects are also subject to strict budgets, the scope and schedule are more often adjusted to stay within cost constraints.

7.1 PLAN COST MANAGEMENT

Plan Cost Management is the process of defining how the project costs will be estimated, budgeted, managed, monitored, and controlled. The key benefit of this process is that it provides guidance and direction on how the project costs will be managed throughout the project. This process is performed once or at predefined points in the project. The inputs, tools and techniques, and outputs of this process are depicted in Figure 7-2. Figure 7-3 depicts the data flow diagram of the process.

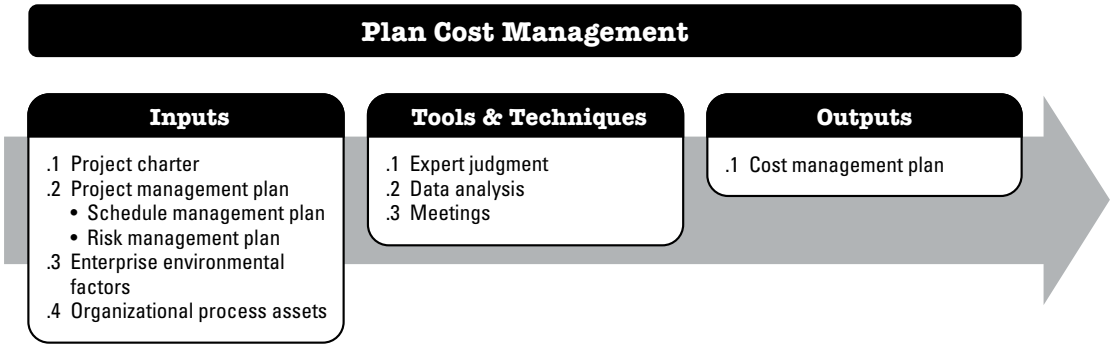

Figure 7-2. Plan Cost Management: Inputs, Tools & Techniques, and Outputs

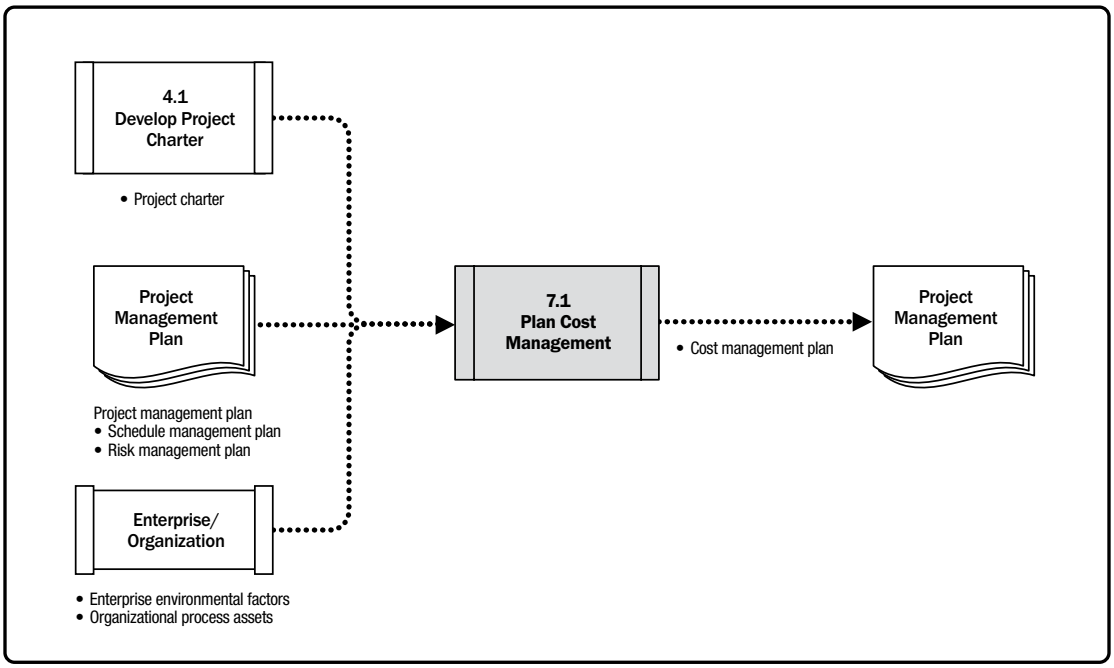

Figure 7-3. Plan Cost Management: Data Flow Diagram

The cost management planning effort occurs early in project planning and sets the framework for each of the cost management processes so that performance of the processes will be efficient and coordinated. The cost management processes and their associated tools and techniques are documented in the cost management plan. The cost management plan is a component of the project management plan.

7.1.1 PLAN COST MANAGEMENT: INPUTS

7.1.1.1 PROJECT CHARTER

Described in Section 4.2.3.1. The project charter provides the preapproved financial resources from which the detailed project costs are developed. The project charter also defines the project approval requirements that will influence the management of the project costs.

7.1.1.2 PROJECT MANAGEMENT PLAN

Described in Section 4.2.3.1. Project management plan components include but are not limited to:

- **Schedule management plan.** Described in Section 6.1.3.1. The schedule management plan establishes the criteria and the activities for developing, monitoring, and controlling the schedule. The schedule management plan provides processes and controls that will impact cost estimation and management.
- **Risk management plan.** Described in Section 11.1.3.1. The risk management plan provides the approach for identifying, analyzing, and monitoring risks. The risk management plan provides processes and controls that will impact cost estimation and management.

7.1.1.3 ENTERPRISE ENVIRONMENTAL FACTORS

The enterprise environmental factors that can influence the Plan Cost Management process include but are not limited to:

- Organizational culture and structure can influence cost management.
- Market conditions describe what products, services, and results are available in the regional and global markets.
- Currency exchange rates for project costs are sourced from more than one country.

- Published commercial information such as resource cost rate information is often available from commercial databases that track skills and human resource costs, and provide standard costs for material and equipment. Published seller price lists are another source of information.
- Project management information system provides alternative possibilities for managing cost.
- Productivity differences in different parts of the world can have a large influence on the cost of projects.

7.1.1.4 ORGANIZATIONAL PROCESS ASSETS

The organizational process assets that can influence the Plan Cost Management process include but are not limited to:

- Financial controls procedures (e.g., time reporting, required expenditure and disbursement reviews, accounting codes, and standard contract provisions);
- Historical information and lessons learned repository;
- Financial databases; and
- Existing formal and informal cost estimating and budgeting-related policies, procedures, and guidelines.

7.1.2 PLAN COST MANAGEMENT: TOOLS AND TECHNIQUES

7.1.2.1 EXPERT JUDGMENT

Described in Section 4.1.2.1 Expertise should be considered from individuals or groups with specialized knowledge or training in the following topics:

- Previous similar projects;
- Information in the industry, discipline, and application area;
- Cost estimating and budgeting; and
- Earned value management.

7.1.2.2 DATA ANALYSIS

A data analysis technique that can be used for this process includes but is not limited to alternatives analysis. Alternatives analysis can include reviewing strategic funding options such as: self-funding, funding with equity, or funding with debt. It can also include consideration of ways to acquire project resources such as making, purchasing, renting, or leasing.

7.1.2.3 MEETINGS

Project teams may hold planning meetings to develop the cost management plan. Attendees may include the project manager, the project sponsor, selected project team members, selected stakeholders, anyone with responsibility for project costs, and others as needed.

7.1.3 PLAN COST MANAGEMENT: OUTPUTS

7.1.3.1 COST MANAGEMENT PLAN

The cost management plan is a component of the project management plan and describes how the project costs will be planned, structured, and controlled. The cost management processes and their associated tools and techniques are documented in the cost management plan.

For example, the cost management plan can establish the following:

- **Units of measure.** Each unit used in measurements (such as staff hours, staff days, or weeks for time measures; meters, liters, tons, kilometers, or cubic yards for quantity measures; or lump sum in currency form) is defined for each of the resources.
- **Level of precision.** This is the degree to which cost estimates will be rounded up or down (e.g., US$995.59 to US$1,000), based on the scope of the activities and magnitude of the project.
- **Level of accuracy.** The acceptable range (e.g., ±10%) used in determining realistic cost estimates is specified, and may include an amount for contingencies.

- **Organizational procedures links.** The work breakdown structure (WBS) (Section 5.4) provides the framework for the cost management plan, allowing for consistency with the estimates, budgets, and control of costs. The WBS component used for the project cost accounting is called the control account. Each control account is assigned a unique code or account number(s) that links directly to the performing organization's accounting system.
- **Control thresholds.** Variance thresholds for monitoring cost performance may be specified to indicate an agreed-upon amount of variation to be allowed before some action needs to be taken. Thresholds are typically expressed as percentage deviations from the baseline plan.
- **Rules of performance measurement.** Earned value management (EVM) rules of performance measurement are set. For example, the cost management plan may:
  - Define the points in the WBS at which measurement of control accounts will be performed;
  - Establish the EVM techniques (e.g., weighted milestones, fixed-formula, percent complete, etc.) to be employed; and
  - Specify tracking methodologies and the EVM computation equations for calculating projected estimate at completion (EAC) forecasts to provide a validity check on the bottom-up EAC.
- **Reporting formats.** The formats and frequency for the various cost reports are defined.
- **Additional details.** Additional details about cost management activities include but are not limited to:
  - Description of strategic funding choices,
  - Procedure to account for fluctuations in currency exchange rates, and
  - Procedure for project cost recording.

