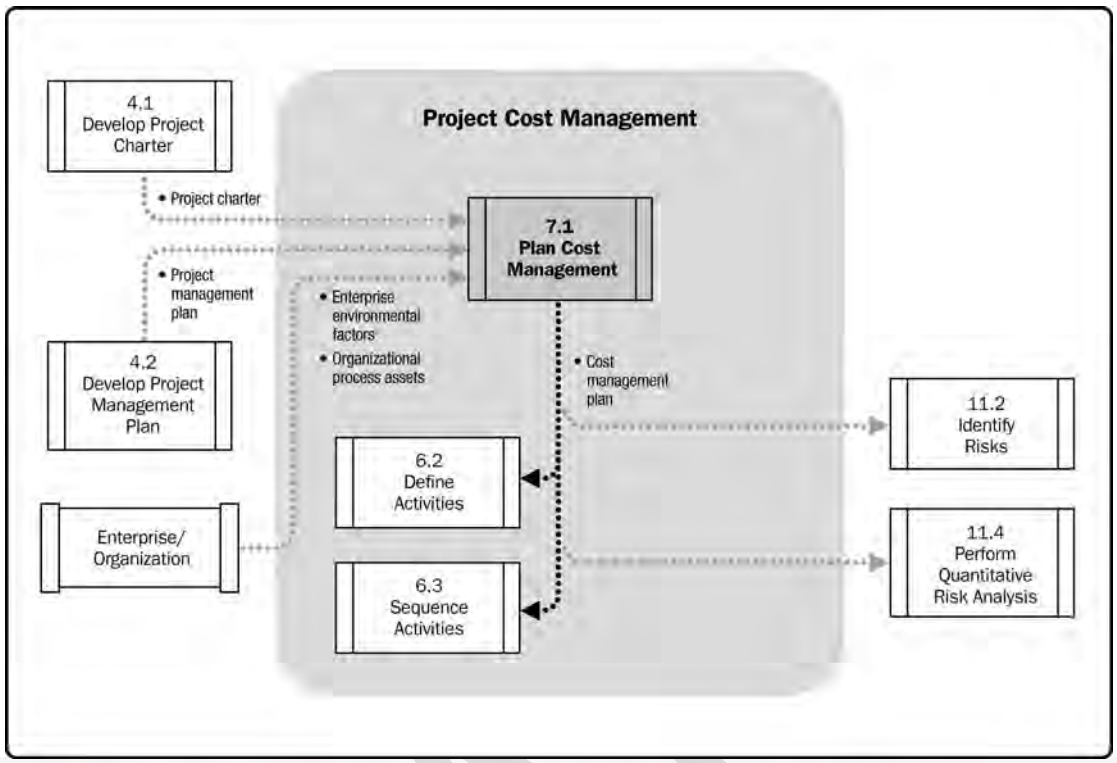

Figure 7-3. Plan Cost Management: Data Flow Diagram

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 Management Plan

Described in Section 4.2.3.1. The project management plan contains information used to develop the cost management plan, which contains, but is not limited to:

- **Scope baseline.** The scope baseline includes the project scope statement and WBS detail for cost estimation and management.
- **Schedule baseline.** The schedule baseline defines when the project costs will be incurred.
- **Other information.** Other cost-related scheduling, risk, and communications decisions from the project management plan.

7.1.1.2 Project Charter

Described in Section 4.1.3.1. The project charter provides the summary budget 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.

7.1.1.3 Enterprise Environmental Factors

Described in Section 2.1.5. The enterprise environmental factors that influence the Plan Cost Management process include, but are not limited to:

- Organizational culture and structure can all influence cost management;
- Market conditions describe what products, services, and results are available in the regional and global market;
- Currency exchange rates for project costs 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; and
- Project management information system, which provides alternative possibilities for managing cost.

7.1.1.4 Organizational Process Assets

Described in Section 2.1.4. The organizational process assets that 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 knowledge bases;
- 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

Expert judgment, guided by historical information, provides valuable insight about the environment and information from prior similar projects. Expert judgment can also suggest whether to combine methods and how to reconcile differences between them.

Judgment based upon expertise in an application area, Knowledge Area, discipline, industry, etc., as appropriate for the activity being performed should be used in developing the cost management plan.

7.1.2.2 Analytical Techniques

Developing the cost management plan may involve choosing strategic options to fund the project such as: self-funding, funding with equity, or funding with debt. The cost management plan may also detail ways to finance project resources such as making, purchasing, renting, or leasing. These decisions, like other financial decisions affecting the project, may affect project schedule and/or risks.

Organizational policies and procedures may influence which financial techniques are employed in these decisions. Techniques may include (but are not limited to): payback period, return on investment, internal rate of return, discounted cash flow, and net present value.

7.1.2.3 Meetings

Project teams may hold planning meetings to develop the cost management plan. Attendees at these meetings 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, weeks for time measures; or 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.** The degree to which activity cost estimates will be rounded up or down (e.g., US$100.49 to US$100, or 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 activity 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 earned value measurement techniques (e.g., weighted milestones, fixed-formula, percent complete, etc.) to be employed; and
  - Specify tracking methodologies and the earned value management computation equations for calculating projected estimate at completion (EAC) forecasts to provide a validity check on the bottom-up EAC.

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

- **Reporting formats.** The formats and frequency for the various cost reports are defined.
- **Process descriptions.** Descriptions of each of the other cost management processes are documented.

- **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.

7.2 Estimate Costs

Estimate Costs is the process of developing an approximation of the monetary resources needed to complete project activities. The key benefit of this process is that it determines the amount of cost required to complete project work. 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

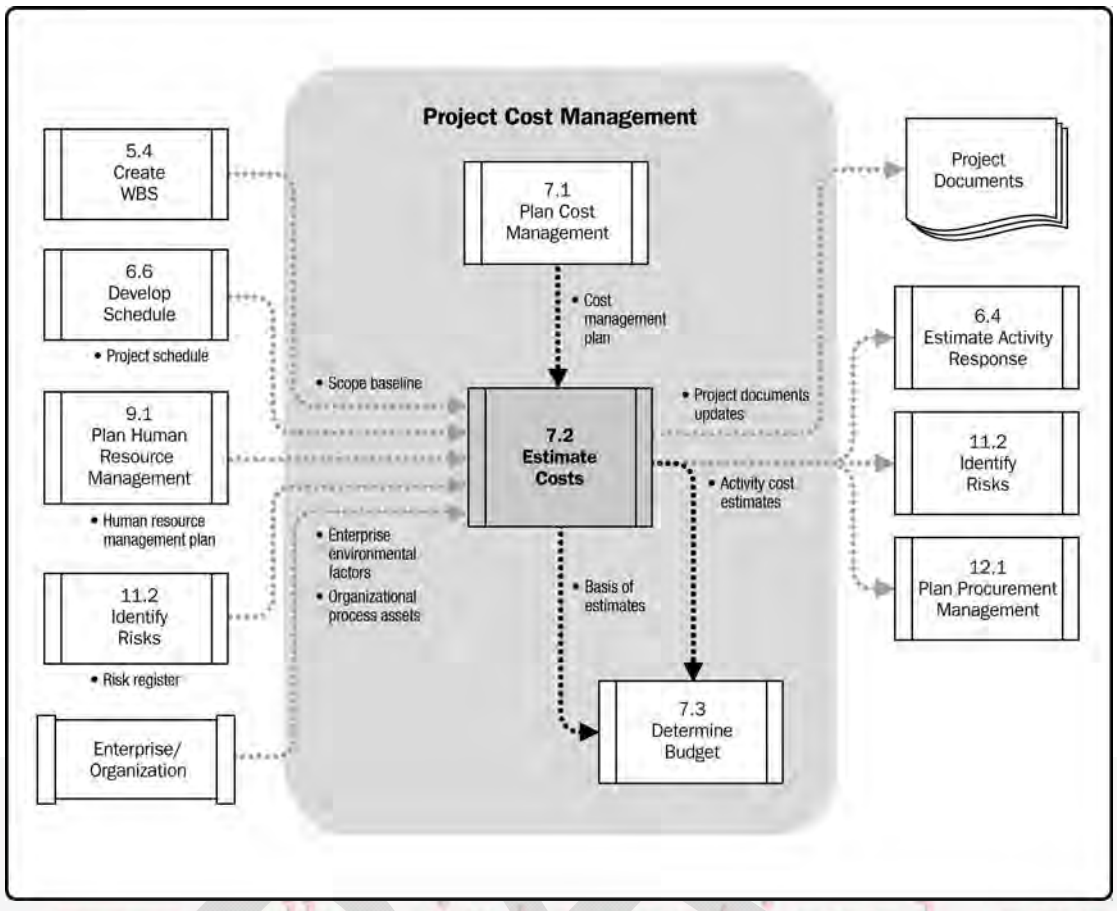

Figure 7-5. Estimate Costs Data Flow Diagram

Cost estimates are 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.

Sources of input information are derived from the outputs of processes in other Knowledge Areas. Once received, all of this information will remain available as inputs to all of the cost management processes.

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. A cost estimate is a quantitative assessment of the likely costs for resources required to complete the activity. Cost estimates may be presented at the activity level or in summary form.

7.2.1 Estimate Costs: Inputs

7.2.1.1 Cost Management Plan

Described in Section 7.1.3.1. The cost management plan defines how project costs will be managed and controlled. It includes the method used and the level of accuracy required to estimate activity cost.

7.2.1.2 Human Resource Management Plan

Described in Section 9.1.3.1. The human resource management plan provides project staffing attributes, personnel rates, and related rewards/recognition, which are necessary components for developing the project cost estimates.

7.2.1.3 Scope Baseline

The scope baseline is comprised of the following:

- **Project scope statement.** The project scope statement (Section 5.3.3.1) provides the product description, acceptance criteria, key deliverables, project boundaries, assumptions, and constraints about the project. One basic assumption that needs to be made when estimating project costs is whether the estimates will be limited to direct project costs only or whether the estimates will also include indirect costs. Indirect costs are those costs that cannot be directly traced to a specific project and therefore will be accumulated and allocated equitably over multiple projects by some approved and documented accounting procedure. One of the most common constraints for many projects is a limited project budget. Examples of other constraints are required delivery dates, available skilled resources, and organizational policies.
- **Work breakdown structure.** The WBS (Section 5.4) provides the relationships among all the components of the project and the project deliverables.
- **WBS dictionary.** The WBS dictionary (Section 5.4.3.1) provides detailed information about the deliverables and a description of the work for each component in the WBS required to produce each deliverable.

Additional information that may be found in the scope baseline with contractual and legal implications, such as health, safety, security, performance, environmental, insurance, intellectual property rights, licenses, and permits. All of this information should be considered when developing the cost estimates.

7.2.1.4 Project Schedule

Described in Section 6.6.3.2. The type and quantity of resources and the amount of time which those resources are applied to complete the work of the project are major factors in determining the project cost. Schedule activity resources and their respective durations are used as key inputs to this process. Estimate Activity Resources (Section 6.4) involves determining the availability of staff, the number of staff hours required, and quantities of material and equipment needed to perform schedule activities. It is closely coordinated with cost estimating. Activity

duration estimates (Section 6.5.3.1) will affect cost estimates on any project where the project budget includes an allowance for the cost of financing (including interest charges) and where resources are applied per unit of time for the duration of the activity. Activity duration estimates can also affect cost estimates that have time-sensitive costs included in them, such as union labor with regularly expiring collective bargaining agreements or materials with seasonal cost variations.

7.2.1.5 Risk Register

Described in Section 11.2.3.1. The risk register should be reviewed to consider risk response costs. Risks, which can be either threats or opportunities, typically have an impact on both activity and overall project costs. As a general rule, when the project experiences a negative risk event, the near-term cost of the project will usually increase, and there will sometimes be a delay in the project schedule. In a similar way, the project team should be sensitive to potential opportunities that can benefit the business either by directly reducing activity costs or by accelerating the schedule.

7.2.1.6 Enterprise Environmental Factors

Described in Section 2.1.5. The enterprise environmental factors that 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.

7.2.1.7 Organizational Process Assets

Described in Section 2.1.4. The organizational process assets that influence the Estimate Costs process include, but are not limited to:

- Cost estimating policies,
- Cost estimating templates,
- Historical information, and
- Lessons learned.

7.2.2 Estimate Costs: Tools and Techniques

7.2.2.1 Expert Judgment

Expert judgment, guided by historical information, provides valuable insight about the environment and information from prior similar projects. Expert judgment can also be used to determine whether to combine methods of estimating and how to reconcile differences between them.

7.2.2.2 Analogous Estimating

Analogous cost estimating uses the values such as scope, cost, budget, and duration or measures of scale such as size, weight, and complexity from a previous, similar project as the

basis for estimating the same parameter or measurement for a current project. When estimating costs, this technique relies on the actual cost of previous, similar projects as the basis for estimating the cost of the current project. It is a gross value estimating approach, sometimes adjusted for known differences in project complexity.

Analogous cost estimating is frequently used to estimate a value when there is a limited amount of detailed information about the project, for example, in the early phases of a project. Analogous cost estimating uses historical information and expert judgment.

Analogous cost estimating is generally less costly and less time consuming than other techniques, but it is also generally less accurate. Analogous cost estimates can be applied to a total project or to segments of a project, in conjunction with other estimating methods. Analogous estimating is most reliable when the previous projects are similar in fact and not just in appearance, and the project team members preparing the estimates have the needed expertise.

7.2.2.3 Parametric Estimating

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 upon 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

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 and complexity of the individual activity or work package.

7.2.2.5 Three-Point Estimating

The accuracy of single-point activity 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 activity cost based on analysis of the best-case scenario for the activity.
- **Pessimistic** (*cP*). The activity 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** (from a traditional PERT analysis). 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 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, which are accepted and for which contingent or mitigating responses are developed. 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 provide for a specific activity, for the whole project, or both. 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.

Estimates may also be produced for the amount of management reserve to be funded 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.

7.2.2.7 Cost of Quality (COQ)

Assumptions about costs of quality (Section 8.1.2.2) may be used to prepare the activity cost estimate.

7.2.2.8 Project Management Software

Project management software applications, computerized spreadsheets, simulation, and statistical tools are used to assist with cost estimating. Such tools can simplify the use of some cost-estimating techniques and thereby facilitate rapid consideration of cost estimate alternatives.

7.2.2.9 Vendor Bid Analysis

Cost estimating methods may include analysis of what the project should cost, based on the responsive bids from qualified vendors. When projects are awarded to a vendor under competitive processes, additional cost estimating work may be required of the project team to examine the price of individual deliverables and to derive a cost that supports the final total project cost.

7.2.2.10 Group Decision-Making Techniques

Team-based approaches, such as brainstorming, the Delphi or nominal group techniques, are useful for engaging team members to improve estimate accuracy and commitment to the emerging estimates. By involving a structured group of people who are close to the technical execution of work in the estimation process, additional information is gained and more accurate estimates are obtained. Additionally, when people are involved in the estimation process, their commitment towards meeting the resulting estimates increases.

7.2.3 Estimate Costs: Outputs

7.2.3.1 Activity Cost Estimates

Activity cost estimates are quantitative assessments of the probable costs required to complete project work. Cost estimates can be presented in summary form or in detail. Costs are estimated for all resources that are applied to the activity 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 activity 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,
- Indication of the range of possible estimates (e.g., €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 include, but are not limited to, the risk register.

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. 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.

