CHAPTER 6

Project Time Management

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Project Time Management includes the processes required to accomplish timely completion of the project. Figure 6-1 provides an overview of the Project Time Management processes and Figure 6-2 provides a process flow diagram of those processes and their inputs, outputs, and other related Knowledge Area processes. The Project Time Management processes include the following:

6.1 Activity Definition – identifying the specific schedule activities that need to be performed to produce the various project deliverables.

6.2 Activity Sequencing – identifying and documenting dependencies among schedule activities.

6.3 Activity Resource Estimating – estimating the type and quantities of resources required to perform each schedule activity.

6.4 Activity Duration Estimating – estimating the number of work periods that will be needed to complete individual schedule activities.

6.5 Schedule Development – analyzing activity sequences, durations, resource requirements, and schedule constraints to create the project schedule.

6.6 Schedule Control – controlling changes to the project schedule.

These processes interact with each other and with processes in the other Knowledge Areas as well. Each process can involve effort from one or more persons or groups of persons, based on the needs of the project. Each process occurs at least once in every project and occurs in one or more project phases, if the project is divided into phases. Although the processes are presented here as discrete components with well-defined interfaces, in practice they can overlap and interact in ways not detailed here. Process interactions are discussed in detail in Chapter 3.

On some projects, especially ones of smaller scope, activity sequencing, activity resource estimating, activity duration estimating, and schedule development are so tightly linked that they are viewed as a single process that can be performed by a person over a relatively short period of time. These processes are presented here as distinct processes because the tools and techniques for each are different.

Although not shown here as a discrete process, the work involved in performing the six processes of Project Time Management is preceded by a planning effort by the project management team. This planning effort is part of the Develop Project Management Plan process (Section 4.3), which produces a schedule management plan that sets the format and establishes criteria for developing and controlling the project schedule. The project time management processes, and their associated tools and techniques, vary by application area, are usually defined as part of the project life cycle (Section 2.1), and are documented in the schedule management plan. The schedule management plan is contained in, or is a subsidiary plan of, the project management plan (introduction to Section 4.3), and may be formal or informal, highly detailed or broadly framed, based upon the needs of the project.