For more specific information regarding earned value management, refer to the *Practice Standard for Earned Value Management – Second Edition* [17].

7.2 ESTIMATE COSTS

Estimate Costs is the process of developing an approximation of the cost of resources needed to complete project work. The key benefit of this process is that it determines the monetary resources required for the project. This process is performed periodically throughout the project as needed. The inputs, tools and techniques, and outputs of this process are depicted in Figure 7-4. Figure 7-5 depicts the data flow diagram of the process.

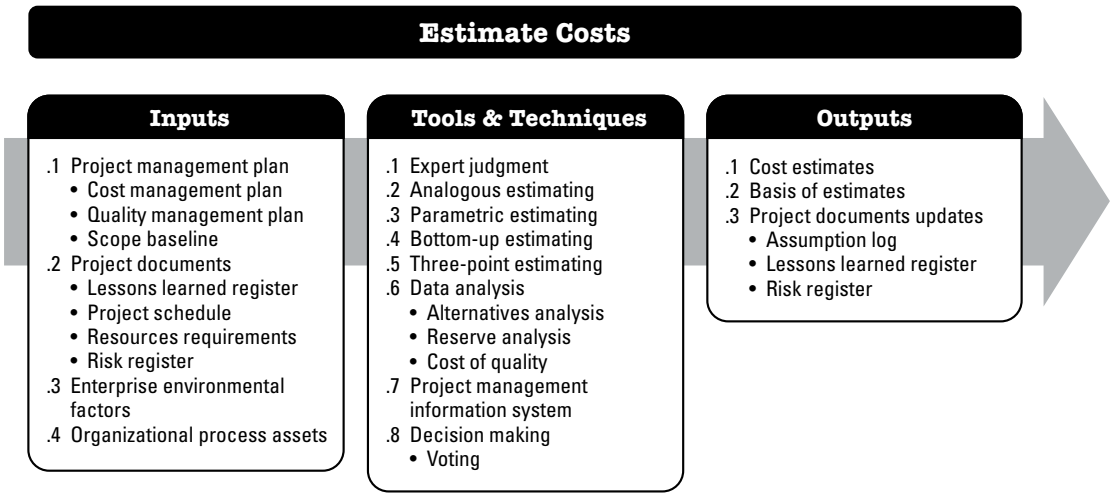

Figure 7-4. Estimate Costs: Inputs, Tools & Techniques, and Outputs

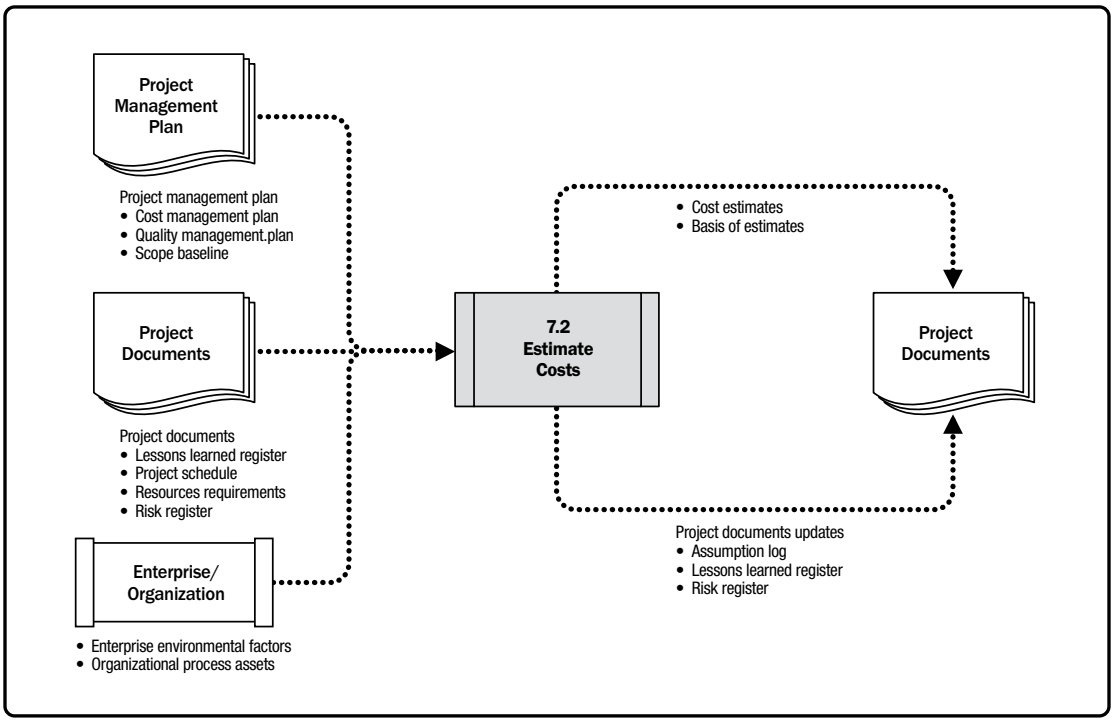

Figure 7-5. Estimate Costs: Data Flow Diagram

A cost estimate is a quantitative assessment of the likely costs for resources required to complete the activity. It is a prediction that is based on the information known at a given point in time. Cost estimates include the identification and consideration of costing alternatives to initiate and complete the project. Cost trade-offs and risks should be considered, such as make versus buy, buy versus lease, and the sharing of resources in order to achieve optimal costs for the project.

Cost estimates are generally expressed in units of some currency (i.e., dollars, euros, yen, etc.), although in some instances other units of measure, such as staff hours or staff days, are used to facilitate comparisons by eliminating the effects of currency fluctuations.

Cost estimates should be reviewed and refined during the course of the project to reflect additional detail as it becomes available and assumptions are tested. The accuracy of a project estimate will increase as the project progresses through the project life cycle. For example, a project in the initiation phase may have a rough order of magnitude (ROM) estimate in the range of –25% to +75%. Later in the project, as more information is known, definitive estimates could narrow the range of accuracy to –5% to +10%. In some organizations, there are guidelines for when such refinements can be made and the degree of confidence or accuracy that is expected.

Costs are estimated for all resources that will be charged to the project. This includes but is not limited to labor, materials, equipment, services, and facilities, as well as special categories such as an inflation allowance, cost of financing, or contingency costs. Cost estimates may be presented at the activity level or in summary form.

7.2.1 ESTIMATE COSTS: INPUTS

7.2.1.1 PROJECT MANAGEMENT PLAN

Described in Section 4.2.3.1. Project management plan components include but are not limited to:

- **Cost management plan.** Described in Section 7.1.3.1. The cost management plan describes estimating methods that can be used and the level of precision and accuracy required for the cost estimate.
- **Quality management plan.** Described in Section 8.1.3.1. The quality management plan describes the activities and resources necessary for the project management team to achieve the quality objectives set for the project.

- **Scope baseline.** Described in Section 5.4.3.1. The scope baseline includes the project scope statement, WBS, and WBS dictionary:
  - *Project scope statement.* The scope statement (Section 5.3.3.1) reflects funding constraints by period for the expenditure of project funds or other financial assumptions and constraints.
  - *Work breakdown structure.* The WBS (Section 5.4.3.1) provides the relationships among all the project deliverables and their various components.
  - *WBS dictionary.* The WBS dictionary (Section 5.4.3.) and related detailed statements of work provide an identification of the deliverables and a description of the work in each WBS component required to produce each deliverable.

7.2.1.2 PROJECT DOCUMENTS

Project documents that can be considered as inputs for this process include but are not limited to:

- **Lessons learned register.** Described in Section 4.4.3.1. Lessons learned earlier in the project with regard to developing cost estimates can be applied to later phases in the project to improve the accuracy and precision of the cost estimates.
- **Project schedule.** Described in Section 6.5.3.2. The schedule includes the type, quantity, and amount of time that team and physical resources will be active on the project. The duration estimates (Section 6.4.3.1) will affect cost estimates when resources are charged per unit of time and when there are seasonal fluctuations in costs. The schedule also provides useful information for projects that incorporate the cost of financing (including interest charges).
- **Resource requirements.** Described in Section 9.2.3.1. Resource requirements identify the types and quantities of resources required for each work package or activity.
- **Risk register.** Described in Section 11.2.3.1. The risk register contains details of individual project risks that have been identified and prioritized, and for which risk responses are required. The risk register provides detailed information that can be used to estimate costs.

7.2.1.3 ENTERPRISE ENVIRONMENTAL FACTORS

The enterprise environmental factors that can influence the Estimate Costs process include but are not limited to:

- **Market conditions.** These conditions describe what products, services, and results are available in the market, from whom, and under what terms and conditions. Regional and/or global supply and demand conditions greatly influence resource costs.
- **Published commercial information.** Resource cost rate information is often available from commercial databases that track skills and human resource costs, and provide standard costs for material and equipment. Published seller price lists are another source of information.
- **Exchange rates and inflation.** For large-scale projects that extend multiple years with multiple currencies, the fluctuations of currencies and inflation need to be understood and built into the Estimate Cost process.