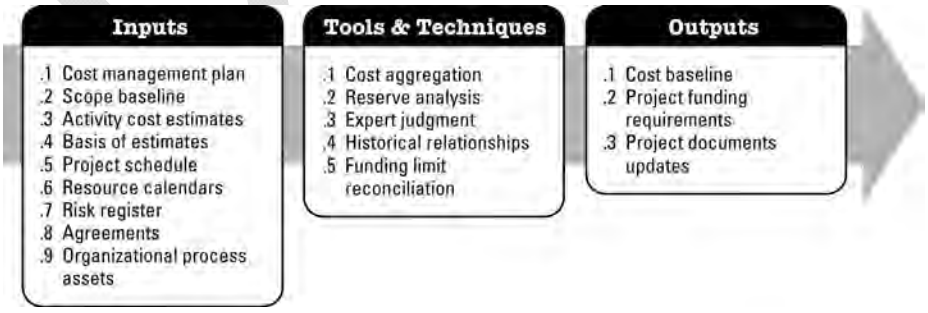

Figure 7-6. Determine Budget: Inputs, Tools & Techniques, and Outputs

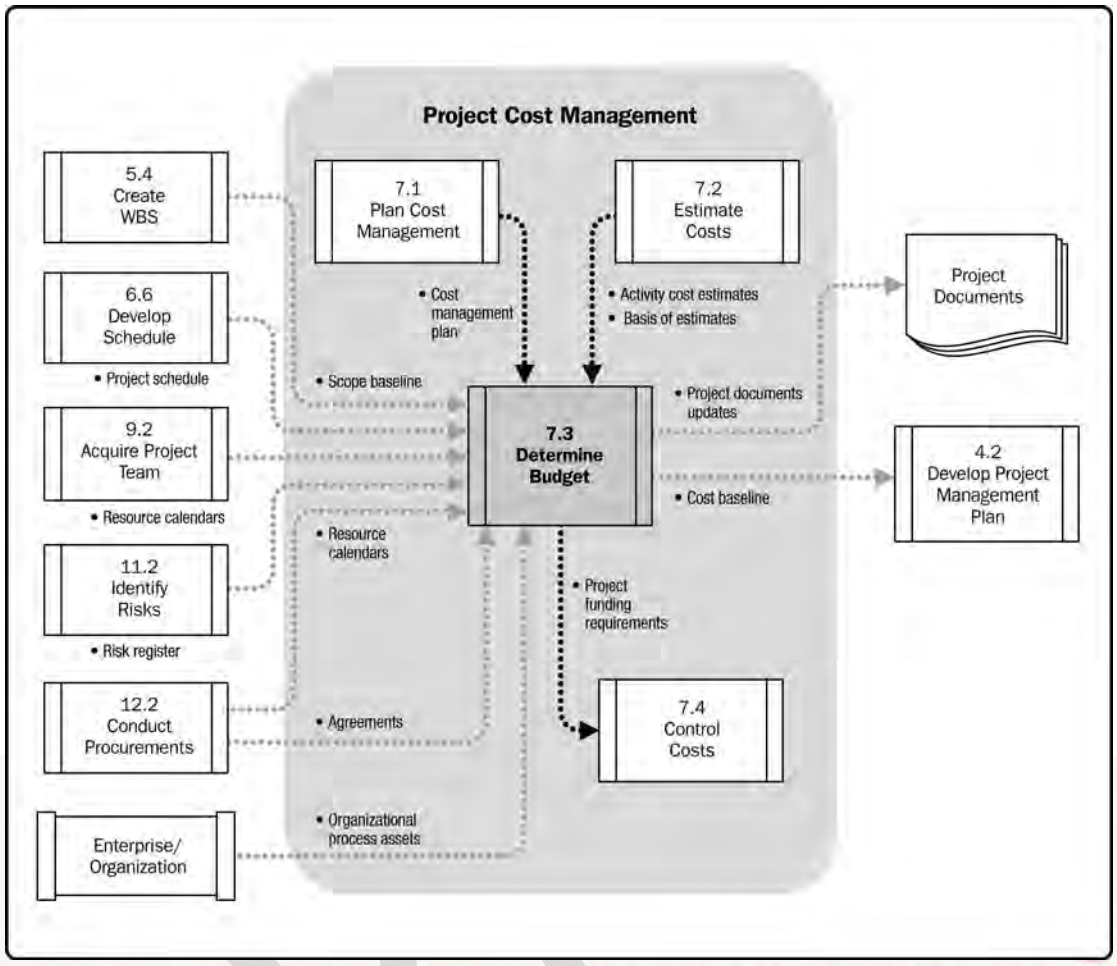

Figure 7-7. Determine Budget Data Flow Diagram

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, but excludes management reserves.

7.3.1 Determine Budget: Inputs

7.3.1.1 Cost Management Plan

Described in Section 7.1.3.1. The cost management plan describes how the project costs will be managed and controlled.

7.3.1.2 Scope Baseline

- **Project scope statement.** Formal limitations by period for the expenditure of project funds can be mandated by the organization, by agreement (Section 12.2.3.2), or by other entities such as government agencies. These funding constraints are reflected in the project scope statement.
- **Work breakdown structure.** The WBS (Section 5.4) provides the relationships among all the project deliverables and their various components.

- **WBS dictionary.** The WBS dictionary (Section 5.4.3.1) 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.

7.3.1.3 Activity 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.

7.3.1.4 Basis of Estimates

Described in Section 7.2.3.2. 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.

7.3.1.5 Project Schedule

Described in Section 6.6.3.2. 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.

7.3.1.6 Resource Calendars

Described in Sections 9.2.3.2 and 12.2.3.3. Resource calendars provide information on which resources are assigned to the project and when they are assigned. This information can be used to indicate resource costs over the duration of the project.

7.3.1.7 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 document updates described in Section 11.5.3.2.

7.3.1.8 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.

7.3.1.9 Organizational Process Assets

Described in Section 2.1.4. The organizational process assets that influence the Determine Budget process include, but are not limited to:

- Existing formal and informal cost budgeting-related policies, procedures, and guidelines;
- Cost budgeting tools; and
- Reporting methods.

7.3.2 Determine Budget: Tools and Techniques

7.3.2.1 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.

7.3.2.2 Reserve Analysis

Budget reserve analysis can establish both the contingency reserves and the management reserves for the project. Management and contingency reserves are addressed in more detail in Section 7.2.2.6.

7.3.2.3 Expert Judgment

Expert judgment, guided by experience in an application area, Knowledge Area, discipline, industry, or similar project, aids in determining the budget. Such expertise may be provided by any group or person with specialized education, knowledge, skill, experience, or training. Expert judgment is available from many sources, including, but not limited to:

- Other units within the performing organization,
- Consultants,
- Stakeholders, including customers,
- Professional and technical associations, and
- Industry groups.

7.3.2.4 Historical Relationships

Any historical relationships that result in parametric estimates or analogous estimates involve the use of 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.

7.3.3 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 and is used as a basis for comparison to actual results. It 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. Activity cost estimates for the various project activities along with any contingency reserves

(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.

Management reserves (Section 7.2.2.6) 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.

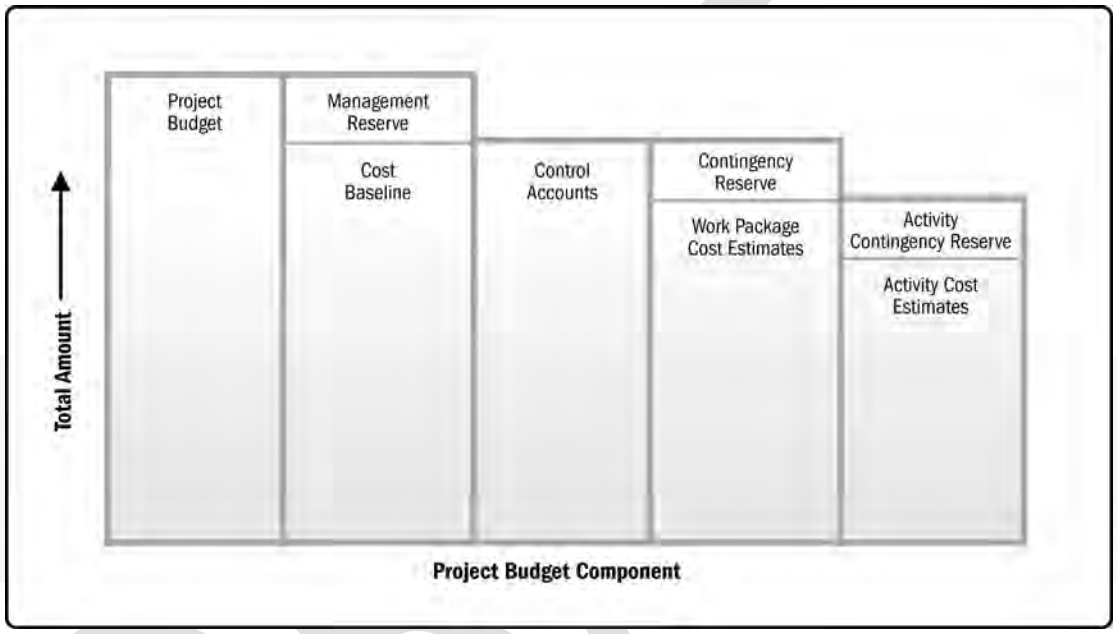

Figure 7-8. Project Budget Components

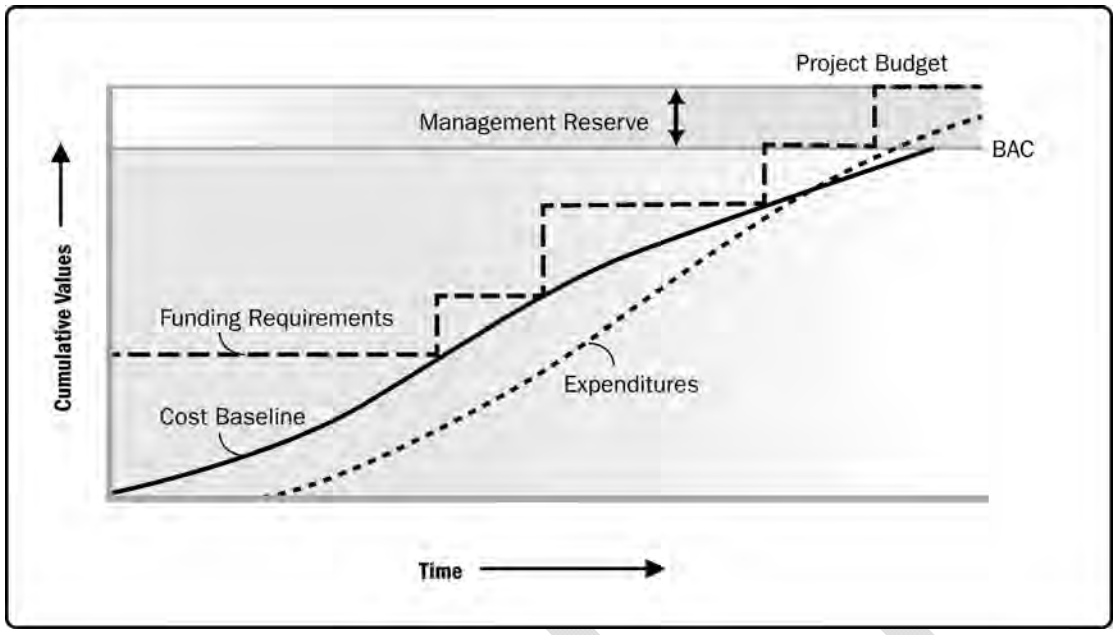

Figure 7-9. Cost Baseline, Expenditures, and Funding Requirements

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 that are not continuous, and may not be evenly distributed, which appear as steps as shown 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 include, but are not limited to:

- Risk register,
- Activity cost estimates, and
- Project schedule.

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 it provides the means to recognize variance from the plan in order to take corrective action and minimize risk. 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.

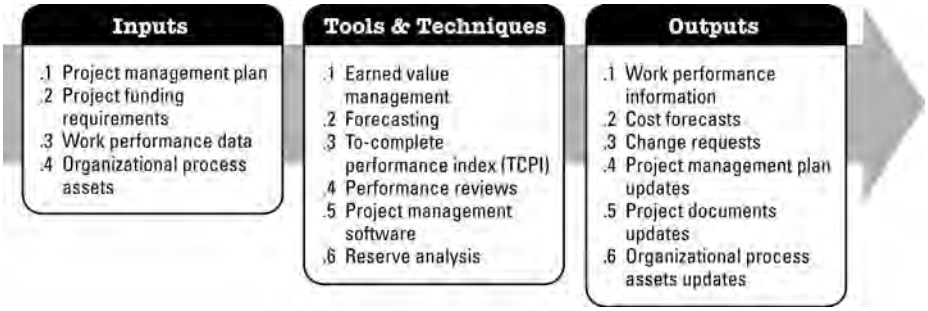

Figure 7-10. Control Costs: Inputs, Tools & Techniques, and Outputs

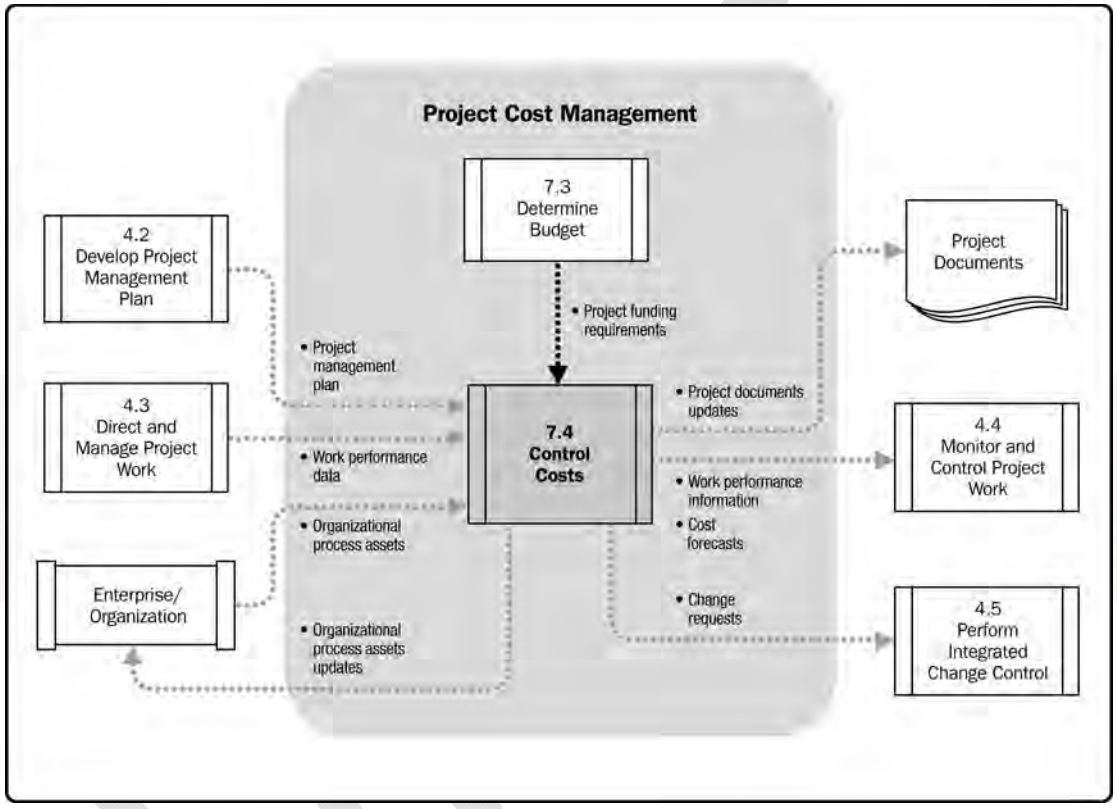

Figure 7-11. Control Costs Data Flow Diagram

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 4.5). 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 allow the project team to stay within the authorized funding. Much of the effort of cost control involves analyzing the relationship between the consumption of project funds to the physical work being accomplished for such expenditures. The key to effective cost control is the management of the approved cost baseline and the changes to that 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. The project management plan contains the following information that is used to control cost:

- **Cost baseline.** The cost baseline is compared with actual results to determine if a change, corrective action, or preventive action is necessary.
- **Cost management plan.** The cost management plan describes how the project costs will be managed and controlled (Section 7.1.3.1).

7.4.1.2 Project Funding Requirements

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

7.4.1.3 Work Performance Data

Described in Section 4.3.3.2. Work performance data includes information about project progress, such as which activities have started, their progress, and which deliverables have finished. Information also includes costs that have been authorized and incurred.

7.4.1.4 Organizational Process Assets

Described in Section 2.1.4. 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 Earned Value Management

Earned value management (EVM) is a methodology that combines scope, schedule, and resource measurements to assess project performance and progress. It is a commonly used method of performance measurement for projects. It integrates the scope baseline with the cost baseline, along with the schedule baseline, to form the performance baseline, which helps the project management team assess and measure project performance and progress. It is a project

management technique that requires the formation of an integrated baseline against which performance can be measured for the duration of the project. The principles of EVM can be applied to all projects in any industry. 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 component, not including management reserve. This budget is allocated by phase over the life of the project, but at a given moment, 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.

Variances from the approved baseline will also be monitored:

- **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 EVM 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 EVM 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 methodology (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

The SV and CV values can be converted to efficiency indicators to reflect the cost and schedule performance of any project for comparison against all other projects or within a portfolio of projects. The variances are useful for determining project status.

- **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 using its time. 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 EVM 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. The indices are useful for determining project status and providing a basis for estimating project cost and schedule outcome. *Equation:* CPI = EV/AC

The 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.