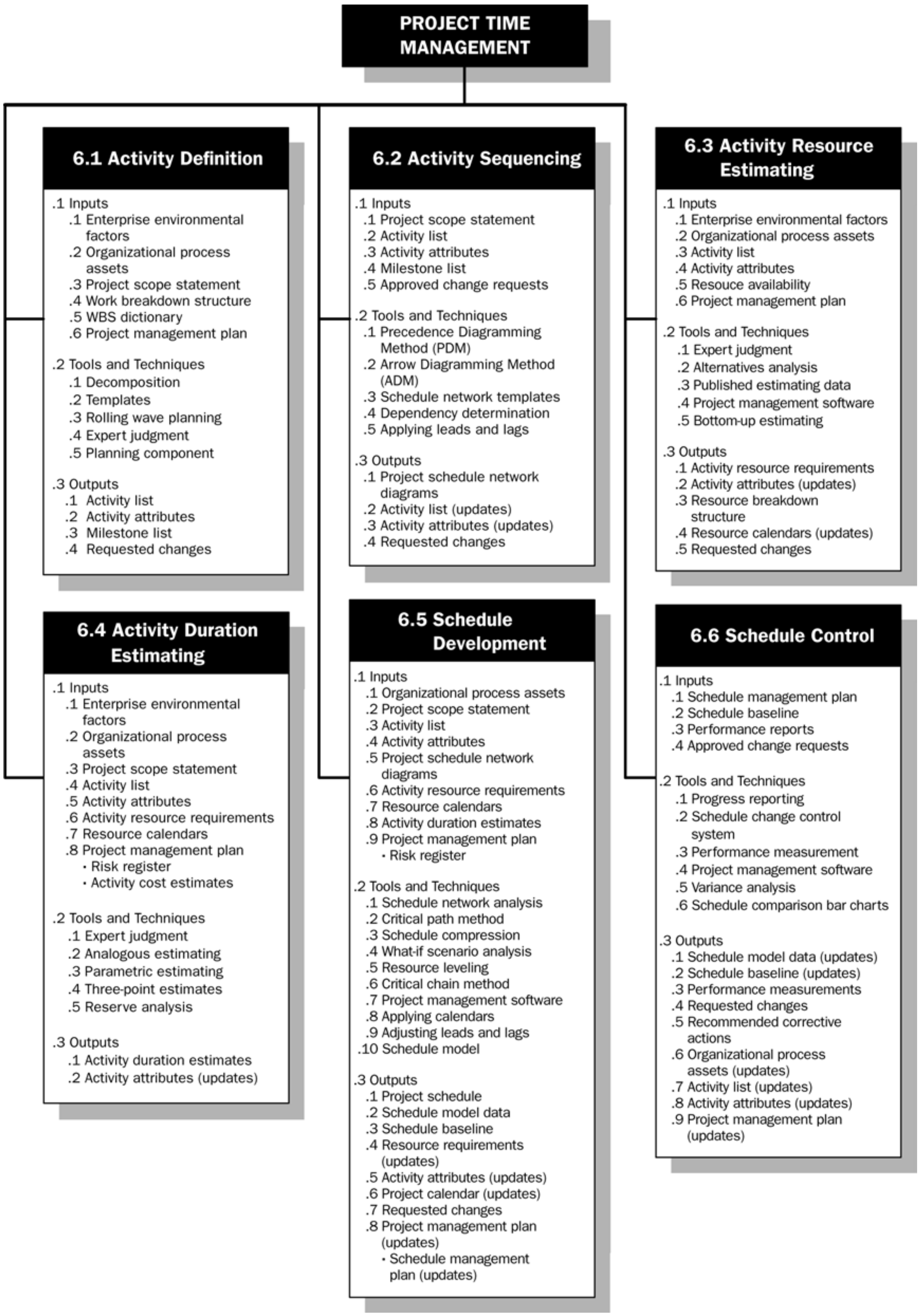
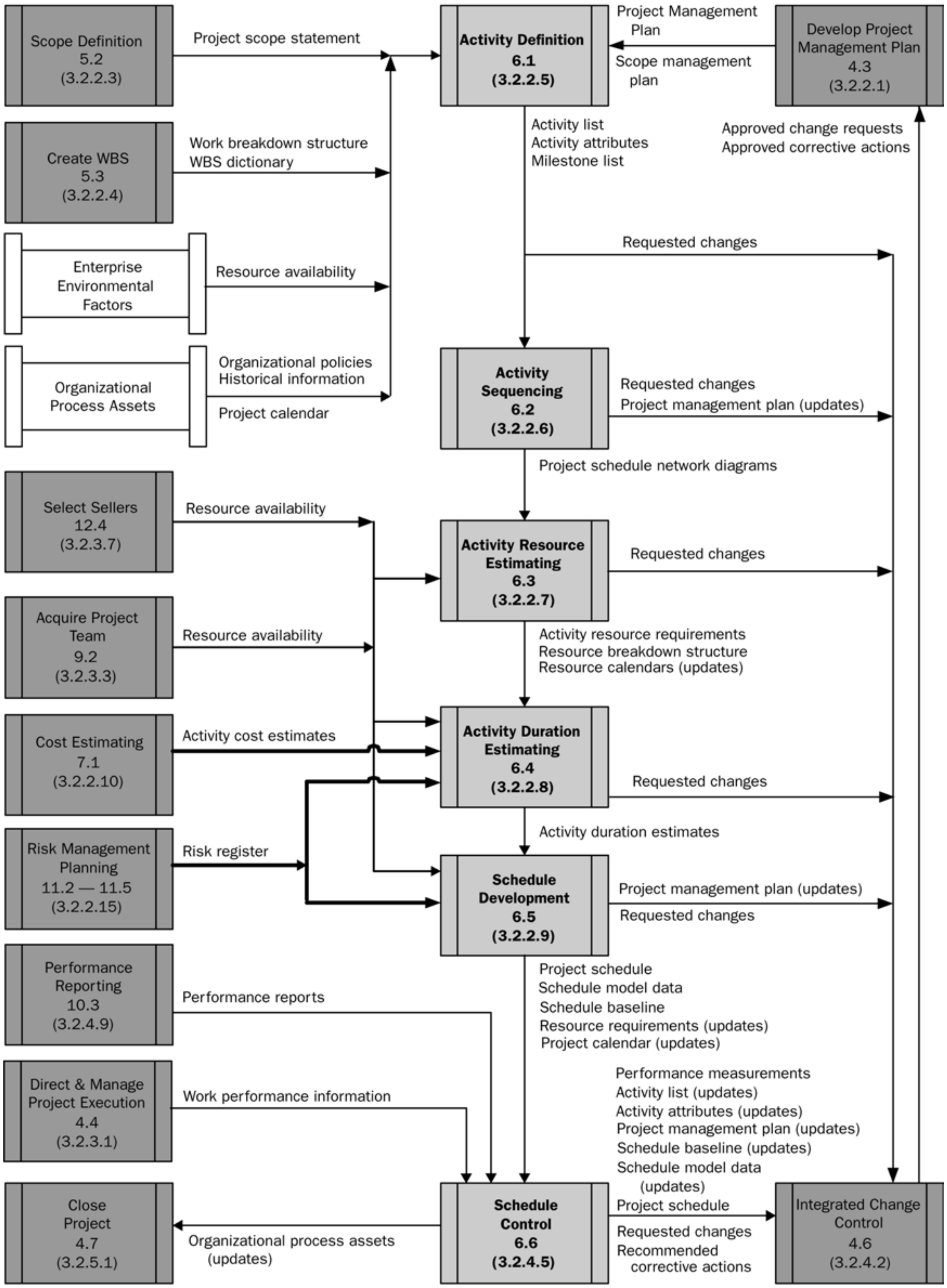


Figure 6-1. Project Time Management Overview



Note: Not all process interactions and data flow among the processes are shown.