7.2.1.4 ORGANIZATIONAL PROCESS ASSETS

The organizational process assets that can influence the Estimate Costs process include but are not limited to:

- Cost estimating policies,
- Cost estimating templates,
- Historical information and lessons learned repository.

7.2.2 ESTIMATE COSTS: TOOLS AND TECHNIQUES

7.2.2.1 EXPERT JUDGMENT

Described in Section 4.1.2.1 Expertise should be considered from individuals or groups with specialized knowledge or training in the following topics:

- Previous similar projects;
- Information in the industry, discipline, and application area; and
- Cost estimating methods.

7.2.2.2 ANALOGOUS ESTIMATING

Described in Section 6.4.2.2. Analogous cost estimating uses values, or attributes, of a previous project that are similar to the current project. Values and attributes of the projects may include but are not limited to: scope, cost, budget, duration, and measures of scale (e.g., size, weight). Comparison of these project values, or attributes, becomes the basis for estimating the same parameter or measurement for the current project.

7.2.2.3 PARAMETRIC ESTIMATING

Described in Section 6.4.2.3. Parametric estimating uses a statistical relationship between relevant historical data and other variables (e.g., square footage in construction) to calculate a cost estimate for project work. This technique can produce higher levels of accuracy depending on the sophistication and underlying data built into the model. Parametric cost estimates can be applied to a total project or to segments of a project, in conjunction with other estimating methods.

7.2.2.4 BOTTOM-UP ESTIMATING

Described in Section 6.4.2.5. Bottom-up estimating is a method of estimating a component of work. The cost of individual work packages or activities is estimated to the greatest level of specified detail. The detailed cost is then summarized or "rolled up" to higher levels for subsequent reporting and tracking purposes. The cost and accuracy of bottom-up cost estimating are typically influenced by the size or other attributes of the individual activity or work package.

7.2.2.5 THREE-POINT ESTIMATING

Described in Section 6.4.2.4. The accuracy of single-point cost estimates may be improved by considering estimation uncertainty and risk and using three estimates to define an approximate range for an activity's cost:

- **Most likely (*cM*).** The cost of the activity, based on realistic effort assessment for the required work and any predicted expenses.
- **Optimistic (*cO*).** The cost based on analysis of the best-case scenario for the activity.
- **Pessimistic (*cP*).** The cost based on analysis of the worst-case scenario for the activity.

Depending on the assumed distribution of values within the range of the three estimates, the expected cost, *cE*, can be calculated using a formula. Two commonly used formulas are triangular and beta distributions. The formulas are:

- **Triangular distribution.** $cE = (cO + cM + cP) / 3$
- **Beta distribution.** $cE = (cO + 4cM + cP) / 6$

Cost estimates based on three points with an assumed distribution provide an expected cost and clarify the range of uncertainty around the expected cost.

7.2.2.6 DATA ANALYSIS

Data analysis techniques that can be used in the Estimate Costs process include but are not limited to:

- **Alternatives analysis.** Alternatives analysis is a technique used to evaluate identified options in order to select which options or approaches to use to execute and perform the work of the project. An example would be evaluating the cost, schedule, resource, and quality impacts of buying versus making a deliverable.
- **Reserve analysis.** Cost estimates may include contingency reserves (sometimes called contingency allowances) to account for cost uncertainty. Contingency reserves are the budget within the cost baseline that is allocated for identified risks. Contingency reserves are often viewed as the part of the budget intended to address the known-unknowns that can affect a project. For example, rework for some project deliverables could be anticipated, while the amount of this rework is unknown. Contingency reserves may be estimated to account for this unknown amount of rework. Contingency reserves can be provided at any level from the specific activity to the entire project. The contingency reserve may be a percentage of the estimated cost, a fixed number, or may be developed by using quantitative analysis methods.

  As more precise information about the project becomes available, the contingency reserve may be used, reduced, or eliminated. Contingency should be clearly identified in cost documentation. Contingency reserves are part of the cost baseline and the overall funding requirements for the project.
- **Cost of quality.** Assumptions about costs of quality (Section 8.1.2.3) may be used to prepare the estimates. This includes evaluating the cost impact of additional investment in conformance versus the cost of nonconformance. It can also include looking at short-term cost reductions versus the implication of more frequent problems later on in the product life cycle.

7.2.2.7 PROJECT MANAGEMENT INFORMATION SYSTEM (PMIS)

Described in Section 4.3.2.2. The project management information system can include spreadsheets, simulation software, and statistical analysis tools to assist with cost estimating. Such tools simplify the use of some cost-estimating techniques and thereby facilitate rapid consideration of cost estimate alternatives.

7.2.2.8 DECISION MAKING

The decision-making techniques that can be used in the Estimate Costs process include but are not limited to voting. Described in Section 5.2.2.4, voting is an assessment process having multiple alternatives with an expected outcome in the form of future actions. These techniques are useful for engaging team members to improve estimate accuracy and commitment to the emerging estimates.

7.2.3 ESTIMATE COSTS: OUTPUTS

7.2.3.1 COST ESTIMATES

Cost estimates include quantitative assessments of the probable costs required to complete project work, as well as contingency amounts to account for identified risks, and management reserve to cover unplanned work. Cost estimates can be presented in summary form or in detail. Costs are estimated for all resources that are applied to the cost estimate. This includes but is not limited to direct labor, materials, equipment, services, facilities, information technology, and special categories such as cost of financing (including interest charges), an inflation allowance, exchange rates, or a cost contingency reserve. Indirect costs, if they are included in the project estimate, can be included at the activity level or at higher levels.

7.2.3.2 BASIS OF ESTIMATES

The amount and type of additional details supporting the cost estimate vary by application area. Regardless of the level of detail, the supporting documentation should provide a clear and complete understanding of how the cost estimate was derived.

Supporting detail for cost estimates may include:

- Documentation of the basis of the estimate (i.e., how it was developed),
- Documentation of all assumptions made,
- Documentation of any known constraints,
- Documentation of identified risks included when estimating costs,
- Indication of the range of possible estimates (e.g., US$10,000 (±10%) to indicate that the item is expected to cost between a range of values), and
- Indication of the confidence level of the final estimate.

7.2.3.3 PROJECT DOCUMENTS UPDATES

Project documents that may be updated as a result of carrying out this process include but are not limited to:

- **Assumption log.** Described in Section 4.1.3.2. During the Cost Estimates process, new assumptions may be made, new constraints may be identified, and existing assumptions or constraints may be revisited and changed. The assumption log should be updated with this new information.
- **Lessons learned register.** Described in Section 4.4.3.1. The lessons learned register can be updated with techniques that were efficient and effective in developing cost estimates.
- **Risk register.** Described in Section 11.2.3.1. The risk register may be updated when appropriate risk responses are chosen and agreed upon during the Estimate Cost process.

7.3 DETERMINE BUDGET

Determine Budget is the process of aggregating the estimated costs of individual activities or work packages to establish an authorized cost baseline. The key benefit of this process is that it determines the cost baseline against which project performance can be monitored and controlled. This process is performed once or at predefined points in the project. The inputs, tools and techniques, and outputs of this process are depicted in Figure 7-6. Figure 7-7 depicts the data flow diagram of the process.

A project budget includes all the funds authorized to execute the project. The cost baseline is the approved version of the time-phased project budget that includes contingency reserves, but excludes management reserves.