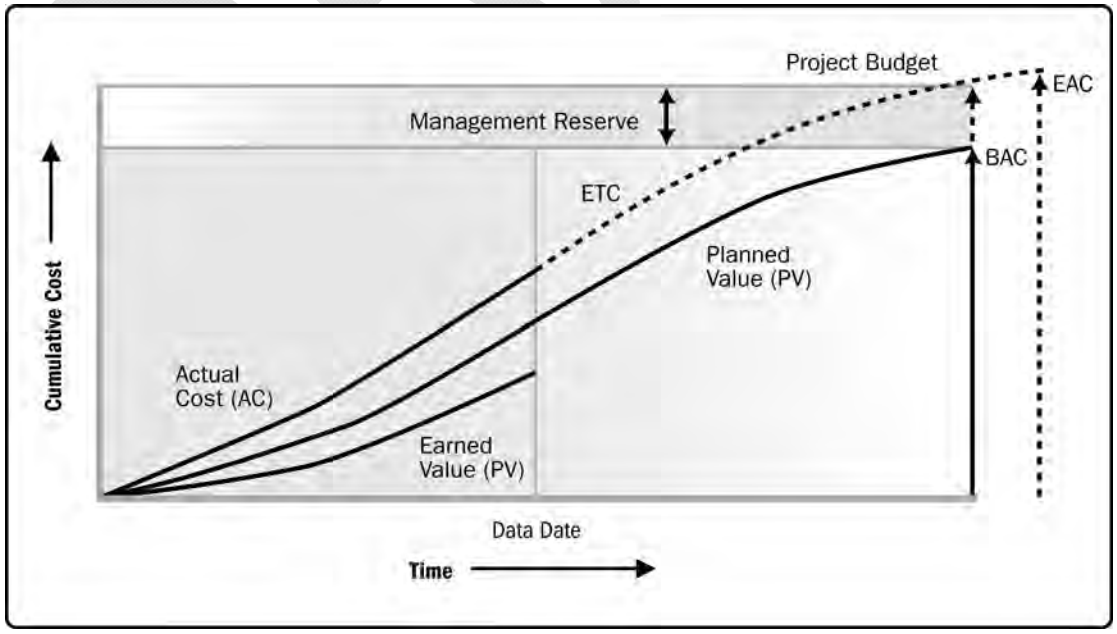

Figure 7-12. Earned Value, Planned Value, and Actual Costs

7.4.2.2 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. The EVM method 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 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)]

Each of these approaches is applicable for any given project and will provide the project management team with an "early warning" signal if the EAC forecasts are not within acceptable tolerances.

7.4.2.3 To-Complete Performance Index (TCPI)

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, schedule, and technical performance. This level of performance is displayed as the TCPI (EAC) line. The equation for the TCPI based on the EAC: (BAC – EV) / (EAC – AC). The EVM formulas are provided in Table 7-1.

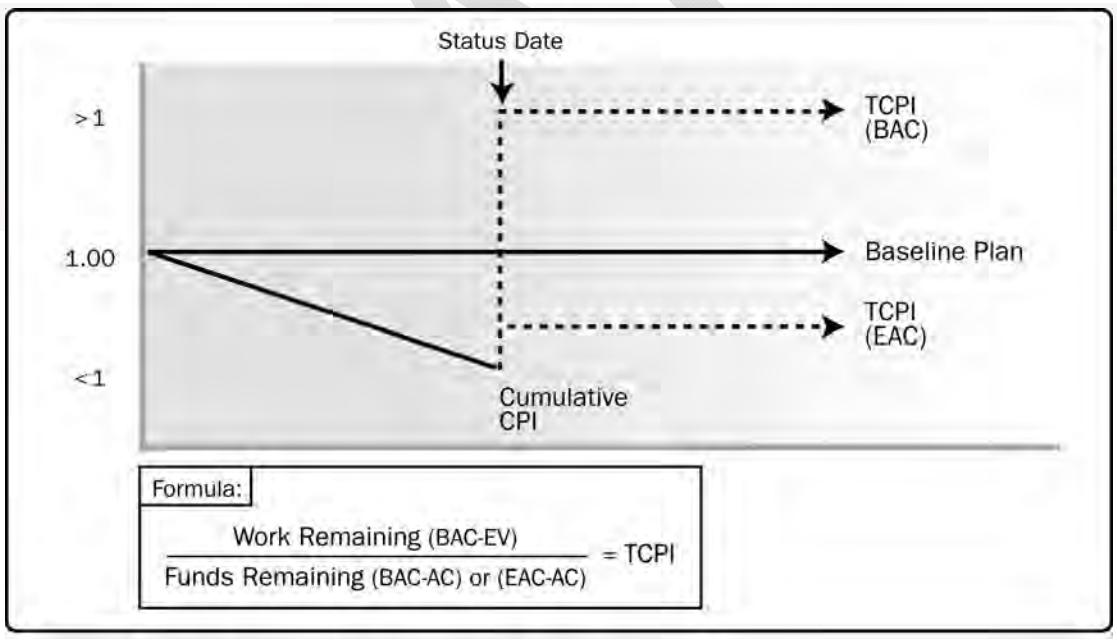

Figure 7-13. To-Complete Performance Index (TCPI)

7.4.2.4 Performance Reviews

Performance reviews compare cost performance over time, schedule activities or work packages overrunning and underrunning the budget, and estimated funds needed to complete work in progress. If EVM is being used, the following information is determined:

- **Variance analysis.** 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 earned value management, similar variance analyses can be performed by comparing planned activity cost against actual activity 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 preventative 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 (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.

- **Trend analysis.** 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 EAC and completion dates.
- **Earned value performance.** Earned value performance compares the performance measurement baseline to actual schedule and cost performance. If EVM is not being used, then the analysis of the cost baseline against actual costs for the work performed is used for cost performance comparisons.

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

7.4.2.5 Project Management Software

Project management software is 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.

7.4.2.6 Reserve Analysis

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 mitigation events or other contingencies. Or, if the probable risk events 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. Management and contingency reserves are addressed in more detail in Section 7.2.2.6.

7.4.3 Control Costs: Outputs

7.4.3.1 Work Performance Information

The calculated CV, SV, CPI, SPI, TCPI, and VAC values for WBS components, in particular the work packages and control accounts, are documented and communicated to stakeholders.

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

Analysis of project performance may result in a change request to the cost baseline or other components of the project management plan. Change requests may include preventive or corrective actions, and are processed for review and disposition through the Perform Integrated Change Control process (Section 4.5).

7.4.3.4 Project Management Plan Updates

Elements of the project management plan that may be updated include, but are not limited to:

- **Cost baseline.** Changes to the cost baseline are incorporated in response to approved changes in scope, activity 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.
- **Cost management plan.** 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.

7.4.3.5 Project Documents Updates

Project documents that may be updated include, but are not limited to:

- Cost estimates, and
- Basis of estimates.

7.4.3.6 Organizational Process Assets Updates

Organizational process assets that may be updated include, but are not limited to:

- Causes of variances,
- Corrective action chosen and the reasons,
- Financial databases, and
- Other types of lessons learned from project cost control.

8

PROJECT QUALITY MANAGEMENT

Project Quality Management includes the processes and activities of the performing organization that determine quality policies, objectives, and responsibilities so that the project will satisfy the needs for which it was undertaken. Project Quality Management uses policies and procedures to implement, within the project's context, the organization's quality management system and, as appropriate, it supports continuous process improvement activities as undertaken on behalf of the performing organization. Project Quality Management works to ensure that the project requirements, including product requirements, are met and validated.

Figure 8-1 provides an overview of the Project Quality Management processes, which include:

8.1 Plan Quality Management—The process of identifying quality requirements and/or standards for the project and its deliverables and documenting how the project will demonstrate compliance with quality requirements.

8.2 Perform Quality Assurance—The process of auditing the quality requirements and the results from quality control measurements to ensure that appropriate quality standards and operational definitions are used.

8.3 Control Quality—The process of monitoring and recording results of executing the quality activities to assess performance and recommend necessary changes.

These processes interact with each other and with processes in other Knowledge Areas as described in detail in Section 3 and Annex A1.

Project Quality Management addresses the management of the project and the deliverables of the project. It applies to all projects, regardless of the nature of their deliverables. Quality measures and techniques are specific to the type of deliverables being produced by the project. For example, the project quality management of software deliverables may use different approaches and measures from those used when building a nuclear power plant. In either case, failure to meet the quality requirements can have serious, negative consequences for any or all of the project's stakeholders. For example:

- Meeting customer requirements by overworking the project team may result in decreased profits and increased project risks, employee attrition, errors, or rework.
- Meeting project schedule objectives by rushing planned quality inspections may result in undetected errors, decreased profits, and increased post-implementation risks.

Quality and *grade* are not the same concepts. Quality as a delivered performance or result is "the degree to which a set of inherent characteristics fulfill requirements. (ISO 9000)" Grade as a design intent is a category assigned to deliverables having the same functional use but different technical characteristics. The project manager and the project management team are responsible for managing the tradeoffs associated with delivering the required levels of both

quality and grade. While a quality level that fails to meet quality requirements is always a problem, a low grade of quality may not be a problem. For example:

- It may not be a problem if a suitable low-grade software product (one with a limited number of features) is of high quality (no obvious defects, readable manual). In this example, the product would be appropriate for its general purpose of use.
- It may be a problem if a high-grade software product (one with numerous features) is of low quality (many defects, poorly organized user documentation). In essence, its high-grade feature set would prove ineffective and/or inefficient due to its low quality.

The project management team should determine the appropriate levels of accuracy and precision for use in the quality management plan. *Precision* is a measure of exactness. For example, the magnitude for each increment on the measurement's number line is the interval that determines the measurement's precision—the greater the number of increments, the greater the precision. *Accuracy* is an assessment of correctness. For example, if the measured value of an item is very close to the true value of the characteristic being measured, the measurement is more accurate. An illustration of this concept is the comparison of archery targets. Arrows clustered tightly in one area of the target, even if they are not clustered in the bull's-eye, are considered to have high precision. Targets where the arrows are more spread out but equidistant from the bull's-eye are considered to have the same degree of accuracy. Targets where the arrows are both tightly grouped and within the bull's-eye are considered to be both accurate and precise. Precise measurements are not necessarily accurate measurements, and accurate measurements are not necessarily precise measurements.

The basic approach to project quality management as described in this section is intended to be compatible with that of the International Organization for Standardization (ISO) quality standards. Every project should have a quality management plan. Project teams should follow the quality management plan and should have data to demonstrate compliance with the plan.

In the context of achieving ISO compatibility, modern quality management approaches seek to minimize variation and to deliver results that meet defined requirements. These approaches recognize the importance of:

- **Customer satisfaction.** Understanding, evaluating, defining, and managing requirements so that customer expectations are met. This requires a combination of conformance to requirements (to ensure the project produces what it was created to produce) and fitness for use (the product or service needs to satisfy the real needs).
- **Prevention over inspection.** Quality should be planned, designed, and built into—not inspected into the project's management or the project's deliverables. The cost of preventing mistakes is generally much less than the cost of correcting mistakes when they are found by inspection or during usage.
- **Continuous improvement.** The PDCA (plan-do-check-act) cycle is the basis for quality improvement as defined by Shewhart and modified by Deming. In addition, quality improvement initiatives such as Total Quality Management (TQM), Six Sigma, and Lean Six Sigma could improve the quality of the project's management as well as the quality of the project's product. Commonly used process improvement models include Malcolm Baldrige, Organizational Project Management Maturity Model (OPM3®), and Capability Maturity Model Integrated (CMMI®).

- **Management Responsibility.** Success requires the participation of all members of the project team. Nevertheless, management retains, within its responsibility for quality, a related responsibility to provide suitable resources at adequate capacities.
- **Cost of quality (COQ).** Cost of quality refers to the total cost of the conformance work and the nonconformance work that should be done as a compensatory effort because, on the first attempt to perform that work, the potential exists that some portion of the required work effort may be done or has been done incorrectly. The costs for quality work may be incurred throughout the deliverable's life cycle. For example, decisions made by the project team can impact the operational costs associated with using a completed deliverable. Post-project quality costs may be incurred because of product returns, warranty claims, and recall campaigns. Therefore, because of the temporary nature of projects and the potential benefits that may be derived from reducing the post-project cost of quality, sponsoring organizations may choose to invest in product quality improvement. These investments generally are made in the areas of conformance work that act to prevent defects or act to mitigate the costs of defects by inspecting out nonconforming units. Refer to Figure 8-2 and Section 8.1.2.2. Moreover, the issues related to post-project COQ should be the concern of program management and portfolio management such that project, program, and portfolio management offices should apply appropriate reviews, templates, and funding allocations for this purpose.

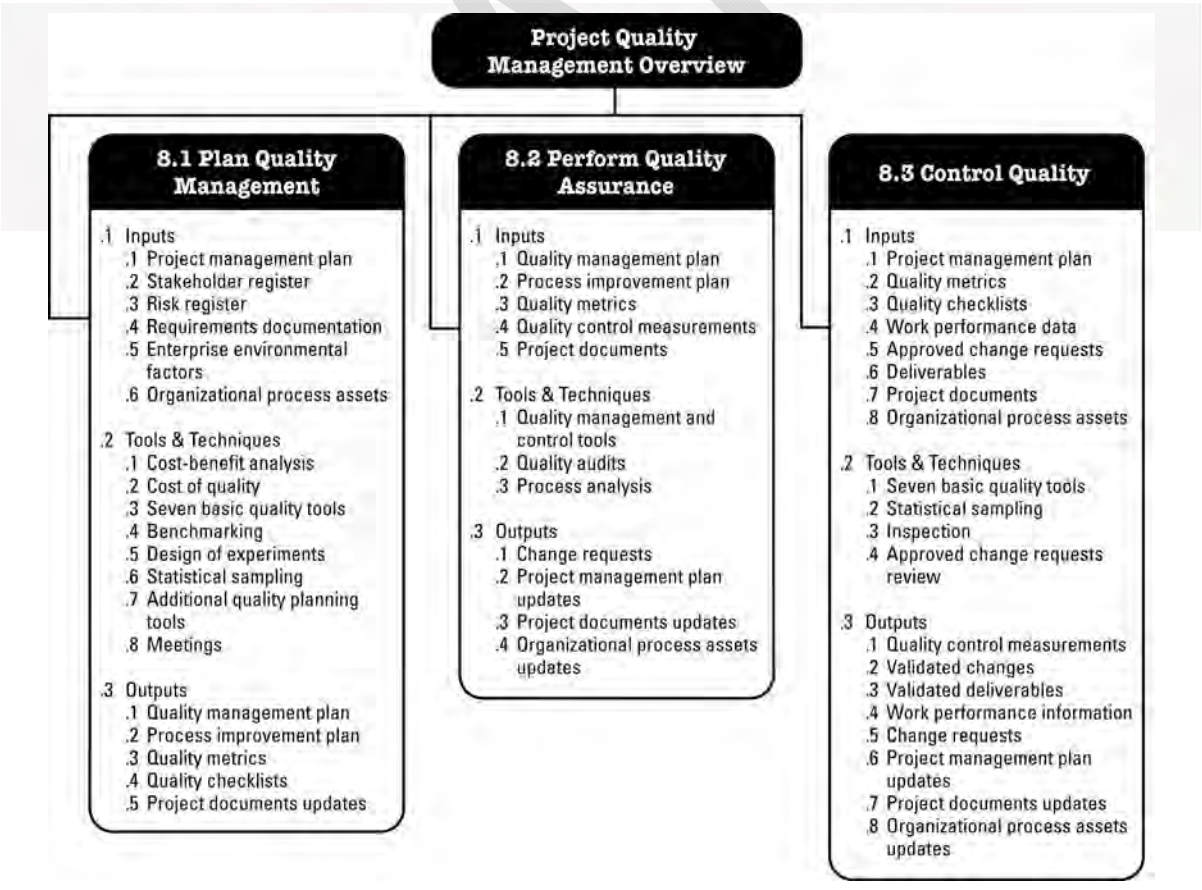

Figure 8-1. Project Quality Management Overview

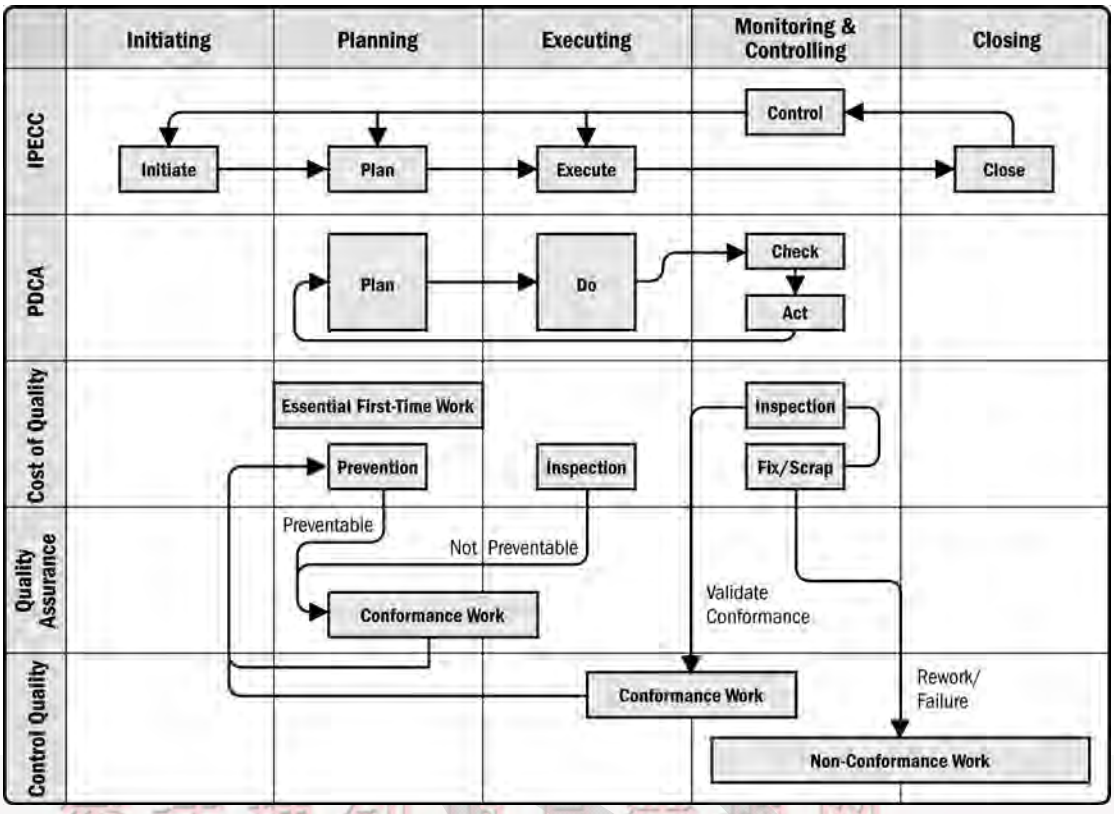

Figure 8-2. Fundamental Relationships of Quality Assurance and Control Quality to the IPECC, PDCA, Cost of Quality Models and Project Management Process Groups

8.1 Plan Quality Management

Plan Quality Management is the process of identifying quality requirements and/or standards for the project and its deliverables, and documenting how the project will demonstrate compliance with relevant quality requirements. The key benefit of this process is that it provides guidance and direction on how quality will be managed and validated throughout the project. The inputs, tools and techniques, and outputs of this process are depicted in Figure 8-3. Figure 8-4 depicts the data flow diagram of the process.