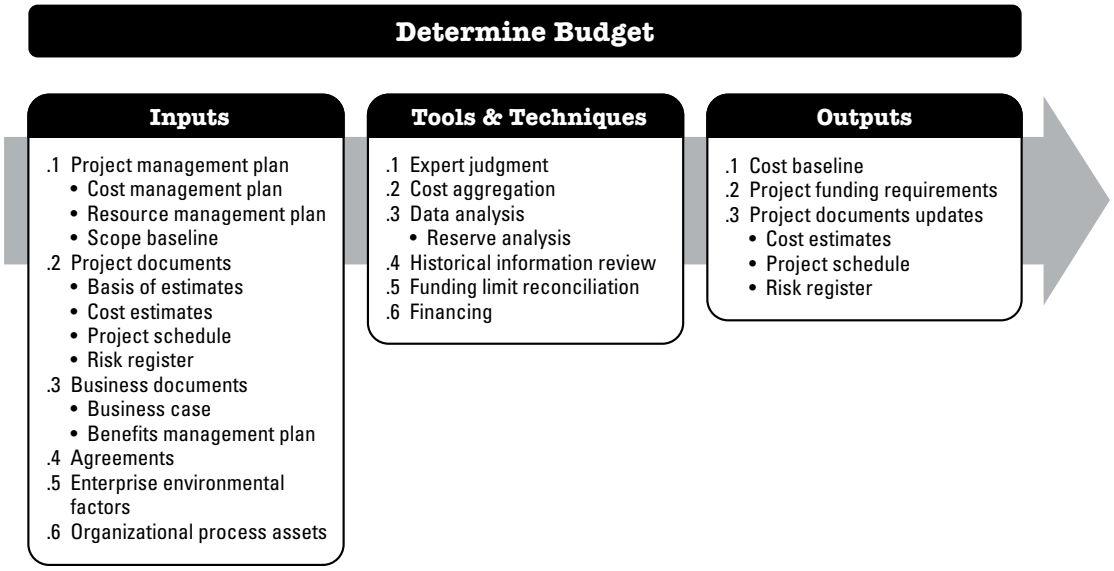

Figure 7-6. Determine Budget: Inputs, Tools & Techniques, and Outputs

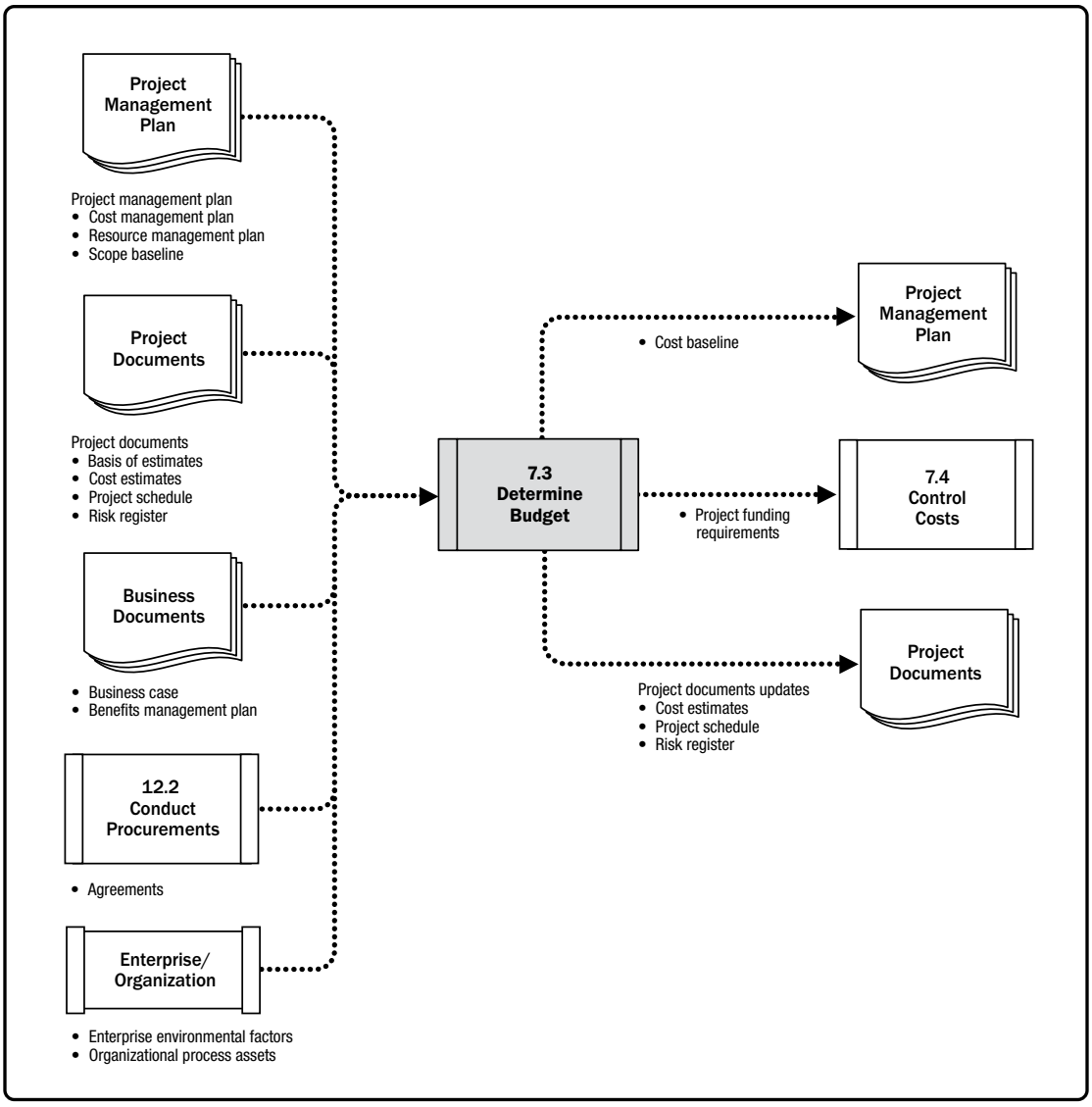

Figure 7-7. Determine Budget: Data Flow Diagram

7.3.1 DETERMINE BUDGET: INPUTS

7.3.1.1 PROJECT MANAGEMENT PLAN

Described in Section 4.2.3.1. Project management plan components include but are not limited to:

- **Cost management plan.** Described in Section 7.1.3.1. The cost management plan describes how the project costs will be structured into the project budget.
- **Resource management plan.** Described in Section 9.1.3.1. The resource management plan provides information on rates (personnel and other resources), estimation of travel costs, and other foreseen costs that are necessary to estimate the overall project budget.
- **Scope baseline.** Described in Section 5.4.3.1. The scope baseline includes the project scope statement, WBS, and WBS dictionary details for cost estimation and management.

7.3.1.2 PROJECT DOCUMENTS

Examples of project documents that can be considered as inputs for this process include but are not limited to:

- **Basis of estimates.** Described in Section 6.4.3.2. Supporting detail for cost estimates contained in the basis for estimates should specify any basic assumptions dealing with the inclusion or exclusion of indirect or other costs in the project budget.
- **Cost estimates.** Described in Section 7.2.3.1. Cost estimates for each activity within a work package are aggregated to obtain a cost estimate for each work package.
- **Project schedule.** Described in Section 6.5.3.2. The project schedule includes planned start and finish dates for the project's activities, milestones, work packages, and control accounts. This information can be used to aggregate costs to the calendar periods in which the costs are planned to be incurred.
- **Risk register.** Described in Section 11.2.3.1. The risk register should be reviewed to consider how to aggregate the risk response costs. Updates to the risk register are included with project documents updates described in Section 11.5.3.3.

7.3.1.3 BUSINESS DOCUMENTS

Described in Section 1.2.6. The business documents that can be considered as inputs for this process include but are not limited to:

- **Business case.** The business case identifies the critical success factors for the project, including financial success factors.
- **Benefits management plan.** The benefits management plan includes the target benefits, such as net present value calculations, timeframe for realizing benefits, and the metrics associated with the benefits.

7.3.1.4 AGREEMENTS

Described in Section 12.2.3.2. Applicable agreement information and costs relating to products, services, or results that have been or will be purchased are included when determining the budget.

7.3.1.5 ENTERPRISE ENVIRONMENTAL FACTORS

The enterprise environmental factors that can influence the Estimate Costs process include but are not limited to exchange rates. For large-scale projects that extend multiple years with multiple currencies, the fluctuations of currencies need to be understood and built into the Determine Budget process.

7.3.1.6 ORGANIZATIONAL PROCESS ASSETS

The organizational process assets that can influence the Determine Budget process include but are not limited to:

- Existing formal and informal cost budgeting-related policies, procedures, and guidelines;
- Historical information and lessons learned repository.
- Cost budgeting tools; and
- Reporting methods.

7.3.2 DETERMINE BUDGET: TOOLS AND TECHNIQUES

7.3.2.1 EXPERT JUDGMENT

Described in Section 4.1.2.1. Expertise should be considered from individuals or groups with specialized knowledge or training in the following topics:

- Previous similar projects;
- Information in the industry, discipline, and application area;
- Financial principles; and
- Funding requirement and sources.

7.3.2.2 COST AGGREGATION

Cost estimates are aggregated by work packages in accordance with the WBS. The work package cost estimates are then aggregated for the higher component levels of the WBS (such as control accounts) and, ultimately, for the entire project.

7.3.2.3 DATA ANALYSIS

A data analysis technique that can be used in the Determine Budget process includes but is not limited to reserve analysis, which can establish the management reserves for the project. Management reserves are an amount of the project budget withheld for management control purposes and are reserved for unforeseen work that is within scope of the project. Management reserves are intended to address the unknown unknowns that can affect a project. The management reserve is not included in the cost baseline but is part of the overall project budget and funding requirements. When an amount of management reserves is used to fund unforeseen work, the amount of management reserve used is added to the cost baseline, thus requiring an approved change to the cost baseline.

7.3.2.4 HISTORICAL INFORMATION REVIEW

Reviewing historical information can assist in developing parametric estimates or analogous estimates. Historical information may include project characteristics (parameters) to develop mathematical models to predict total project costs. Such models may be simple (e.g., residential home construction is based on a certain cost per square foot of space) or complex (e.g., one model of software development costing uses multiple separate adjustment factors, each of which has numerous points within it).

Both the cost and accuracy of analogous and parametric models can vary widely. They are most likely to be reliable when:

- Historical information used to develop the model is accurate,
- Parameters used in the model are readily quantifiable, and
- Models are scalable, such that they work for large projects, small projects, and phases of a project.

7.3.2.5 FUNDING LIMIT RECONCILIATION

The expenditure of funds should be reconciled with any funding limits on the commitment of funds for the project. A variance between the funding limits and the planned expenditures will sometimes necessitate the rescheduling of work to level out the rate of expenditures. This is accomplished by placing imposed date constraints for work into the project schedule.

7.3.2.6 FINANCING

Financing entails acquiring funding for projects. It is common for long-term infrastructure, industrial, and public services projects to seek external sources of funds. If a project is funded externally, the funding entity may have certain requirements that are required to be met.

7.3.3 DETERMINE BUDGET: OUTPUTS

7.3.3.1 COST BASELINE

The cost baseline is the approved version of the time-phased project budget, excluding any management reserves, which can only be changed through formal change control procedures. It is used as a basis for comparison to actual results. The cost baseline is developed as a summation of the approved budgets for the different schedule activities.