Figure 8-3. Plan Quality Management Inputs, Tools & Techniques, and Outputs

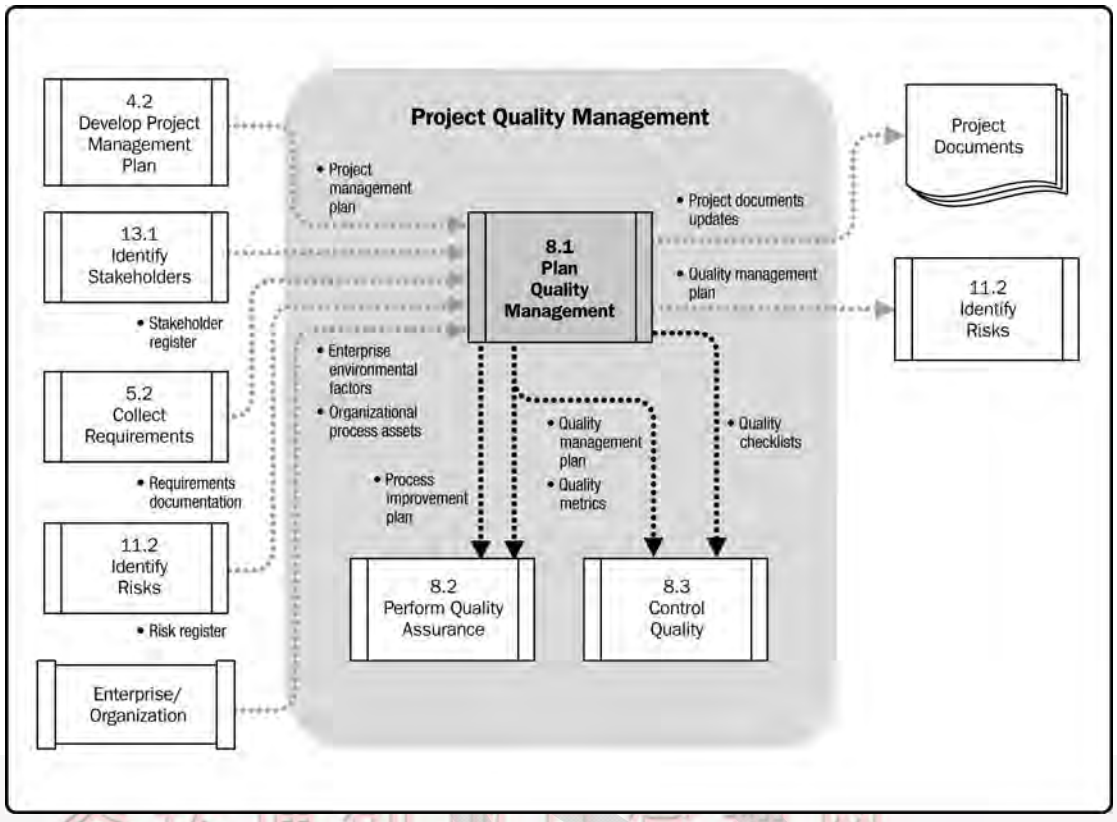

Figure 8-4. Plan Quality Management Data Flow Diagram

Quality planning should be performed in parallel with the other planning processes. For example, proposed changes in the deliverables to meet identified quality standards may require cost or schedule adjustments and a detailed risk analysis of the impact to plans.

The quality planning techniques discussed here are those used most frequently on projects. There are many others that may be useful on certain projects or in some application areas.

8.1.1 Plan Quality Management: Inputs

8.1.1.1 Project Management Plan

Described in Section 4.2.3.1. The project management plan is used to develop the quality management plan. The information used for the development of the quality management plan includes, but is not limited to:

- **Scope baseline.** The scope baseline (Section 5.4.3.1) includes:
  - *Project scope statement.* The project scope statement contains the project description, major project deliverables, and acceptance criteria. The product scope often contains details of technical issues and other concerns that can affect quality planning and that should have been identified as a result of the planning processes in Project Scope Management. The definition of acceptance criteria may significantly increase or decrease quality costs and therefore, project costs. Satisfying all acceptance criteria that the needs of the sponsor and/or customer have been met.

- *Work breakdown structure (WBS).* The WBS identifies the deliverables and the work packages used to measure project performance.
- *WBS dictionary.* The WBS dictionary provides detailed information for WBS elements.

- **Schedule baseline.** The schedule baseline documents the accepted schedule performance measures, including start and finish dates (Section 6.6.3.1).
- **Cost baseline.** The cost baseline documents the accepted time interval being used to measure cost performance (Section 7.3.3.1).
- **Other management plans**. These plans contribute to the overall project quality and may highlight actionable areas of concern with regard to the project's quality.

8.1.1.2 Stakeholder Register

Described in Section 13.1.3.1. The stakeholder register aids in identifying those stakeholders possessing a particular interest in, or having an impact on, quality.

8.1.1.3 Risk Register

Described in Section 11.2.3.1. The risk register contains information on threats and opportunities that may impact quality requirements.

8.1.1.4 Requirements Documentation

Described in Section 5.2.3.1. Requirements documentation captures the requirements that the project shall meet pertaining to stakeholder expectations. The components of the requirements documentation include, but are not limited to, project (including product) and quality requirements. The requirements are used by the project team to help plan how quality control will be implemented on the project.

8.1.1.5 Enterprise Environmental Factors

Described in Section 2.1.5. The enterprise environmental factors that influence the Plan Quality Management process include, but are not limited to:

- Governmental agency regulations;
- Rules, standards, and guidelines specific to the application area;
- Working or operating conditions of the project or its deliverables that may affect project quality; and
- Cultural perceptions that may influence expectations about quality.

8.1.1.6 Organizational Process Assets

Described in Section 2.1.4. The organizational process assets that influence the Plan Quality Management process include, but are not limited to:

- Organizational quality policies, procedures, and guidelines. The performing organization's quality policy, as endorsed by senior management, sets the organization's intended direction on implementing its quality management approach.
- Historical databases; and
- Lessons learned from previous phases or projects.

8.1.2 Plan Quality Management: Tools and Techniques

8.1.2.1 Cost-Benefit Analysis

The primary benefits of meeting quality requirements include less rework, higher productivity, lower costs, increased stakeholder satisfaction, and increased profitability. A cost-benefit analysis for each quality activity compares the cost of the quality step to the expected benefit.

8.1.2.2 Cost of Quality (COQ)

Cost of quality includes all costs incurred over the life of the product by investment in preventing nonconformance to requirements, appraising the product or service for conformance to requirements, and failing to meet requirements (rework). Failure costs are often categorized into internal (found by the project) and external (found by the customer). Failure costs are also called cost of poor quality. Figure 8-5 provides some examples to consider in each area.

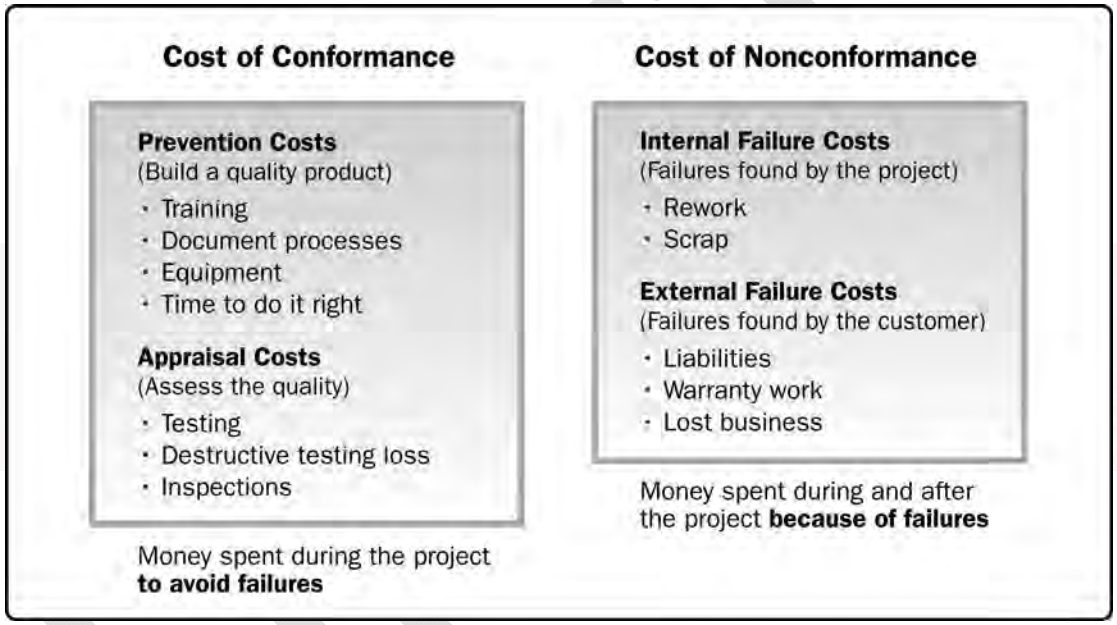

Figure 8-5. Cost of Quality

8.1.2.3 Seven Basic Quality Tools

The seven basic quality tools, also known in the industry as 7QC Tools, are used within the context of the PDCA Cycle to solve quality-related problems. As conceptually illustrated in Figure 8-7, the seven basic quality tools are:

- *Cause-and-effect diagrams*, which are also known as fishbone diagrams or as Ishikawa diagrams. The problem statement placed at the head of the fishbone is used as a starting point to trace the problem's source back to its actionable root cause. The problem statement typically describes the problem as a gap to be closed or as an objective to be achieved. The causes are found by looking at the problem statement and asking "why" until the actionable root cause has been identified or until the reasonable possibilities on each fishbone have been exhausted. Fishbone diagrams often prove useful in linking the undesirable effects seen as special variation to the

assignable cause on which project teams should implement corrective actions to eliminate the special variation detected in a control chart.

- *Flowcharts*, which are also referred to as process maps because they display the sequence of steps and the branching possibilities that exist for a process that transforms one or more inputs into one or more outputs. Flowcharts show the activities, decision points, branching loops, parallel paths, and the overall order of processing by mapping the operational details of procedures that exist within a horizontal value chain of a SIPOC model (Figure 8-6). Flowcharts may prove useful in understanding and estimating the cost of quality in a process. This is obtained by using the workflow branching logic and associated relative frequencies to estimate expected monetary value for the conformance and nonconformance work required to deliver the expected conforming output.

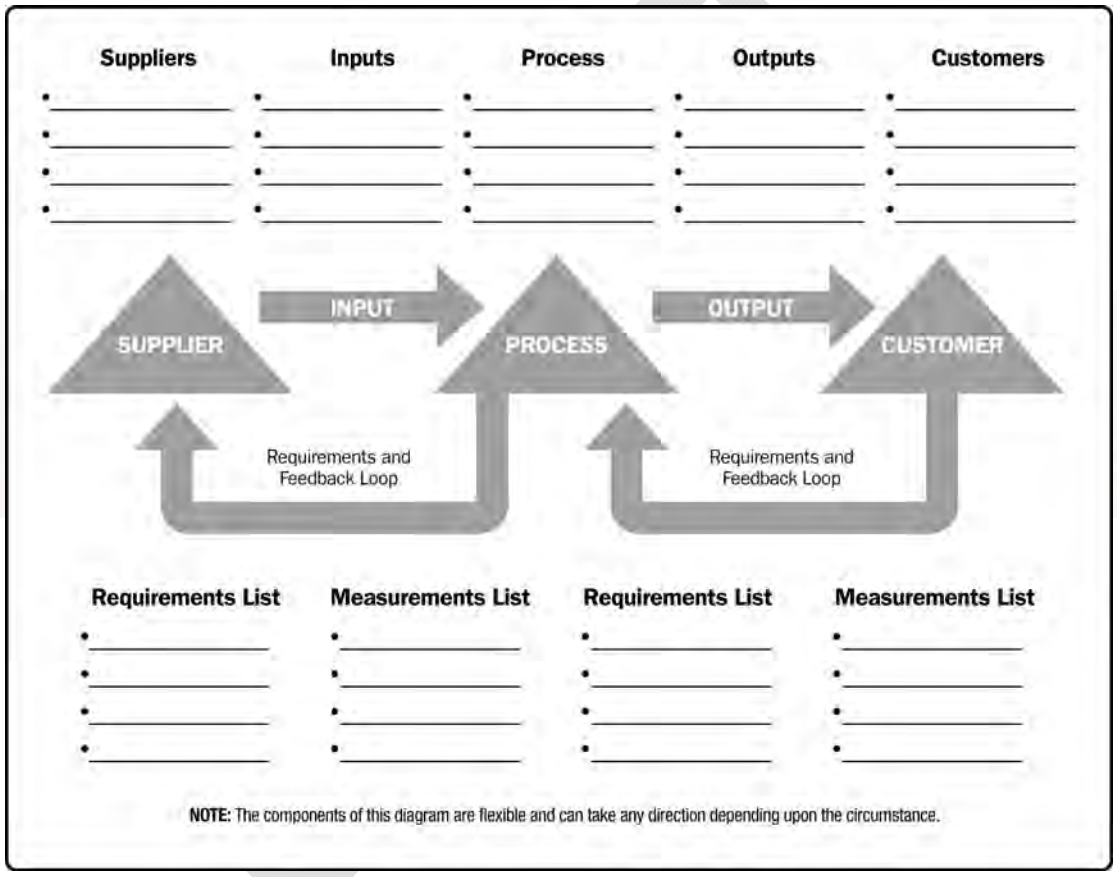

Figure 8-6. The SIPOC Model

- *Checksheets*, which are also known as tally sheets and may be used as a checklist when gathering data. Checksheets are used to organize facts in a manner that will facilitate the effective collection of useful data about a potential quality problem. They are especially useful for gathering attributes data while performing inspections to identify defects. For example, data about the frequencies or consequences of defects collected in checksheets are often displayed using Pareto diagrams.
- *Pareto diagrams*, exist as a special form of vertical bar chart and are used to identify the vital few sources that are responsible for causing most of a problem's effects. The

categories shown on the horizontal axis exist as a valid probability distribution that accounts for 100% of the possible observations. The relative frequencies of each specified cause listed on the horizontal axis decrease in magnitude until the default source named "*other*" accounts for any nonspecified causes. Typically, the Pareto diagram will be organized into categories that measure either frequencies or consequences.