Figure 7-8 illustrates the various components of the project budget and cost baseline. Cost estimates for the various project activities, along with any contingency reserves (see Section 7.2.2.6) for these activities, are aggregated into their associated work package costs. The work package cost estimates, along with any contingency reserves estimated for the work packages, are aggregated into control accounts. The summation of the control accounts make up the cost baseline. Since the cost estimates that make up the cost baseline are directly tied to the schedule activities, this enables a time-phased view of the cost baseline, which is typically displayed in the form of an S-curve, as is illustrated in Figure 7-9. For projects that use earned value management, the cost baseline is referred to as the performance measurement baseline.

Management reserves (Section 7.2.2.3) are added to the cost baseline to produce the project budget. As changes warranting the use of management reserves arise, the change control process is used to obtain approval to move the applicable management reserve funds into the cost baseline.

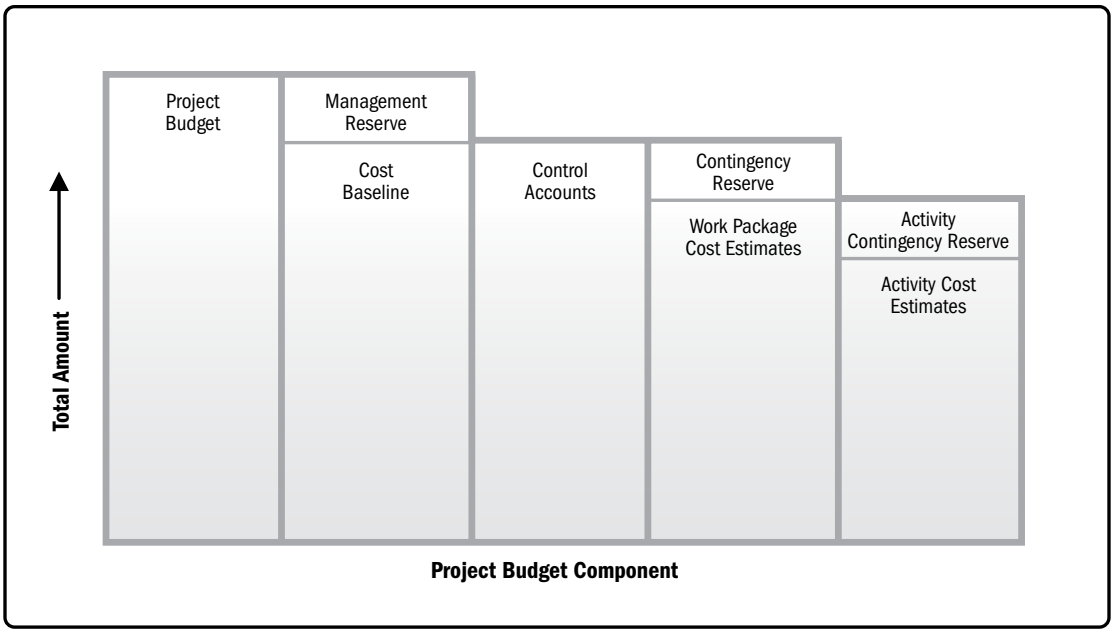

Figure 7-8. Project Budget Components

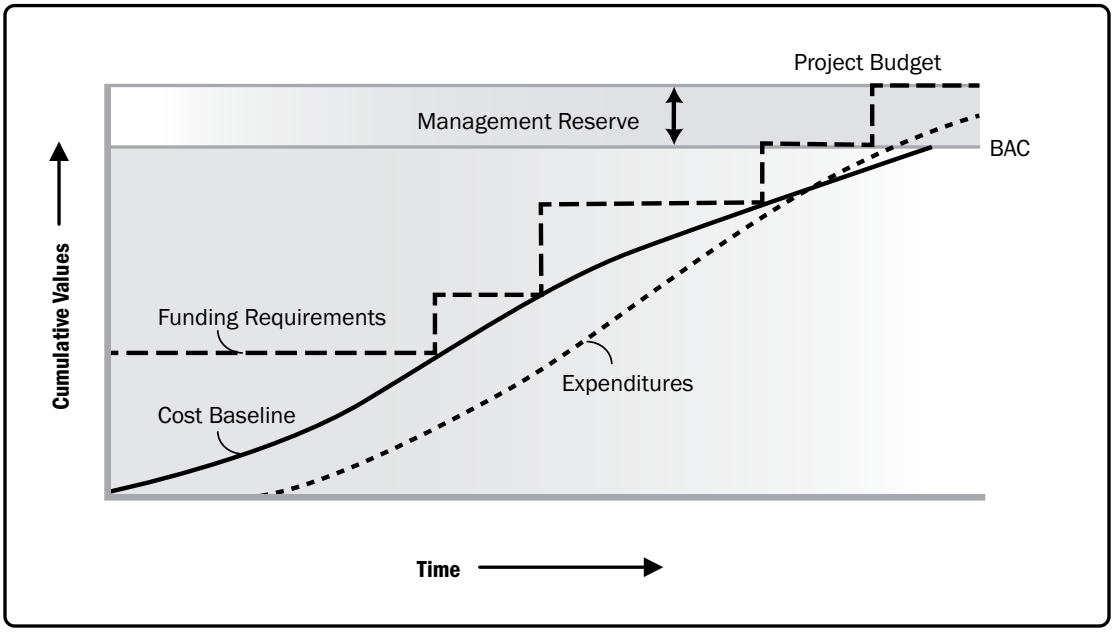

Figure 7-9. Cost Baseline, Expenditures, and Funding Requirements

7.3.3.2 PROJECT FUNDING REQUIREMENTS

Total funding requirements and periodic funding requirements (e.g., quarterly, annually) are derived from the cost baseline. The cost baseline will include projected expenditures plus anticipated liabilities. Funding often occurs in incremental amounts, and may not be evenly distributed, which appear as steps in Figure 7-9. The total funds required are those included in the cost baseline plus management reserves, if any. Funding requirements may include the source(s) of the funding.

7.3.3.3 PROJECT DOCUMENTS UPDATES

Project documents that may be updated as a result of carrying out this process include but are not limited to:

- **Cost estimates.** Described in Section 7.2.3.1. Cost estimates are updated to record any additional information.
- **Project schedule.** Described in Section 6.5.3.2. Estimated costs for each activity may be recorded as part of the project schedule.
- **Risk register.** Described in Section 11.2.3.1. New risks identified during this process are recorded in the risk register and managed using the risk management processes.

7.4 CONTROL COSTS

Control Costs is the process of monitoring the status of the project to update the project costs and managing changes to the cost baseline. The key benefit of this process is that the cost baseline is maintained throughout the project. This process is performed throughout the project. The inputs, tools and techniques, and outputs of this process are depicted in Figure 7-10. Figure 7-11 depicts the data flow diagram of the process.