- *Histograms,* are a special form of bar chart and are used to describe the central tendency, dispersion, and shape of a statistical distribution. Unlike the control chart, the histogram does not consider the influence of time on the variation that exists within a distribution.
- *Control charts,* are used to determine whether or not a process is stable or has predictable performance. Upper and lower specification limits are based on requirements of the agreement. They reflect the maximum and minimum values allowed. There may be penalties associated with exceeding the specification limits. Upper and lower control limits are different from specification limits. The control limits are determined using standard statistical calculations and principles to ultimately establish the natural capability for a stable process. The project manager and appropriate stakeholders may use the statistically calculated control limits to identify the points at which corrective action will be taken to prevent unnatural performance. The corrective action typically seeks to maintain the natural stability of a stable and capable process. For repetitive processes, the control limits are generally set at ±3 s around a process mean that has been set at 0 s. A process is considered out of control when: (1) a data point exceeds a control limit; (2) seven consecutive plot points are above the mean; or (3) seven consecutive plot points are below the mean.

  Control charts can be used to monitor various types of output variables. Although used most frequently to track repetitive activities required for producing manufactured lots, control charts may also be used to monitor cost and schedule variances, volume, and frequency of scope changes, or other management results to help determine if the project management processes are in control.
- *Scatter diagrams,* plot ordered pairs (*X, Y*) and are sometimes called correlation charts because they seek to explain a change in the dependent variable, *Y,* in relationship to a change observed in the corresponding independent variable, *X*. The direction of correlation may be proportional (positive correlation), inverse (negative correlation), or a pattern of correlation may not exist (zero correlation). If correlation can be established, a regression line can be calculated and used to estimate how a change to the independent variable will influence the value of the dependent variable.

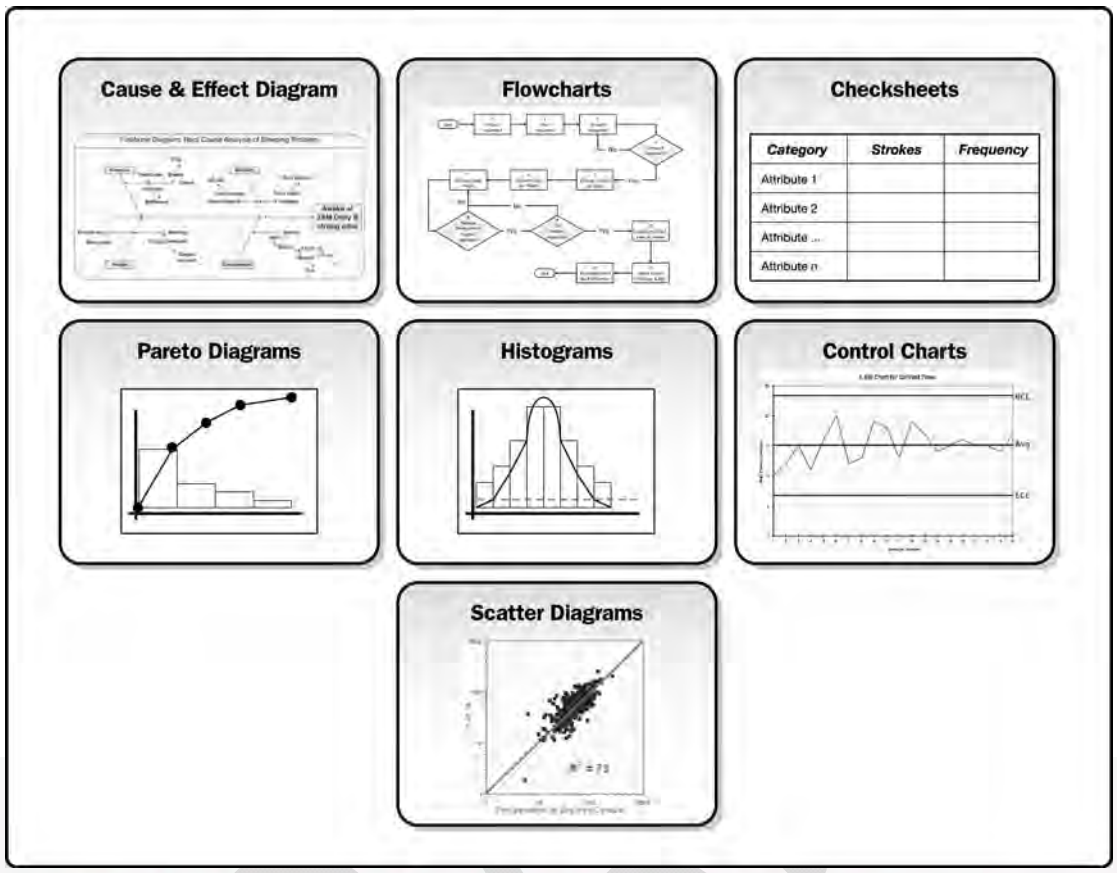

Figure 8-7. Storyboard Illustrating a Conceptual Example of Each of the Seven Basic Quality Tools

8.1.2.4 Benchmarking

Benchmarking involves comparing actual or planned project practices to those of comparable projects to identify best practices, generate ideas for improvement, and provide a basis for measuring performance.

Benchmarked projects may exist within the performing organization or outside of it, or can be within the same application area. Benchmarking allows for analogies from projects in a different application area to be made.

8.1.2.5 Design of Experiments

Design of experiments (DOE) is a statistical method for identifying which factors may influence specific variables of a product or process under development or in production. DOE may be used during the Plan Quality Management process to determine the number and type of tests and their impact on cost of quality.

DOE also plays a role in optimizing products or processes. DOE is used to reduce the sensitivity of product performance to sources of variations caused by environmental or manufacturing differences. One important aspect of this technique is that it provides a statistical framework for systematically changing all of the important factors, rather than changing the factors one at a time. Analysis of the experimental data should provide the optimal conditions for the product or process, highlight the factors that influence the results, and reveal the presence of interactions and synergy among the factors. For example, automotive designers use this

technique to determine which combination of suspension and tires will produce the most desirable ride characteristics at a reasonable cost.

8.1.2.6 Statistical Sampling

Statistical sampling involves choosing part of a population of interest for inspection (for example, selecting ten engineering drawings at random from a list of seventy-five). Sample frequency and sizes should be determined during the Plan Quality Management process so the cost of quality will include the number of tests, expected scrap, etc.

There is a substantial body of knowledge on statistical sampling. In some application areas, it may be necessary for the project management team to be familiar with a variety of sampling techniques to assure the sample selected represents the population of interest.

8.1.2.7 Additional Quality Planning Tools

Other quality planning tools are used to define the quality requirements and to plan effective quality management activities. These include, but are not limited to:

- **Brainstorming.** This technique is used to generate ideas (defined in Section 11.2.2.2).
- **Force field analysis.** These are diagrams of the forces for and against change.
- **Nominal group technique.** This technique is used to allow ideas to be brainstormed in small groups and then reviewed by a larger group.
- **Quality management and control tools.** These tools are used to link and sequence the activities identified (defined in Section 8.2.2.1).

8.1.2.8 Meetings

Project teams may hold planning meetings to develop the quality management plan. Attendees at these meetings may include the project manager; the project sponsor; selected project team members; selected stakeholders; anyone with responsibility for Project Quality Management activities namely Plan Quality Management, Perform Quality Assurance, or Control Quality; and others as needed.

8.1.3 Plan Quality Management: Outputs

8.1.3.1 Quality Management Plan

The quality management plan is a component of the project management plan that describes how the organization's quality policies will be implemented. It describes how the project management team plans to meet the quality requirements set for the project.

The quality management plan may be formal or informal, detailed, or broadly framed. The style and detail of the quality management plan are determined by the requirements of the project. The quality management plan should be reviewed early in the project to ensure that decisions are based on accurate information. The benefits of this review can include a sharper focus on the project's value proposition and reductions in costs and in the frequency of schedule overruns that were caused by rework.

8.1.3.2 Process Improvement Plan

The process improvement plan is a subsidiary or component of the project management plan (Section 4.2.3.1). The process improvement plan details the steps for analyzing project

management and product development processes to identify activities that enhance their value. Areas to consider include:

- **Process boundaries.** Describe the purpose of the process, the start and end of the process, its inputs and outputs, the process owner, and the stakeholders of the process.
- **Process configuration.** Provides a graphic depiction of processes, with interfaces identified, used to facilitate analysis.
- **Process metrics.** Along with control limits, allows analysis of process efficiency.
- **Targets for improved performance.** Guide the process improvement activities.

8.1.3.3 Quality Metrics

A quality metric specifically describes a project or product attribute and how the control quality process will measure it. A measurement is an actual value. The tolerance defines the allowable variations to the metric. For example, if the quality objective is to stay within the approved budget by ± 10%, the specific quality metric is used to measure the cost of every deliverable and determine the percent variance from the approved budget for that deliverable. Quality metrics are used in the perform quality assurance and control quality processes. Some examples of quality metrics include on-time performance, cost control, defect frequency, failure rate, availability, reliability, and test coverage.

8.1.3.4 Quality Checklists

A checklist is a structured tool, usually component-specific, used to verify that a set of required steps has been performed. Based on the project's requirements and practices, checklists may be simple or complex. Many organizations have standardized checklists available to ensure consistency in frequently performed tasks. In some application areas, checklists are also available from professional associations or commercial service providers. Quality checklists should incorporate the acceptance criteria included in the scope baseline.

8.1.3.5 Project Documents Updates

Project documents that may be updated include, but are not limited to:

- Stakeholder register (Section 13.1.3.1); and
- Responsibility assignment matrix (Section 9.1.2.1); and
- WBS and WBS Dictionary.

8.2 Perform Quality Assurance

Perform Quality Assurance is the process of auditing the quality requirements and the results from quality control measurements to ensure that appropriate quality standards and operational definitions are used. The key benefit of this process is that it facilitates the improvement of quality processes. The inputs, tools and techniques, and outputs of this process are depicted in Figure 8-8. Figure 8-9 depicts the data flow diagram of the process.

Figure 8-8. Perform Quality Assurance: Inputs, Tools & Techniques, and Outputs

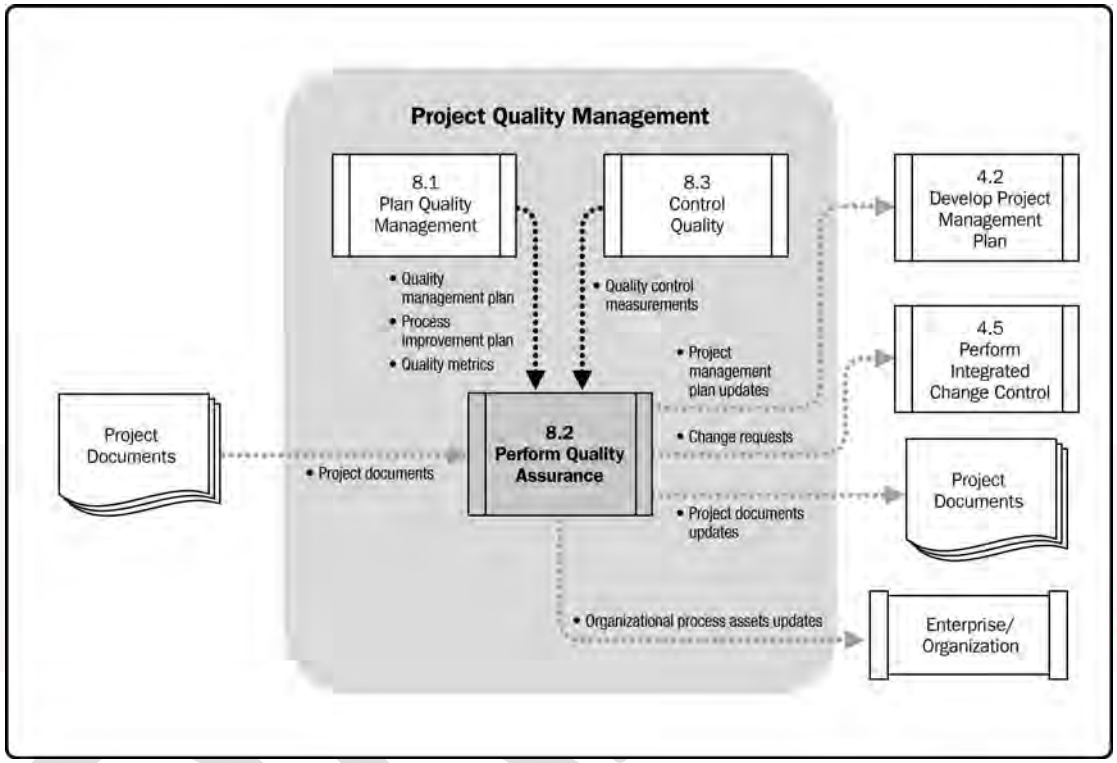

Figure 8-9. Perform Quality Assurance Data Flow Diagram

The quality assurance process implements a set of planned and systematic acts and processes defined within the project's quality management plan. Quality assurance seeks to build confidence that a future output or an unfinished output, also known as work in progress, will be completed in a manner that meets the specified requirements and expectations. Quality assurance contributes to the state of being certain about quality by preventing defects through the planning processes or by inspecting out defects during the work-in-progress stage of implementation. Perform Quality Assurance is an execution process that uses data created during Plan Quality Management (Section 8.1) and Control Quality (Section 8.3) processes.

In project management, the prevention and inspection aspects of quality assurance should have a demonstrable influence on the project. Quality assurance work will fall under the conformance work category in the cost of quality framework.

A quality assurance department, or similar organization, often oversees quality assurance activities. Quality assurance support, regardless of the unit's title, may be provided to the project team, the management of the performing organization, the customer or sponsor, as well as other stakeholders not actively involved in the work of the project.

Perform Quality Assurance also provides an umbrella for continuous process improvement, which is an iterative means for improving the quality of all processes. Continuous process improvement reduces waste and eliminates activities that do not add value. This allows processes to operate at increased levels of efficiency and effectiveness.

8.2.1 Perform Quality Assurance: Inputs

8.2.1.1 Quality Management Plan

Described in Section 8.1.3.1. The quality management plan describes the quality assurance and continuous process improvement approaches for the project.

8.2.1.2 Process Improvement Plan

Described in Section 8.1.3.2. The project's quality assurance activities should be supportive of and consistent with the performing organization's process improvement plans.

8.2.1.3 Quality Metrics

Described in Section 8.1.3.3. The quality metrics provide the attributes that should be measured and the allowable variations.

8.2.1.4 Quality Control Measurements

Described in Section 8.3.3.1. Quality control measurements are the results of control quality activities. They are used to analyze and evaluate the quality of the processes of the project against the standards of the performing organization or the requirements specified. Quality control measurements can also compare the processes used to create the measurements, and validate actual measurements to determine their level of correctness.

8.2.1.5 Project Documents

Project documents may influence quality assurance work and should be monitored within the context of a system for configuration management.

8.2.2 Perform Quality Assurance: Tools and Techniques

8.2.2.1 Quality Management and Control Tools

The Perform Quality Assurance process uses the tools and techniques of the Plan Quality Management and Control Quality processes. In addition, other tools that are available include (see also Figure 8-10):

- **Affinity diagrams.** The affinity diagram is similar to mind-mapping techniques in that they are used to generate ideas that can be linked to form organized patterns of thought about a problem. In project management, the creation of the WBS may be enhanced by using the affinity diagram to give structure to the decomposition of scope.
- **Process decision program charts (PDPC)**. Used to understand a goal in relation to the steps for getting to the goal. The PDPC is useful as a method for contingency planning because it aids teams in anticipating intermediate steps that could derail achievement of the goal.
- **Interrelationship digraphs.** An adaptation of relationship diagrams. The interrelationship digraphs provide a process for creative problem solving in moderately complex scenarios that possess intertwined logical relationships for up to

50 relevant items. The interrelationship digraph may be developed from data generated in other tools such as the affinity diagram, the tree diagram, or the fishbone diagram.

- **Tree diagrams.** Also known as systematic diagrams and may be used to represent decomposition hierarchies such as the WBS, RBS (risk breakdown structure), and OBS (organizational breakdown structure). In project management, tree diagrams are useful in visualizing the parent-to-child relationships in any decomposition hierarchy that uses a systematic set of rules that define a nesting relationship. Tree diagrams can be depicted horizontally (such as a risk breakdown structure) or vertically (such as a team hierarchy or OBS). Because tree diagrams permit the creation of nested branches that terminate into a single decision point, they are useful as decision trees for establishing an expected value for a limited number of dependent relationships that have been diagramed systematically.
- **Prioritization matrices.** Identify the key issues and the suitable alternatives to be prioritized as a set of decisions for implementation. Criteria are prioritized and weighted before being applied to all available alternatives to obtain a mathematical score that ranks the options.
- **Activity network diagrams**. Previously known as arrow diagrams. They include both the AOA (Activity on Arrow) and, most commonly used, AON (Activity on Node) formats of a network diagram. Activity network diagrams are used with project scheduling methodologies such as program evaluation and review technique (PERT), critical path method (CPM), and precedence diagramming method (PDM).
- **Matrix diagrams**. A quality management and control tool used to perform data analysis within the organizational structure created in the matrix. The matrix diagram seeks to show the strength of relationships between factors, causes, and objectives that exist between the rows and columns that form the matrix.