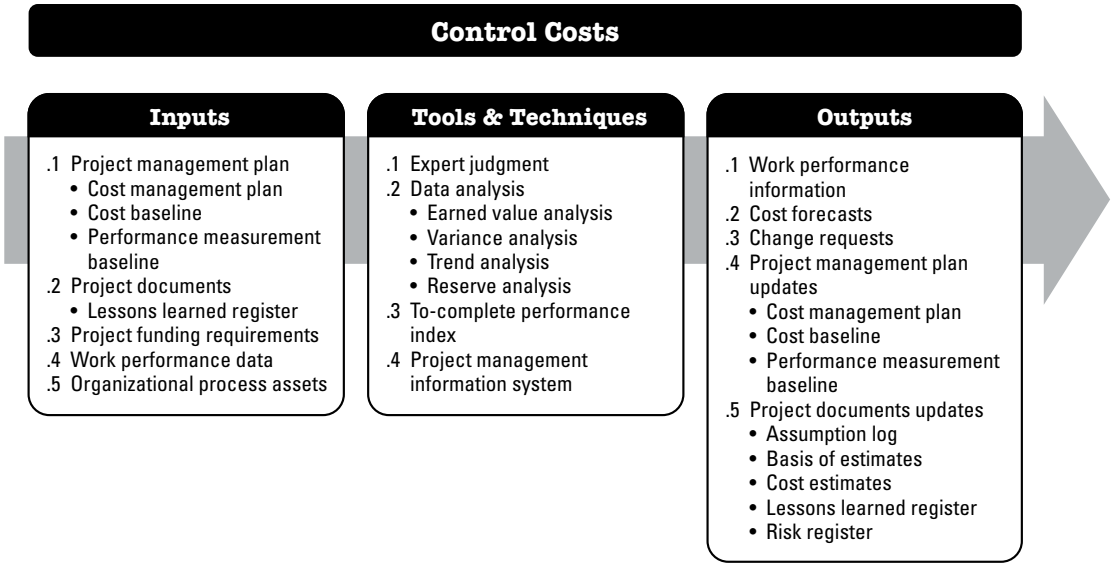

Figure 7-10. Control Costs: Inputs, Tools & Techniques, and Outputs

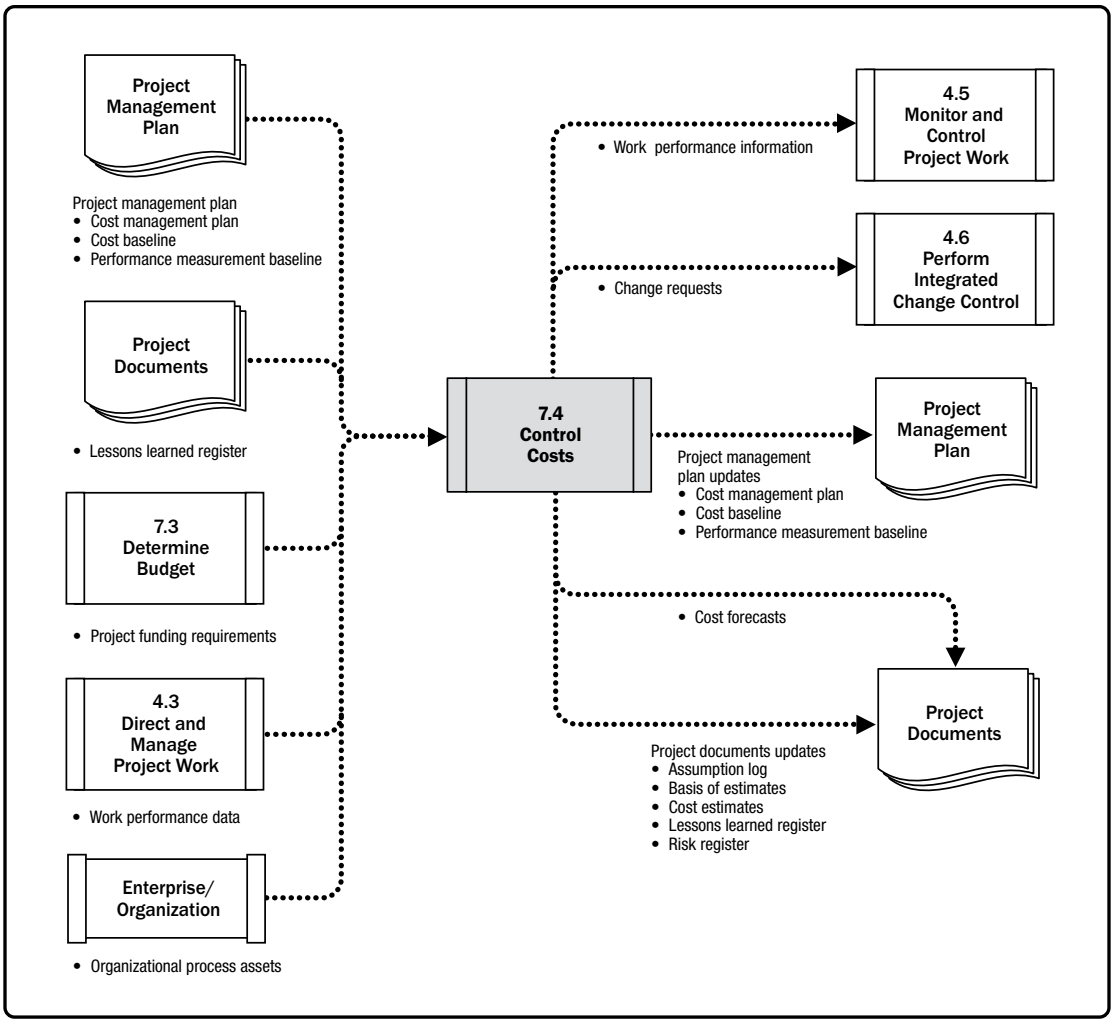

Figure 7-11. Control Costs: Data Flow Diagram

Updating the budget requires knowledge of the actual costs spent to date. Any increase to the authorized budget can only be approved through the Perform Integrated Change Control process (Section 4.6). Monitoring the expenditure of funds without regard to the value of work being accomplished for such expenditures has little value to the project, other than to track the outflow of funds. Much of the effort of cost control involves analyzing the relationship between the consumption of project funds and the work being accomplished for such expenditures. The key to effective cost control is the management of the approved cost baseline.

Project cost control includes:

- Influencing the factors that create changes to the authorized cost baseline;
- Ensuring that all change requests are acted on in a timely manner;
- Managing the actual changes when and as they occur;
- Ensuring that cost expenditures do not exceed the authorized funding by period, by WBS component, by activity, and in total for the project;
- Monitoring cost performance to isolate and understand variances from the approved cost baseline;
- Monitoring work performance against funds expended;
- Preventing unapproved changes from being included in the reported cost or resource usage;
- Informing appropriate stakeholders of all approved changes and associated cost; and
- Bringing expected cost overruns within acceptable limits.

7.4.1 CONTROL COSTS: INPUTS

7.4.1.1 PROJECT MANAGEMENT PLAN

Described in Section 4.2.3.1. Project management plan components include but are not limited to:

- **Cost management plan.** Described in Section 7.1.3.1. The cost management plan describes how the project costs will be managed and controlled.
- **Cost baseline.** Described in Section 7.3.3.1. The cost baseline is compared with actual results to determine if a change, corrective action, or preventive action is necessary.
- **Performance measurement baseline.** Described in Section 4.2.3.1. When using earned value analysis, the performance measurement baseline is compared to actual results to determine if a change, corrective action, or preventive action is necessary.

7.4.1.2. PROJECT DOCUMENTS

Examples of project documents that can be considered as inputs for this process include but are not limited to the lessons learned register. Described in Section 4.4.3.1. Lessons learned earlier in the project can be applied to later phases in the project to improve cost control.

7.4.1.3 PROJECT FUNDING REQUIREMENTS

Described in Section 7.3.3.2. The project funding requirements include projected expenditures plus anticipated liabilities.

7.4.1.4 WORK PERFORMANCE DATA

Described in Section 4.3.3.2. Work performance data contains data on project status such as which costs have been authorized, incurred, invoiced, and paid.

7.4.1.5 ORGANIZATIONAL PROCESS ASSETS

The organizational process assets that can influence the Control Costs process include but are not limited to:

- Existing formal and informal cost control-related policies, procedures, and guidelines;
- Cost control tools; and
- Monitoring and reporting methods to be used.

7.4.2 CONTROL COSTS: TOOLS AND TECHNIQUES

7.4.2.1 EXPERT JUDGMENT

Described in Section 4.1.2.1. Examples of expert judgment during the Control Costs process include but are not limited to:

- Variance analysis,
- Earned value analysis,
- Forecasting, and
- Financial analysis.

7.4.2.2 DATA ANALYSIS

Data analysis techniques that can be used to control costs include but are not limited to:

- **Earned value analysis (EVA).** Earned value analysis compares the performance measurement baseline to the actual schedule and cost performance. EVM integrates the scope baseline with the cost baseline and schedule baseline to form the performance measurement baseline. EVM develops and monitors three key dimensions for each work package and control account:
  - *Planned value.* Planned value (PV) is the authorized budget assigned to scheduled work. It is the authorized budget planned for the work to be accomplished for an activity or work breakdown structure (WBS) component, not including management reserve. This budget is allocated by phase over the life of the project, but at a given point in time, planned value defines the physical work that should have been accomplished. The total of the PV is sometimes referred to as the performance measurement baseline (PMB). The total planned value for the project is also known as budget at completion (BAC).
  - *Earned value.* Earned value (EV) is a measure of work performed expressed in terms of the budget authorized for that work. It is the budget associated with the authorized work that has been completed. The EV being measured needs to be related to the PMB, and the EV measured cannot be greater than the authorized PV budget for a component. The EV is often used to calculate the percent complete of a project. Progress measurement criteria should be established for each WBS component to measure work in progress. Project managers monitor EV, both incrementally to determine current status and cumulatively to determine the long-term performance trends.
  - *Actual cost.* Actual cost (AC) is the realized cost incurred for the work performed on an activity during a specific time period. It is the total cost incurred in accomplishing the work that the EV measured. The AC needs to correspond in definition to what was budgeted in the PV and measured in the EV (e.g., direct hours only, direct costs only, or all costs including indirect costs). The AC will have no upper limit; whatever is spent to achieve the EV will be measured.

- **Variance analysis.** Described in Section 4.5.2.2. Variance analysis, as used in EVM, is the explanation (cause, impact, and corrective actions) for cost (CV = EV – AC), schedule (SV = EV – PV), and variance at completion (VAC = BAC – EAC) variances. Cost and schedule variances are the most frequently analyzed measurements. For projects not using formal earned value analysis, similar variance analyses can be performed by comparing planned cost against actual cost to identify variances between the cost baseline and actual project performance. Further analysis can be performed to determine the cause and degree of variance relative to the schedule baseline and any corrective or preventive actions needed. Cost performance measurements are used to assess the magnitude of variation to the original cost baseline. An important aspect of project cost control includes determining the cause and degree of variance relative to the cost baseline (see Section 7.3.3.1) and deciding whether corrective or preventive action is required. The percentage range of acceptable variances will tend to decrease as more work is accomplished. Examples of variance analysis include but are not limited to:
  - *Schedule variance.* Schedule variance (SV) is a measure of schedule performance expressed as the difference between the earned value and the planned value. It is the amount by which the project is ahead or behind the planned delivery date, at a given point in time. It is a measure of schedule performance on a project. It is equal to the earned value (EV) minus the planned value (PV). The EVA schedule variance is a useful metric in that it can indicate when a project is falling behind or is ahead of its baseline schedule. The EVA schedule variance will ultimately equal zero when the project is completed because all of the planned values will have been earned. Schedule variance is best used in conjunction with critical path method (CPM) scheduling and risk management. Equation: SV = EV – PV.
  - *Cost variance.* Cost variance (CV) is the amount of budget deficit or surplus at a given point in time, expressed as the difference between earned value and the actual cost. It is a measure of cost performance on a project. It is equal to the earned value (EV) minus the actual cost (AC). The cost variance at the end of the project will be the difference between the budget at completion (BAC) and the actual amount spent. The CV is particularly critical because it indicates the relationship of physical performance to the costs spent. Negative CV is often difficult for the project to recover. Equation: CV = EV – AC.

- *Schedule performance index.* The schedule performance index (SPI) is a measure of schedule efficiency expressed as the ratio of earned value to planned value. It measures how efficiently the project team is accomplishing the work. It is sometimes used in conjunction with the cost performance index (CPI) to forecast the final project completion estimates. An SPI value less than 1.0 indicates less work was completed than was planned. An SPI greater than 1.0 indicates that more work was completed than was planned. Since the SPI measures all project work, the performance on the critical path also needs to be analyzed to determine whether the project will finish ahead of or behind its planned finish date. The SPI is equal to the ratio of the EV to the PV. Equation: SPI = EV/PV.
- *Cost performance index.* The cost performance index (CPI) is a measure of the cost efficiency of budgeted resources, expressed as a ratio of earned value to actual cost. It is considered the most critical EVA metric and measures the cost efficiency for the work completed. A CPI value of less than 1.0 indicates a cost overrun for work completed. A CPI value greater than 1.0 indicates a cost underrun of performance to date. The CPI is equal to the ratio of the EV to the AC. Equation: CPI = EV/AC.

◆ **Trend analysis.** Described in Section 4.5.2.2. Trend analysis examines project performance over time to determine if performance is improving or deteriorating. Graphical analysis techniques are valuable for understanding performance to date and for comparison to future performance goals in the form of BAC versus estimate at completion (EAC) and completion dates. Examples of the trend analysis techniques include but are not limited to:

- *Charts.* In earned value analysis, three parameters of planned value, earned value, and actual cost can be monitored and reported on both a period-by-period basis (typically weekly or monthly) and on a cumulative basis. Figure 7-12 uses S-curves to display EV data for a project that is performing over budget and behind the schedule.

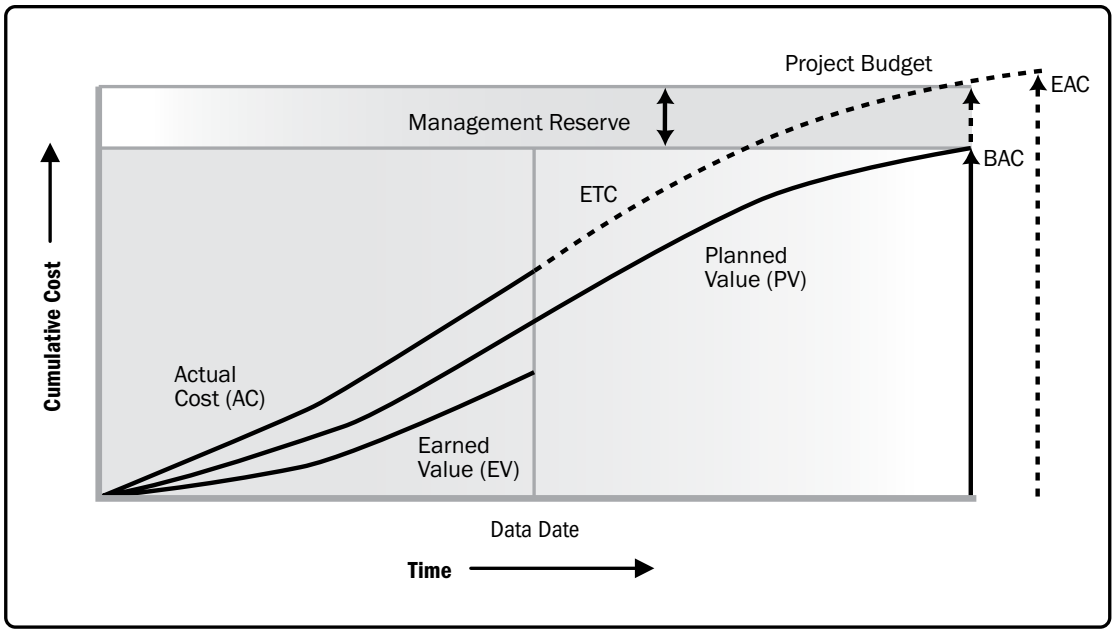

Figure 7-12. Earned Value, Planned Value, and Actual Costs

- *Forecasting.* As the project progresses, the project team may develop a forecast for the estimate at completion (EAC) that may differ from the budget at completion (BAC) based on the project performance. If it becomes obvious that the BAC is no longer viable, the project manager should consider the forecasted EAC. Forecasting the EAC involves making projections of conditions and events in the project's future based on current performance information and other knowledge available at the time of the forecast. Forecasts are generated, updated, and reissued based on work performance data (Section 4.3.3.2) that is provided as the project is executed. The work performance information covers the project's past performance and any information that could impact the project in the future.

  EACs are typically based on the actual costs incurred for work completed, plus an estimate to complete (ETC) the remaining work. It is incumbent on the project team to predict what it may encounter to perform the ETC, based on its experience to date. Earned value analysis works well in conjunction with manual forecasts of the required EAC costs. The most common EAC forecasting approach is a manual, bottom-up summation by the project manager and project team.

  The project manager's bottom-up EAC method builds upon the actual costs and experience incurred for the work completed, and requires a new estimate to complete the remaining project work. Equation: EAC = AC + Bottom-up ETC.

The project manager's manual EAC is quickly compared with a range of calculated EACs representing various risk scenarios. When calculating EAC values, the cumulative CPI and SPI values are typically used. While EVM data quickly provide many statistical EACs, only three of the more common methods are described as follows:

- *EAC forecast for ETC work performed at the budgeted rate.* This EAC method accepts the actual project performance to date (whether favorable or unfavorable) as represented by the actual costs, and predicts that all future ETC work will be accomplished at the budgeted rate. When actual performance is unfavorable, the assumption that future performance will improve should be accepted only when supported by project risk analysis. Equation: EAC = AC + (BAC – EV).
- *EAC forecast for ETC work performed at the present CPI.* This method assumes that what the project has experienced to date can be expected to continue in the future. The ETC work is assumed to be performed at the same cumulative cost performance index (CPI) as that incurred by the project to date. Equation: EAC = BAC / CPI.
- *EAC forecast for ETC work considering both SPI and CPI factors.* In this forecast, the ETC work will be performed at an efficiency rate that considers both the cost and schedule performance indices. This method is most useful when the project schedule is a factor impacting the ETC effort. Variations of this method weight the CPI and SPI at different values (e.g., 80/20, 50/50, or some other ratio) according to the project manager's judgment. Equation: EAC = AC + [(BAC – EV) / (CPI × SPI)].

◆ **Reserve analysis.** Described in Section 7.2.2.6. During cost control, reserve analysis is used to monitor the status of contingency and management reserves for the project to determine if these reserves are still needed or if additional reserves need to be requested. As work on the project progresses, these reserves may be used as planned to cover the cost of risk responses or other contingencies. Conversely, when opportunities are captured and resulting in cost savings, funds may be added to the contingency amount, or taken from the project as margin/profit.

If the identified risks do not occur, the unused contingency reserves may be removed from the project budget to free up resources for other projects or operations. Additional risk analysis during the project may reveal a need to request that additional reserves be added to the project budget.

7.4.2.3 TO-COMPLETE PERFORMANCE INDEX

The to-complete performance index (TCPI) is a measure of the cost performance that is required to be achieved with the remaining resources in order to meet a specified management goal, expressed as the ratio of the cost to finish the outstanding work to the remaining budget. TCPI is the calculated cost performance index that is achieved on the remaining work to meet a specified management goal, such as the BAC or the EAC. If it becomes obvious that the BAC is no longer viable, the project manager should consider the forecasted EAC. Once approved, the EAC may replace the BAC in the TCPI calculation. The equation for the TCPI based on the BAC: (BAC – EV) / (BAC – AC).

The TCPI is conceptually displayed in Figure 7-13. The equation for the TCPI is shown in the lower left as the work remaining (defined as the BAC minus the EV) divided by the funds remaining (which can be either the BAC minus the AC, or the EAC minus the AC).

If the cumulative CPI falls below the baseline (as shown in Figure 7-13), all future work of the project will need to be performed immediately in the range of the TCPI (BAC) (as reflected in the top line of Figure 7-13) to stay within the authorized BAC. Whether this level of performance is achievable is a judgment call based on a number of considerations, including risk, time remaining in the project, and technical performance. This level of performance is displayed as the TCPI (EAC) line. The equation for the TCPI is based on the EAC: (BAC – EV) / (EAC – AC). The EVM formulas are provided in Table 7-1.