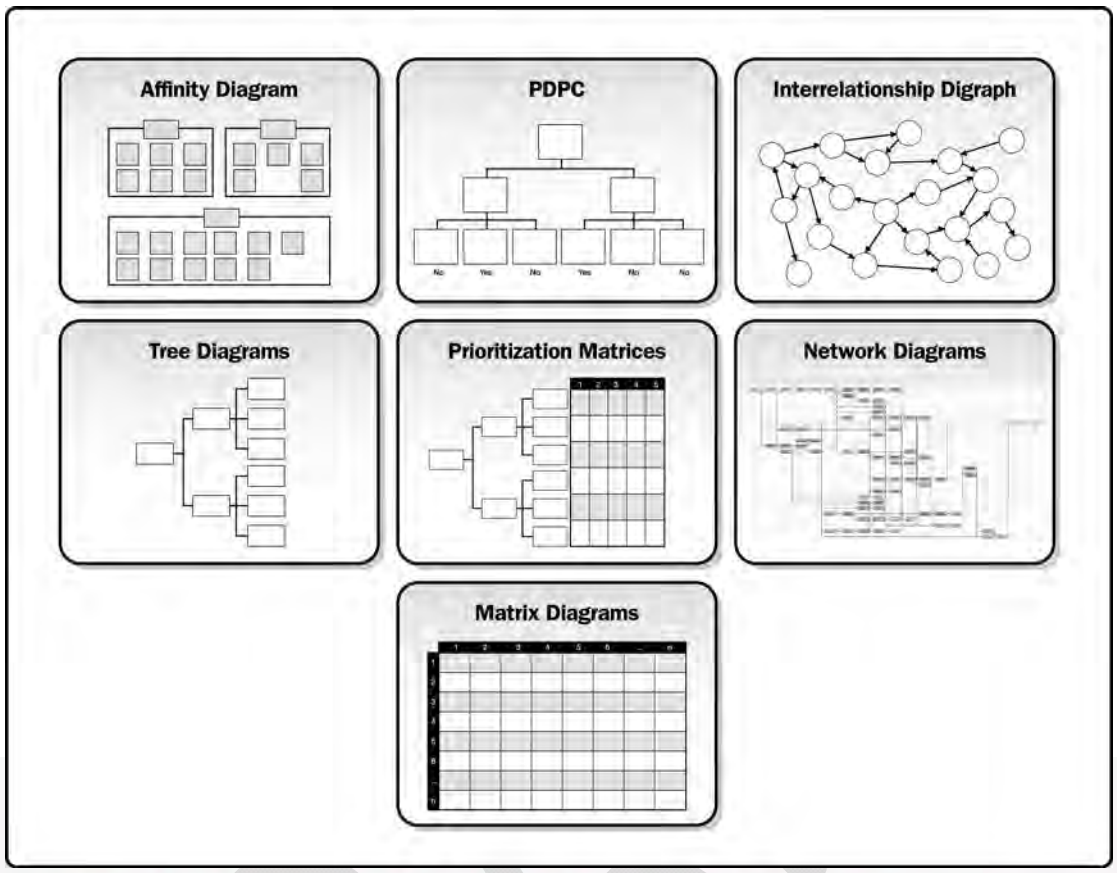

Figure 8-10. Storyboard illustrating the seven quality management and control tools

8.2.2.2 Quality Audits

A quality audit is a structured, independent process to determine if project activities comply with organizational and project policies, processes, and procedures. The objectives of a quality audit may include:

- Identify all good and best practices being implemented;
- Identify all nonconformity, gaps, and shortcomings;
- Share good practices introduced or implemented in similar projects in the organization and/or industry;
- Proactively offer assistance in a positive manner to improve implementation of processes to help the team raise productivity; and
- Highlight contributions of each audit in the lessons learned repository of the organization.

The subsequent effort to correct any deficiencies should result in a reduced cost of quality and an increase in sponsor or customer acceptance of the project's product. Quality audits may be scheduled or random, and may be conducted by internal or external auditors.

Quality audits can confirm the implementation of approved change requests including updates, corrective actions, defect repairs, and preventive actions.

8.2.2.3 Process Analysis

Process analysis follows the steps outlined in the process improvement plan to identify needed improvements. This analysis also examines problems experienced, constraints experienced, and non-value-added activities identified during process operation. Process analysis includes root cause analysis—a specific technique used to identify a problem, discover the underlying causes that lead to it, and develop preventive actions.

8.2.3 Perform Quality Assurance: Outputs

8.2.3.1 Change Requests

Change requests are created and used as input into the Perform Integrated Change Control process (Section 4.5) to allow full consideration of the recommended improvements. Change requests are used to take corrective action, preventive action, or to perform defect repair.

8.2.3.2 Project Management Plan Updates

Elements of the project management plan that may be updated include, but are not limited to:

- Quality management plan (Section 8.1.3.1),
- Scope management plan (Section 5.1.3.1),
- Schedule management plan (Section 6.1.3.1), and
- Cost management plan (7.1.3.1).

8.2.3.3 Project Documents Updates

Project documents that may be updated include, but are not limited to:

- Quality audit reports,
- Training plans, and
- Process documentation.

8.2.3.4 Organizational Process Assets Updates

Elements of the organizational process assets that may be updated include, but are not limited to, the organization's quality standards and the quality management system.

8.3 Control Quality

Control Quality is the process of monitoring and recording results of executing the quality activities to assess performance and recommend necessary changes. The key benefits of this process include: (1) identifying the causes of poor process or product quality and recommending and/or taking action to eliminate them; and (2) validating that project deliverables and work meet the requirements specified by key stakeholders necessary for final acceptance. The inputs, tools and techniques, and outputs of this process are depicted in Figure 8-11. Figure 8-12 depicts the data flow diagram of the process.

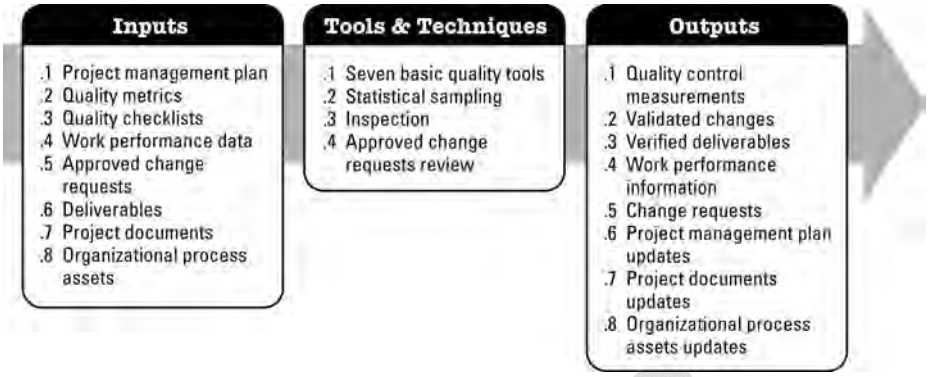

Figure 8-11. Control Quality: Inputs, Tools & Techniques, and Outputs

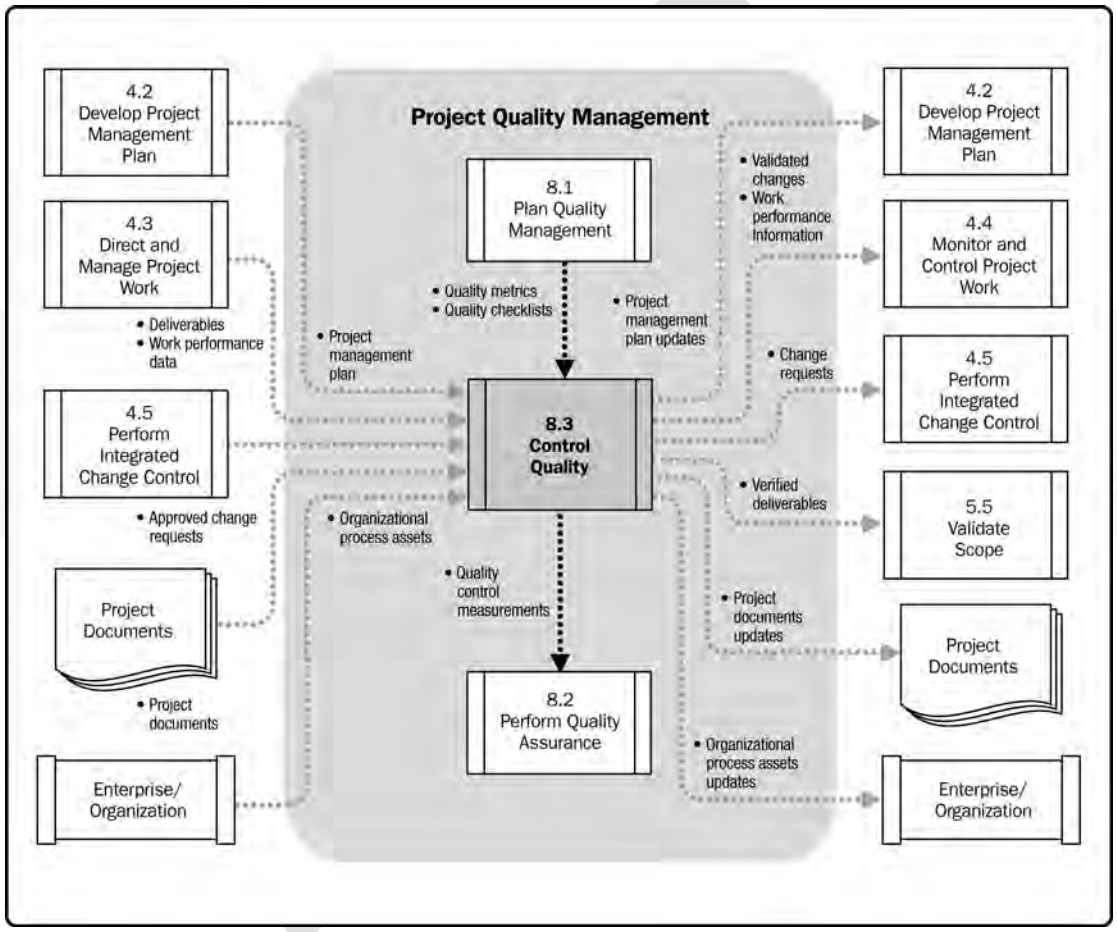

Figure 8-12. Control Quality Data Flow Diagram

The Control Quality process uses a set of operational techniques and tasks to verify that the delivered output will meet the requirements. Quality assurance should be used during the project's planning and executing phases to provide confidence that the stakeholder's requirements will be met and quality control should be used during the project executing and closing phases to formally demonstrate, with reliable data, that the sponsor and/or customer's acceptance criteria have been met.

The project management team may have a working knowledge of statistical control processes to evaluate data contained in the control quality outputs. Among other subjects, the team may find it useful to know the differences between the following pairs of terms:

- Prevention (keeping errors out of the process) and inspection (keeping errors out of the hands of the customer).
- Attribute sampling (the result either conforms or does not conform) and variables sampling (the result is rated on a continuous scale that measures the degree of conformity).
- Tolerances (specified range of acceptable results) and control limits (that identify the boundaries of common variation in a statistically stable process or process performance).

8.3.1 Control Quality: Inputs

8.3.1.1 Project Management Plan

Described in Section 8.1.3.1. The project management plan contains the quality management plan, which is used to control quality. The quality management plan describes how quality control will be performed within the project.

8.3.1.2 Quality Metrics

Described in Section 4.2.3.1. A quality metric describes a project or product attribute and how it will be measured. Some examples of quality metrics include: function points, mean time between failure (MTBF), and mean time to repair (MTTR).

8.3.1.3 Quality Checklists

Described in Section 8.1.3.4. Quality checklists are structured lists that help to verify that the work of the project and its deliverables fulfill a set of requirements.

8.3.1.4 Work Performance Data

Described in Section 4.3.3.2. Work performance data can include:

- Planned vs. actual technical performance,
- Planned vs. actual schedule performance, and
- Planned vs. actual cost performance.

8.3.1.5 Approved Change Requests

As part of the Perform Integrated Change Control process, a change log update indicates that some changes are approved and some are not. Approved change requests may include modifications such as defect repairs, revised work methods, and revised schedule. The timely implementation of approved changes needs to be verified.

8.3.1.6 Deliverables

Described in Section 4.3.3.1. A deliverable is any unique and verifiable product, result, or capability that results in a validated deliverable required by the project.

8.3.1.7 Project Documents

Project documents may include, but are not limited to:

- Agreements,

- Quality audit reports and change logs supported with corrective action plans,
- Training plans and assessments of effectiveness, and
- Process documentation such as those obtained using either the seven basic quality tools or the quality management and control tools shown in Figures 8-7 and 8-10.

8.3.1.8 Organizational Process Assets

Described in Section 2.1.4. The organizational process assets that influence the Control Quality process include, but are not limited to:

- The organization's quality standards and policies,
- Standard work guidelines, and
- Issue and defect reporting procedures and communication policies.

8.3.2 Control Quality: Tools and Techniques

8.3.2.1 Seven Basic Quality Tools

Described in Section 8.1.2.3. The seven basic quality tools are illustrated conceptually in Figure 8-7.

8.3.2.2 Statistical Sampling

Described in Section 8.1.2.6. Samples are selected and tested as defined in the quality management plan.

8.3.2.3 Inspection

An inspection is the examination of a work product to determine if it conforms to documented standards. The results of an inspection generally include measurements and may be conducted at any level. For example, the results of a single activity can be inspected, or the final product of the project can be inspected. Inspections may be called reviews, peer reviews, audits, or walkthroughs. In some application areas, these terms have narrow and specific meanings. Inspections also are used to validate defect repairs.

8.3.2.4 Approved Change Requests Review

All approved change requests should be reviewed to verify that they were implemented as approved.

8.3.3 Control Quality: Outputs

8.3.3.1 Quality Control Measurements

Quality control measurements are the documented results of control quality activities. They should be captured in the format that was specified through the Plan Quality Management process (Section 8.1).

8.3.3.2 Validated Changes

Any changed or repaired items are inspected and will be either accepted or rejected before notification of the decision is provided. Rejected items may require rework.

8.3.3.3 Verified Deliverables

A goal of the Control Quality process is to determine the correctness of deliverables. The results of performing the Control Quality process are verified deliverables. Verified deliverables are an input to Validate Scope (5.5.1.4) for formalized acceptance.

8.3.3.4 Work Performance Information

Work performance information is the performance data collected from various controlling processes, analyzed in context and integrated based on relationships across areas. Examples include information about the project requirements fulfillment such as causes for rejections, rework required, or the need for process adjustments.

8.3.3.5 Change Requests

If the recommended corrective or preventive actions or a defect repair requires a change to the project management plan, a change request (Section 4.4.3.1) should be initiated in accordance with the defined Perform Integrated Change Control (4.5) process.

8.3.3.6 Project Management Plan Updates

Elements of the project management plan that may be updated include, but are not limited to:

- Quality management plan (Section 8.1.3.1), and
- Process improvement plan (Section 8.1.3.2).

8.3.3.7 Project Documents Updates

Project documents that may be updated include, but are not limited to,

- Quality standards;
- Agreements;
- Quality audit reports and change logs supported with corrective action plans;
- Training plans and assessments of effectiveness; and
- Process documentation, such as information obtained using the seven basic quality tools or the quality management and control tools.

8.3.3.8 Organizational Process Assets Updates

Elements of the organizational process assets that may be updated include, but are not limited to:

- **Completed checklists.** When checklists are used, the completed checklists become part of the project documents and organizational process assets (Section 4.1.1.5).
- **Lessons learned documentation.** The causes of variances, the reasoning behind the corrective action chosen, and other types of lessons learned from control quality are documented so they become part of the historical database for both the project and the performing organization.

9

PROJECT HUMAN RESOURCE MANAGEMENT

Project Human Resource Management includes the processes that organize, manage, and lead the project team. The project team is comprised of the people with assigned roles and responsibilities for completing the project. Project team members may have varied skill sets, may be assigned full or part-time, and may be added or removed from the team as the project progresses. Project team members may also be referred to as the project's staff. Although specific roles and responsibilities for the project team members are assigned, the involvement of all team members in project planning and decision making is beneficial. Participation of team members during planning adds their expertise to the process and strengthens their commitment to the project.

Figure 9-1 provides an overview of the Project Human Resource Management processes, which are as follows:

9.1 Plan Human Resource Management—The process of identifying and documenting project roles, responsibilities, required skills, reporting relationships, and creating a staffing management plan.