Table 7-1. Earned Value Calculations Summary Table

Earned Value Analysis					
Abbreviation	**Name**	**Lexicon Definition**	**How Used**	**Equation**	**Interpretation of Result**
PV	Planned Value	The authorized budget assigned to scheduled work.	The value of the work planned to be completed to a point in time, usually the data date, or project completion.		
EV	Earned Value	The measure of work performed expressed in terms of the budget authorized for that work.	The planned value of all the work completed (earned) to a point in time, usually the data date, without reference to actual costs.	EV = sum of the planned value of completed work	
AC	Actual Cost	The realized cost incurred for the work performed on an activity during a specific time period.	The actual cost of all the work completed to a point in time, usually the data date.		
BAC	Budget at Completion	The sum of all budgets established for the work to be performed.	The value of total planned work, the project cost baseline.		
CV	Cost Variance	The amount of budget deficit or surplus at a given point in time, expressed as the difference between the earned value and the actual cost.	The difference between the value of work completed to a point in time, usually the data date, and the actual costs to the same point in time.	CV = EV – AC	Positive = Under planned cost Neutral = On planned cost Negative = Over planned cost
SV	Schedule Variance	The amount by which the project is ahead or behind the planned delivery date, at a given point in time, expressed as the difference between the earned value and the planned value.	The difference between the work completed to a point in time, usually the data date, and the work planned to be completed to the same point in time.	SV = EV – PV	Positive = Ahead of Schedule Neutral = On schedule Negative = Behind Schedule
VAC	Variance at Completion	A projection of the amount of budget deficit or surplus, expressed as the difference between the budget at completion and the estimate at completion.	The estimated difference in cost at the completion of the project.	VAC = BAC – EAC	Positive = Under planned cost Neutral = On planned cost Negative = Over planned cost
CPI	Cost Performance Index	A measure of the cost efficiency of budgeted resources expressed as the ratio of earned value to actual cost.	A CPI of 1.0 means the project is exactly on budget, that the work actually done so far is exactly the same as the cost so far. Other values show the percentage of how much costs are over or under the budgeted amount for work accomplished.	CPI = EV/AC	Greater than 1.0 = Under planned cost Exactly 1.0 = On planned cost Less than 1.0 = Over planned cost
SPI	Schedule Performance Index	A measure of schedule efficiency expressed as the ratio of earned value to planned value.	An SPI of 1.0 means that the project is exactly on schedule, that the work actually done so far is exactly the same as the work planned to be done so far. Other values show the percentage of how much costs are over or under the budgeted amount for work planned.	SPI = EV/PV	Greater than 1.0 = Ahead of schedule Exactly 1.0 = On schedule Less than 1.0 = Behind schedule
EAC	Estimate At Completion	The expected total cost of completing all work expressed as the sum of the actual cost to date and the estimate to complete.	If the CPI is expected to be the same for the remainder of the project, EAC can be calculated using: If future work will be accomplished at the planned rate, use: If the initial plan is no longer valid, use: If both the CPI and SPI influence the remaining work, use:	EAC = BAC/CPI EAC = AC + BAC – EV EAC = AC + Bottom-up ETC EAC = AC + [(BAC – EV)/(CPI x SPI)]	
ETC	Estimate to Complete	The expected cost to finish all the remaining project work.	Assuming work is proceeding on plan, the cost of completing the remaining authorized work can be calculated using: Reestimate the remaining work from the bottom up.	ETC = EAC – AC ETC = Reestimate	
TCPI	To Complete Performance Index	A measure of the cost performance that must be achieved with the remaining resources in order to meet a specified management goal, expressed as the ratio of the cost to finish the outstanding work to the budget available.	The efficiency that must be maintained in order to complete on plan. The efficiency that must be maintained in order to complete the current EAC.	TCPI = (BAC–EV)/(BAC – AC) TCPI = (BAC – EV)/(EAC – AC)	Greater than 1.0 = Harder to complete Exactly 1.0 = Same to complete Less than 1.0 = Easier to complete Greater than 1.0 = Harder to complete Exactly 1.0 = Same to complete Less than 1.0 = Easier to complete

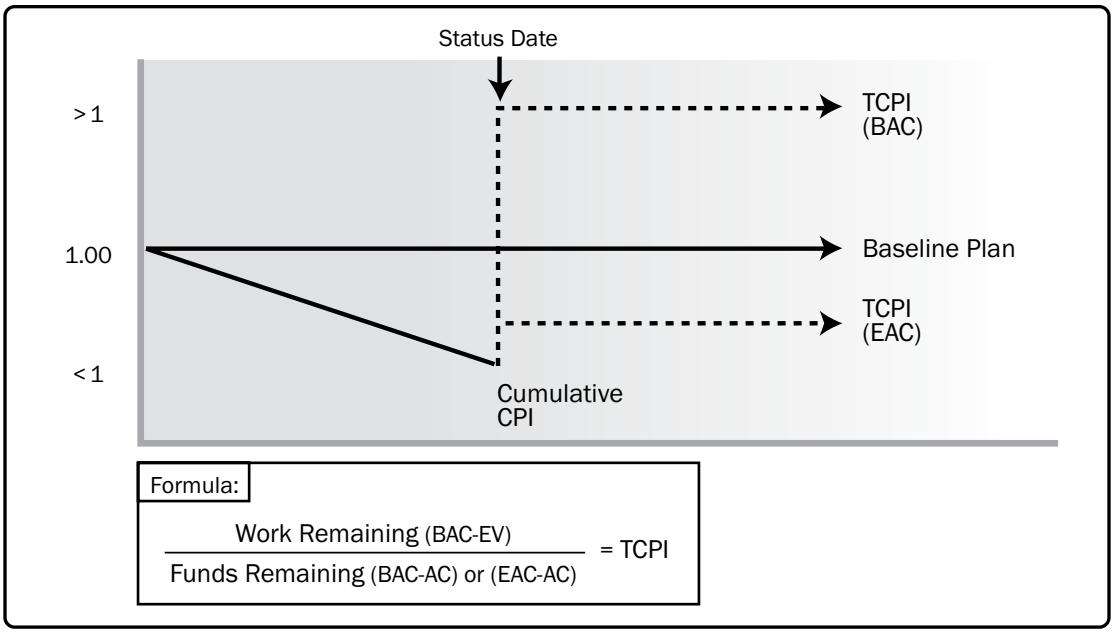

Figure 7-13. To-Complete Performance Index (TCPI)

7.4.2.4 PROJECT MANAGEMENT INFORMATION SYSTEM (PMIS)

Described in Section 4.3.2.2. Project management information systems are often used to monitor the three EVM dimensions (PV, EV, and AC), to display graphical trends, and to forecast a range of possible final project results.

7.4.3 CONTROL COSTS: OUTPUTS

7.4.3.1 WORK PERFORMANCE INFORMATION

Described in Section 4.5.1.3. Work performance information includes information on how the project work is performing compared to the cost baseline. Variances in the work performed and the cost of the work are evaluated at the work package level and control account level. For projects using earned value analysis, CV, CPI, EAC, VAC, and TCPI are documented for inclusion in work performance reports (Section 4.5.3.1).

7.4.3.2 COST FORECASTS

Either a calculated EAC value or a bottom-up EAC value is documented and communicated to stakeholders.

7.4.3.3 CHANGE REQUESTS

Described in Section 4.3.3.4. Analysis of project performance may result in a change request to the cost and schedule baselines or other components of the project management plan. Change requests are processed for review and disposition through the Perform Integrated Change Control process (Section 4.6).

7.4.3.4 PROJECT MANAGEMENT PLAN UPDATES

Any change to the project management plan goes through the organization's change control process via a change request. Components that may require a change request for the project management plan include but are not limited to:

- **Cost management plan.** Described in Section 7.1.3.1. Changes to the cost management plan, such as changes to control thresholds or specified levels of accuracy required in managing the project's cost, are incorporated in response to feedback from relevant stakeholders.
- **Cost baseline.** Described in Section 7.3.3.1. Changes to the cost baseline are incorporated in response to approved changes in scope, resources, or cost estimates. In some cases, cost variances can be so severe that a revised cost baseline is needed to provide a realistic basis for performance measurement.
- **Performance measurement baseline.** Described in Section 4.2.3.1. Changes to the performance measurement baseline are incorporated in response to approved changes in scope, schedule performance, or cost estimates. In some cases, the performance variances can be so severe that a change request is put forth to revise the performance measurement baseline to provide a realistic basis for performance measurement.

7.4.3.5 PROJECT DOCUMENTS UPDATES

Project documents that may be updated as a result of carrying out this process include but are not limited to:

- **Assumption log.** Described in Section 4.1.3.2. Cost performance may indicate the need to revise assumptions on resource productivity and other factors influencing cost performance.
- **Basis of estimates.** Described in Section 6.4.3.2. Cost performance may indicate the need to revisit the original basis of estimates.
- **Cost estimates.** Described in Section 7.2.3.1. Cost estimates may need to be updated to reflect the actual cost efficiency for the project.
- **Lessons learned register.** Described in Section 4.4.3.1. The lessons learned register can be updated with techniques that were effective in maintaining the budget, variance analysis, earned value analysis, forecasting, and corrective actions that were used to respond to cost variances.
- **Risk register.** Described in Section 11.2.3.1. The risk register may be updated if the cost variances have crossed, or are likely to cross, the cost threshold.