9.2 Acquire Project Team—The process of confirming human resource availability and obtaining the team necessary to complete project activities.

9.3 Develop Project Team—The process of improving competencies, team member interaction, and overall team environment to enhance project performance.

9.4 Manage Project Team—The process of tracking team member performance, providing feedback, resolving issues, and managing changes to optimize project performance.

These processes interact with each other and with processes in other Knowledge Areas as described in detail in Section 3 and Annex A1.

As a result of these interactions additional planning may be required throughout the project. For example:

- After initial team members create a work breakdown structure, additional team members may need to be added to the team.
- As additional team members are added to the team, their experience levels, or lack thereof, could decrease or increase project risk, creating the need for additional risk planning.
- When activity durations are estimated, budgeted, scoped, or planned prior to identifying all project team members and their competency levels, the activity durations may change.

The project management team is a subset of the project team and is responsible for the project management and leadership activities such as initiating, planning, executing, monitoring, controlling, and closing the various project phases. This group can also be referred to as the core, executive, or leadership team. For smaller projects, the project management responsibilities may be shared by the entire team or administered solely by the project manager. The project sponsor

works with the project management team, typically assisting with matters such as project funding, clarifying scope, monitoring progress, and influencing stakeholders in both the requesting and performing organization for the project benefit.

Managing and leading the project team includes, but is not limited to:

- **Influencing the project team.** The project manager needs to be aware of and influence, when possible, human resource factors that may impact the project. These factors includes team environment, geographical locations of team members, communications among stakeholders, internal and external politics, cultural issues, organizational uniqueness, and others factors that may alter project performance.
- **Professional and ethical behavior.** The project management team should be aware of, subscribe to, and ensure that all team members follow professional and ethical behavior.

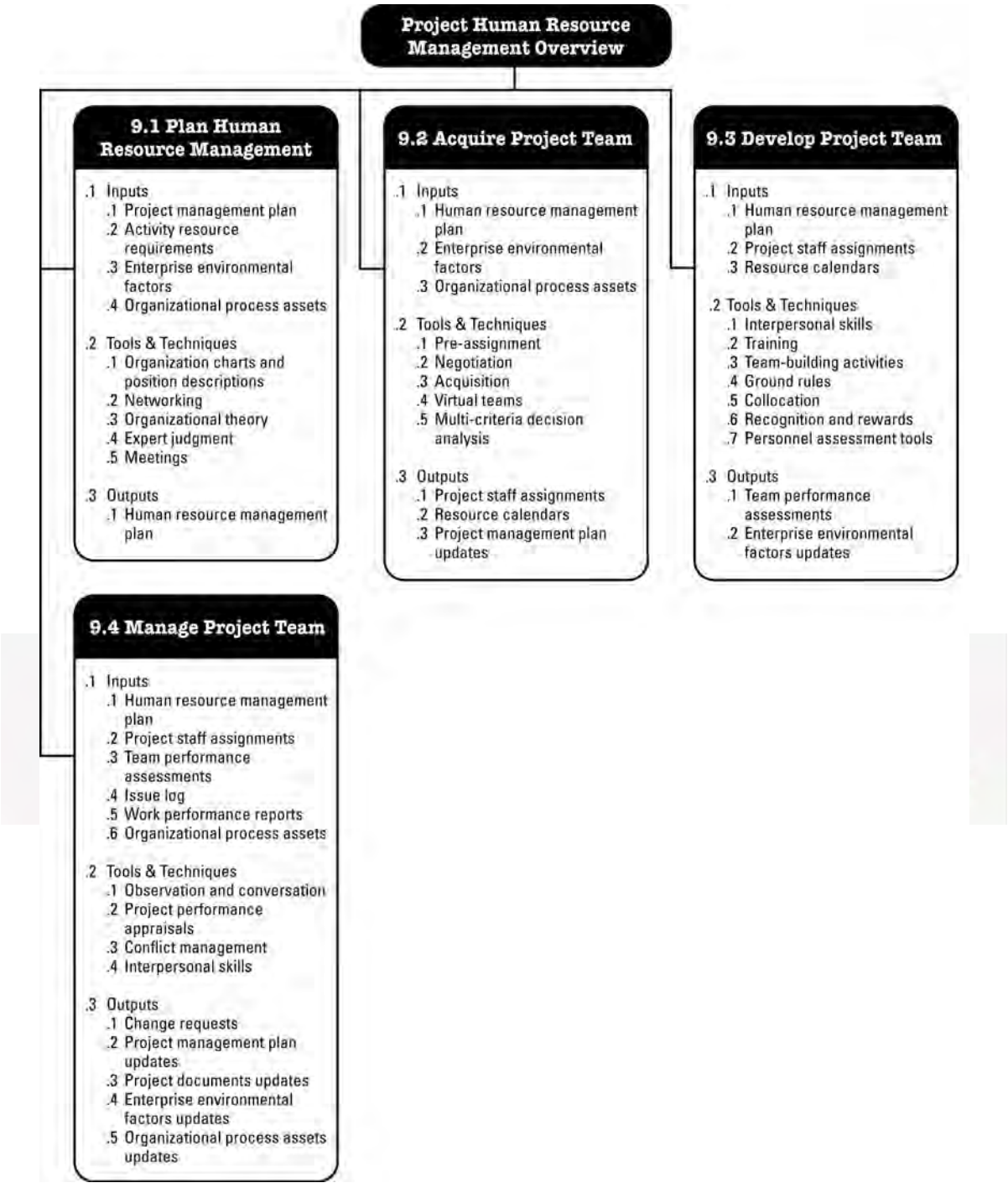

Figure 9-1. Project Human Resource Management Overview

9.1 Plan Human Resource Management

Plan Human Resource Management is the process of identifying and documenting project roles, responsibilities, required skills, reporting relationships, and creating a staffing management plan. The key benefit of this process is that it establishes project roles and responsibilities, project organization charts, and the staffing management plan including the timetable for staff

acquisition and release. The inputs, tools and techniques, and outputs of this process are depicted in Figure 9-2. Figure 9-3 depicts the data flow diagram of the process.

Figure 9-2. Plan Human Resource Management: Inputs, Tools & Techniques, and Outputs

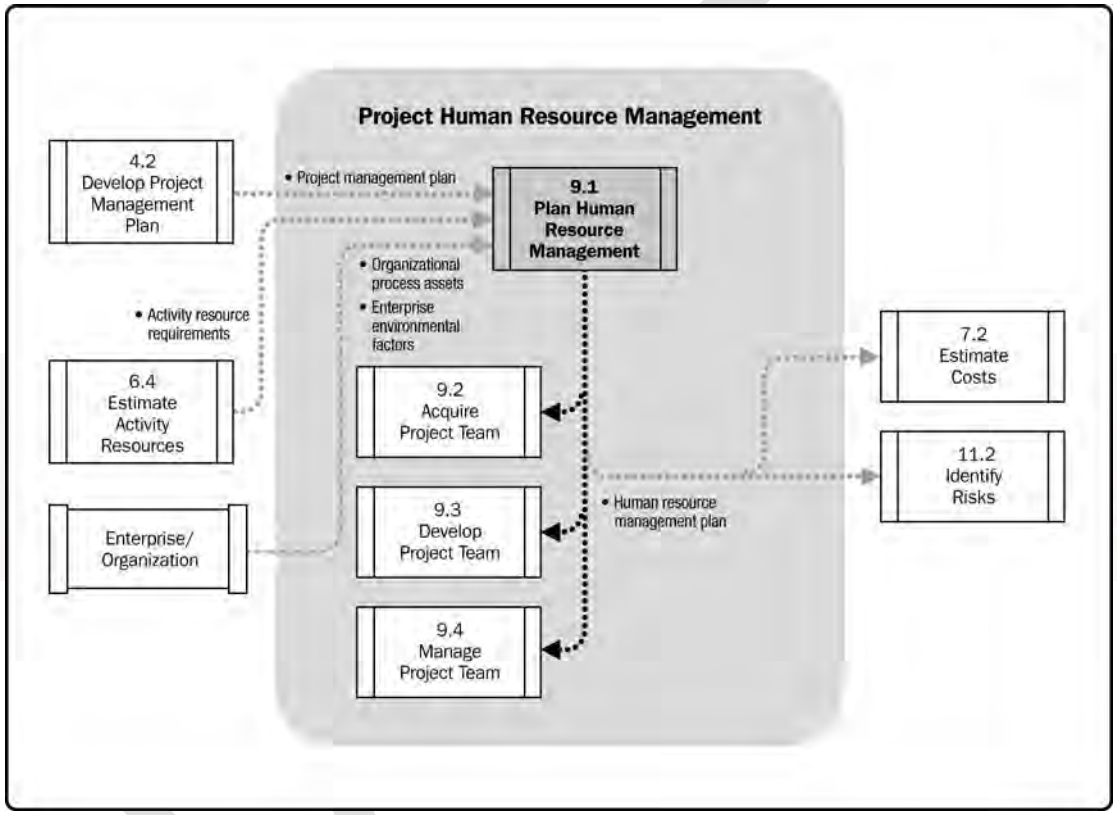

Figure 9-3. Plan Human Resource Management Data Flow Diagram

Human resource planning is used to determine and identify human resources with the necessary skills required for project success. The human resource management plan describes how the roles and responsibilities, reporting relationships, and staffing management will be addressed and structured within a project. It also contains the staffing management plan including timetables for staff acquisition and release, identification of training needs, team-building strategies, plans for recognition and rewards programs, compliance considerations, safety issues, and the impact of the staffing management plan on the organization.

Effective human resource planning should consider and plan for the availability of or competition for scarce resources. Project roles can be designated for teams or team members. Those teams or team members can be from inside or outside the organization performing the project. Other projects may be competing for human resources with the same competencies or

skill sets. Given these factors, project costs, schedules, risks, quality, and other project areas may be significantly affected.

9.1.1 Plan Human Resource Management: Inputs

9.1.1.1 Project Management Plan

Described in Section 4.2.3.1. The project management plan is used to develop the human resource management plan as described in Section 9.1.3.1. The information used for the development of the human resource management plan includes, but is not limited to:

- The project life cycle and the processes that will be applied to each phase,
- How work will be executed to accomplish the project objectives,
- A change management plan that documents how changes will be monitored and controlled,
- A configuration management plan that documents how configuration management will be performed,
- How integrity of the project baselines will be maintained, and
- Needs and methods of communication among stakeholders.

9.1.1.2 Activity Resource Requirements

Described in Section 6.4.3.1. Human resource planning uses activity resource requirements to determine the human resource needs for the project. The preliminary requirements regarding the required project team members and their competencies are progressively elaborated as part of the Plan Human Resource Management process.

9.1.1.3 Enterprise Environmental Factors

Described in Section 2.1.5. The enterprise environmental factors that can influence the Plan Human Resource Management process include, but are not limited to:

- Organizational culture and structure,
- Existing human resources,
- Geographical dispersion of team members,
- Personnel administration policies, and
- Marketplace conditions.

9.1.1.4 Organizational Process Assets

Described in Section 2.1.4. The organizational process assets that can influence the Plan Human Resource Management process include, but are not limited to:

- Organizational standard processes, policies, and role descriptions;
- Templates for organizational charts and position descriptions;
- Lessons learned on organizational structures that have worked in previous projects; and
- Escalation procedures for handling issues within the team and within the performing organization.

9.1.2 Plan Human Resource Management: Tools and Techniques

9.1.2.1 Organization Charts and Position Descriptions

Various formats exist to document team member roles and responsibilities. Most of the formats fall into one of three types (Figure 9-4): hierarchical, matrix, and text-oriented. Additionally, some project assignments are listed in subsidiary plans, such as the risk, quality, or communications management plans. Regardless of the method utilized, the objective is to ensure that each work package has an unambiguous owner and that all team members have a clear understanding of their roles and responsibilities. For example, a hierarchical format may be used to represent high-level roles, while a text-based format may be better suited to document the detailed responsibilities.

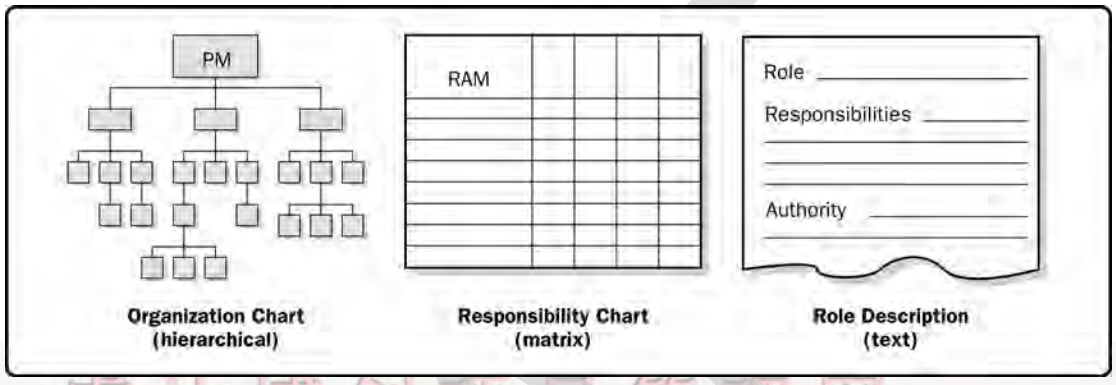

Figure 9-4. Roles and Responsibility Definition Formats

- **Hierarchical-type charts.** The traditional organization chart structure can be used to show positions and relationships in a graphical, top-down format. Work breakdown structures (WBS) designed to show how project deliverables are broken down into work packages provide a way of showing high-level areas of responsibility. While the WBS shows a breakdown of project deliverables, the organizational breakdown structure (OBS) is arranged according to an organization's existing departments, units, or teams with the project activities or work packages listed under each department. An operational department such as information technology or purchasing can see all of its project responsibilities by looking at its portion of the OBS. The resource breakdown structure (RBS) is a hierarchical list of resources related by category and resource type that is used to facilitate planning and controlling of project work. Each descending (lower) level represents an increasingly detailed description of the resource until small enough to be used in conjunction with the work breakdown structure (WBS) to allow the work to be planned, monitored and controlled. The resource breakdown structure is helpful in tracking project costs and can be aligned with the organization's accounting system. It can contain resource categories other than human resources.
- **Matrix-based charts.** A responsibility assignment matrix (RAM) is a grid that shows the project resources assigned to each work package. It is used to illustrate the connections between work packages or activities and project team members. On larger projects, RAMs can be developed at various levels. For example, a high-level RAM can define what a project team group or unit is responsible for within each component of the WBS, while lower-level RAMs are used within the group to

designate roles, responsibilities, and levels of authority for specific activities. The matrix format shows all activities associated with one person and all people associated with one activity. This also ensures that there is only one person accountable for any one task to avoid confusion of responsibility. One example of a RAM is a RACI (responsible, accountable, consult, and inform) chart, shown in Figure 9-5. The sample chart shows the work to be done in the left column as activities. The assigned resources can be shown as individuals or groups. The project manager can select other options such as "lead" and "resource" designations or others, as appropriate for the project. A RACI chart is a useful tool to use when the team consists of internal and external resources in order to ensure clear divisions of roles and expectations.

RACI Chart	Person				
Activity	Ann	Ben	Carlos	Dina	Ed
Create charter	A	R	I	I	I
Collect requirements	I	A	R	C	C
Submit change request	I	A	R	R	C
Develop test plan	A	C	I	I	R

R = Responsible A = Accountable C = Consult I = Inform

Figure 9-5. RACI Matrix

- **Text-oriented formats.** Team member responsibilities that require detailed descriptions can be specified in text-oriented formats. Usually in outline form, the documents provide information such as responsibilities, authority, competencies, and qualifications. The documents are known by various names including position descriptions and role-responsibility-authority forms. These documents can be used as templates for future projects, especially when the information is updated throughout the current project by applying lessons learned.

9.1.2.2 Networking

Networking is the formal and informal interaction with others in an organization, industry, or professional environment. It is a constructive way to understand political and interpersonal factors that will impact the effectiveness of various staffing management options. Human resource management benefits from successful networking by improving knowledge of and access to human resource assets such as strong competencies, specialized experience, and external partnership opportunities. Examples of human resources networking activities include proactive correspondence, luncheon meetings, informal conversations including meetings and events, trade conferences, and symposia. Networking can be a useful technique at the beginning of a project. It can also be an effective way to enhance project management professional development during the project and after the project ends.

9.1.2.3 Organizational Theory

Organizational theory provides information regarding the way in which people, teams, and organizational units behave. Effective use of common themes identified in organizational theory can shorten the amount of time, cost, and effort needed to create the Plan Human Resource Management process outputs and improve planning efficiency. It is important to recognize that different organizational structures have different individual response, individual performance, and personal relationship characteristics. Also, applicable organizational theories may recommend exercising a flexible leadership style that adapts to the changes in a team's maturity level throughout the project life cycle.

9.1.2.4 Expert Judgment

When developing the human resource management plan, expert judgment is used to:

- List the preliminary requirements for the required skills;
- Assess the roles required for the project based on standardized role descriptions within the organization;
- Determine the preliminary effort level and number of resources needed to meet project objectives;
- Determine reporting relationships needed based on the organizational culture;
- Provide guidelines on lead time required for staffing, based on lessons learned and market conditions;
- Identify risks associated with staff acquisition, retention, and release plans; and
- Identify and recommend programs for complying with applicable government and union contracts.

9.1.2.5 Meetings

When planning human resource management of the project, the project management team will hold planning meetings. These meetings leverage a combination of other tools and techniques to allow for all project management team members to reach consensus on the human resource management plan.

9.1.3 Plan Human Resource Management: Outputs

9.1.3.1 Human Resource Management Plan

The human resource management plan, a part of the project management plan, provides guidance on how project human resources should be defined, staffed, managed, and eventually released. The human resource management plan and any subsequent revisions are also inputs into the Develop Project Management Plan process.

The human resource management plan includes, but is not limited to, the following:

- **Roles and responsibilities.** The following should be addressed when listing the roles and responsibilities needed to complete a project:
    - *Role.* The function assumed by or assigned to a person in the project. Examples of project roles are civil engineer, business analyst, and testing coordinator. Role clarity concerning authority, responsibilities, and boundaries should also be documented.

- *Authority*. The right to apply project resources, make decisions, sign approvals, accept deliverables, and influence others to carry out the work of the project. Examples of decisions that need clear authority include the selection of a method for completing an activity, quality acceptance, and how to respond to project variances. Team members operate best when their individual levels of authority match their individual responsibilities.
- *Responsibility*. The assigned duties and work that a project team member is expected to perform in order to complete the project's activities.
- *Competency*. The skill and capacity required to complete assigned activities within the project constraints. If project team members do not possess required competencies, performance can be jeopardized. When such mismatches are identified, proactive responses such as training, hiring, schedule changes, or scope changes are initiated.

- **Project organization charts.** A project organization chart is a graphic display of project team members and their reporting relationships. It can be formal or informal, highly detailed or broadly framed, based on the needs of the project. For example, the project organization chart for a 3,000-person disaster response team will have greater detail than a project organization chart for an internal, twenty-person project.
- **Staffing management plan.** The staffing management plan is a component of the human resource management plan that describes when and how project team members will be acquired and how long they will be needed. It describes how human resource requirements will be met. The staffing management plan can be formal or informal, highly detailed, or broadly framed, depending upon the needs of the project. The plan is updated continually during the project to direct ongoing team member acquisition and development actions. Information in the staffing management plan varies by application area and project size, but items to consider include:
  - *Staff acquisition.* A number of questions arise when planning the acquisition of project team members. For example, whether the human resources come from within the organization or from external, contracted sources; whether the team members need to work in a central location or may work from distant locations; costs associated with each level of expertise needed for the project; and level of assistance that the organization's human resource department and functional managers are able to provide to the project management team.
  - *Resource calendars*. Calendars that identify the working days and shifts on which each specific resource is available. The staffing management plan describes necessary time frames for project team members, either individually or collectively, as well as when acquisition activities such as recruiting should start. One tool for charting human resources is a resource histogram, used by the project management team as a means of providing a visual representation or resources allocation to all interested parties. This chart illustrates the number of hours a person, department, or entire project team that will be needed each week or month over the course of the project. The chart can include a horizontal line that represents the maximum number of hours available from a particular resource. Bars that extend beyond the maximum available hours identify the need for a resource optimization strategy (Section

6.6.2.4), such as adding more resources or modifying the schedule. An example of a resource histogram is illustrated in Figure 9-6.

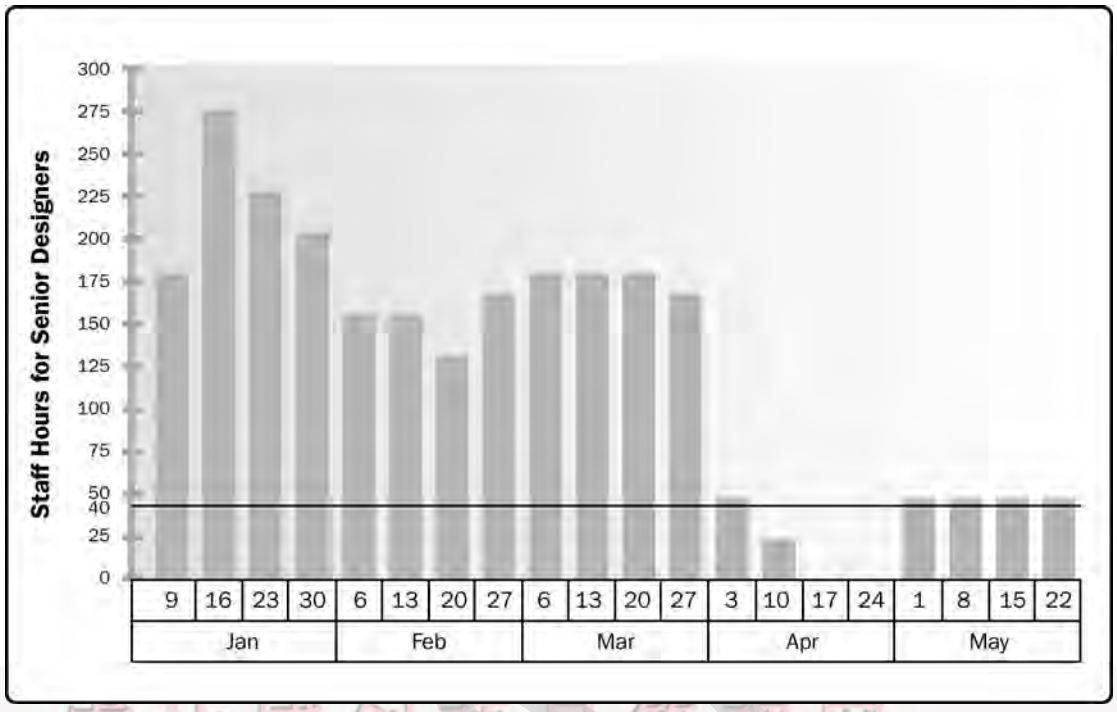

Figure 9-6. Illustrative Resource Histogram

- *Staff release plan.* Determining the method and timing of releasing team members benefits both the project and team members. When team members are released from a project, the costs associated with those resources are no longer charged to the project, thus reducing project costs. Morale is improved when smooth transitions to upcoming projects are already planned. A staff release plan also helps mitigate human resource risks that may occur during or at the end of a project.
- *Training needs.* If it is expected that the team members to be assigned will not have the required competencies, a training plan can be developed as part of the project. The plan can also include ways to help team members obtain certifications that would support their ability to benefit the project.
- *Recognition and rewards.* Clear criteria for rewards and a planned system for their use help promote and reinforce desired behaviors. To be effective, recognition and rewards should be based on activities and performance under a person's control. For example, a team member who is to be rewarded for meeting cost objectives should have an appropriate level of control over decisions that affect expenses. Creating a plan with established times for distribution of rewards ensures that recognition takes place and is not forgotten. Recognition and rewards are part of the Develop Project Team process (Section 9.3).

- *Compliance.* The staffing management plan can include strategies for complying with applicable government regulations, union contracts, and other established human resource policies.
- *Safety.* Policies and procedures that protect team members from safety hazards can be included in the staffing management plan as well as in the risk register.

9.2 Acquire Project Team

Acquire Project Team is the process of confirming human resource availability and obtaining the team necessary to complete project activities. The key benefit of this process consists of outlining and guiding the team selection and responsibility assignment to obtain a successful team. The inputs, tools and techniques, and outputs of this process are depicted in Figure 9-7. Figure 9-8 depicts the data flow diagram of the process.

Figure 9-7. Acquire Project Team: Inputs, Tools & Techniques, and Outputs

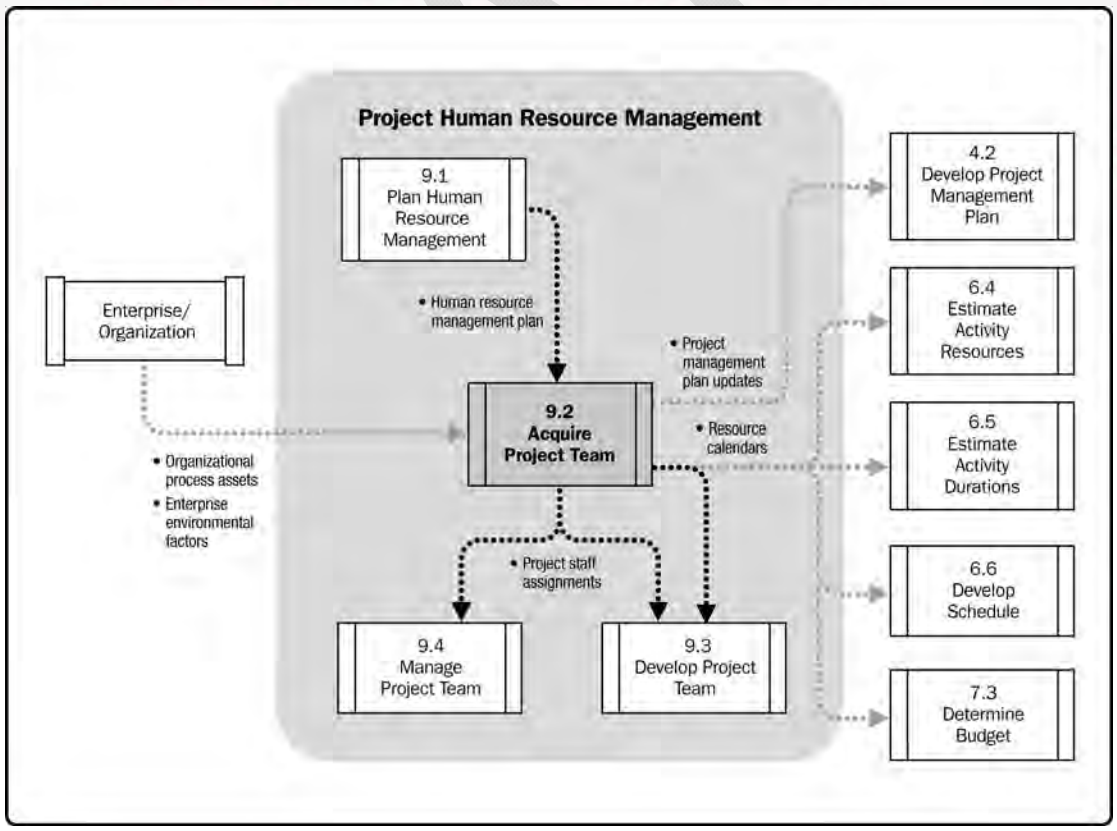

Figure 9-8. Acquire Project Team Data Flow Diagram

The project management team may or may not have direct control over team member selection because of collective bargaining agreements, use of subcontractor personnel, matrix project environment, internal or external reporting relationships, or other various reasons. It is important that the following factors are considered during the process of acquiring the project team:

- The project manager or project management team should effectively negotiate and influence others who are in a position to provide the required human resources for the project.
- Failure to acquire the necessary human resources for the project may affect project schedules, budgets, customer satisfaction, quality, and risks. Insufficient human resources or capabilities decrease the probability of success and, in a worst case scenario, could result in project cancellation.
- If the human resources are not available due to constraints, such as economic factors or previous assignments to other projects, the project manager or project team may be required to assign alternative resources, perhaps with lower competencies, provided there is no violation of legal, regulatory, mandatory, or other specific criteria.

These factors should be considered and planned for in the planning stages of the project. The project manager or project management team will be required to reflect the impact of any unavailability of required human resources in the project schedule, project budget, project risks, project quality, training plans, and the other project management plans.

9.2.1 Acquire Project Team: Inputs

9.2.1.1 Human Resource Management Plan

Described in Section 9.1.3.1. The human resource management plan provides guidance on how project human resources should be identified, staffed, managed, and eventually released. It includes:

- Roles and responsibilities defining the positions, skills, and competencies that the project demands;
- Project organization charts indicating the number of people needed for the project; and
- Staffing management plan delineating the time periods each project team member will be needed and other information important to engage the project team.

9.2.1.2 Enterprise Environmental Factors

Described in Section 2.1.5. The enterprise environmental factors that influence the Acquire Project Team process include, but are not limited to:

- Existing information on human resources including availability, competency levels, prior experience, interest in working on the project and their cost rate;
- Personnel administration policies such as those that affect outsourcing;
- Organizational structure as described in Section 2.3.1; and
- Colocation or multiple locations.

9.2.1.3 Organizational Process Assets

Described in Section 2.1.4. The organizational process assets that influence the Acquire Project Team process include, but are not limited to, organizational standard policies, processes, and procedures.

9.2.2 Acquire Project Team: Tools and Techniques

9.2.2.1 Pre-assignment

When project team members are selected in advance, they are considered pre-assigned. This situation can occur if the project is the result of specific people being identified as part of a competitive proposal, if the project is dependent upon the expertise of particular persons, or if some staff assignments are defined within the project charter.

9.2.2.2 Negotiation

Staff assignments are negotiated on many projects. For example, the project management team may need to negotiate with:

- Functional managers, to ensure that the project receives appropriately competent staff in the required time frame and that the project team members will be able, willing, and authorized to work on the project until their responsibilities are completed;
- Other project management teams within the performing organization, to appropriately assign scarce or specialized human resources; and
- External organizations, vendors, suppliers, contractors, etc., for appropriate, scarce, specialized, qualified, certified, or other such specified human resources. Special consideration should be given to external negotiating policies, practices, processes, guidelines, legal, and other such criteria.

The project management team's ability to influence others plays an important role in negotiating staff assignments, as do the politics of the organizations involved. For example, a functional manager will weigh the benefits and visibility of competing projects when determining where to assign exceptional performers requested by various project teams.

9.2.2.3 Acquisition

When the performing organization is unable to provide the staff needed to complete a project, the required services may be acquired from outside sources. This can involve hiring individual consultants or subcontracting work to another organization.

9.2.2.4 Virtual Teams

The use of virtual teams creates new possibilities when acquiring project team members. Virtual teams can be defined as groups of people with a shared goal who fulfill their roles with little or no time spent meeting face to face. The availability of communication technology such as e-mail, audio conferencing, social media, web-based meetings and video conferencing has made virtual teams feasible. The virtual team model makes it possible to:

- Form teams of people from the same organization who live in widespread geographic areas;
- Add special expertise to a project team even though the expert is not in the same geographic area;
- Incorporate employees who work from home offices;

- Form teams of people who work different shifts, hours, or days;
- Include people with mobility limitations or disabilities; and
- Move forward with projects that would have been ignored due to travel expenses.

There are some disadvantages related to virtual teams, such as possibility for misunderstandings, feeling of isolation, difficulties in sharing knowledge and experience between team members, and cost of appropriate technology. Communication planning becomes increasingly important in a virtual team environment. Additional time may be needed to set clear expectations, facilitate communications, develop protocols for resolving conflict, include people in decision making, understand cultural differences, and share credit in successes.

9.2.2.5 Multi-Criteria Decision Analysis

Selection criteria are often used as a part of acquiring the project team. By use of a multi-criteria decision analysis tool, criteria are developed and used to rate or score potential team members. The criteria are weighted according to the relative importance of the needs within the team. Some examples of selection criteria that can be used to score team members are shown as follows:

- **Availability.** Identify whether the team member is available to work on the project within the time period needed. If there are there any concerns for availability during the project timeline.
- **Cost.** Verify if the cost of adding the team member is within the prescribed budget.
- **Experience.** Verify that the team member has the relevant experience that will contribute to the project success.
- **Ability.** Verify that the team member has the competencies needed by the project.
- **Knowledge.** Consider if the team member has relevant knowledge of the customer, similar implemented projects, and nuances of the project environment.
- **Skills.** Determine whether the member has the relevant skills to use a project tool, implementation, or training.
- **Attitude.** Determine whether the member has the ability to work with others as a cohesive team.
- **International factors.** Consider team member location, time zone and communication capabilities.

9.2.3 Acquire Project Team: Outputs

9.2.3.1 Project Staff Assignments

The project is staffed when appropriate people have been assigned to the team. The documentation of these assignments can include a project team directory, memos to team members, and names inserted into other parts of the project management plan, such as project organization charts and schedules.

9.2.3.2 Resource Calendars

Resource calendars document the time periods that each project team member is available to work on the project. Creating a reliable schedule (Section 6.6.3.1) depends on having a good understanding of each person's availability and schedule constraints, including time zones, work hours, vacation time, local holidays, and commitments to other projects.