Figure 6-2. Project Time Management Process Flow Diagram

6.1 Activity Definition

Defining the schedule activities involves identifying and documenting the work that is planned to be performed. The Activity Definition process will identify the deliverables at the lowest level in the work breakdown structure (WBS), which is called the work package. Project work packages are planned (decomposed) into smaller components called schedule activities to provide a basis for estimating, scheduling, executing, and monitoring and controlling the project work. Implicit in this process is defining and planning the schedule activities such that the project objectives will be met.

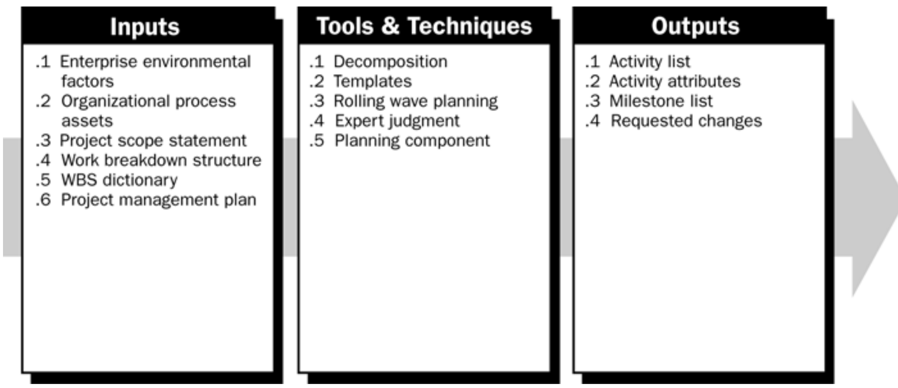


Figure 6-3. Activity Definition: Inputs, Tools & Techniques, and Outputs

6.1.1 Activity Definition: Inputs

.1 Enterprise Environmental Factors

Enterprise environmental factors (Section 4.1.1.3) that can be considered include availability of project management information systems and scheduling software tools.

.2 Organizational Process Assets

Organizational process assets (Section 4.1.1.4) contain the existing formal and informal activity planning-related policies, procedures, and guidelines that are considered in developing the activity definitions. The lessons-learned knowledge base contains historical information regarding activities lists used by previous similar projects that can be considered when defining project schedule activities.

.3 Project Scope Statement

The project deliverables, constraints, and assumptions documented in the project scope statement (Section 5.2.3.1) are considered explicitly during activity definition. Constraints are factors that will limit the project management team's options, such as schedule milestones with imposed completion dates that are required either by management or contract. Assumptions are factors that are considered to be true for project schedule planning, such as work hours per week or the time of the year that construction work will be performed.

.4 Work Breakdown Structure

The work breakdown structure (Section 5.3.3.2) is a primary input to schedule activity definition.

.5 WBS Dictionary

The WBS dictionary (Section 5.3.3.3) is a primary input to schedule activity definition.

.6 Project Management Plan

The project management plan contains the schedule management plan (Chapter 6 introductory material), which provides guidance on the development and planning of schedule activities and the project scope management plan.

6.1.2 Activity Definition: Tools and Techniques

.1 Decomposition

The technique of decomposition, as it is applied to activity definition, involves subdividing the project work packages into smaller, more manageable components called schedule activities. The Activity Definition process defines the final outputs as schedule activities rather than as deliverables, as is done in the Create WBS process (Section 5.3).

The activity list, WBS, and WBS dictionary can be developed either sequentially or concurrently, with the WBS and WBS dictionary being the basis for development of the final activity list. Each work package within the WBS is decomposed into the schedule activities required to produce the work package deliverables. This activity definition is often performed by the project team members responsible for the work package.

.2 Templates

A standard activity list or a portion of an activity list from a previous project is often usable as a template (Section 4.1.1.4) for a new project. The related activity attributes information in the templates can also contain a list of resource skills and their required hours of effort, identification of risks, expected deliverables, and other descriptive information. Templates can also be used to identify typical schedule milestones.

.3 Rolling Wave Planning

The WBS and WBS dictionary reflect the project scope evolution as it becomes more detailed until the work package level is reached. Rolling wave planning is a form of progressive elaboration (Section 1.2.1.3) planning where the work to be accomplished in the near term is planned in detail at a low level of the WBS, while work far in the future is planned for WBS components that are at a relatively high level of the WBS. The work to be performed within another one or two reporting periods in the near future is planned in detail as work is being completed during the current period. Therefore, schedule activities can exist at various levels of detail in the project's life cycle. During early strategic planning, when information is less defined, activities might be kept at the milestone level.

.4 **Expert Judgment**

Project team members or other experts who are experienced and skilled in developing detailed project scope statements, WBSs, and project schedules can provide expertise in defining activities.

.5 **Planning Component**

When insufficient definition of the project scope is available to decompose a branch of the WBS down to the work package level, the last component in that branch of the WBS can be used to develop a high-level project schedule for that component. These planning components are selected and used by the project team to plan and schedule future work at various higher levels within the WBS. The schedule activities used for these planning components may be summary activities that are not enough to support detailed estimating, scheduling, executing, monitoring, or controlling of the project work. Two planning components are:

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- **Control Account.** A management control point can be placed at selected management points (specific components at selected levels) of the work breakdown structure above the work package level. These control points are used as a basis for planning when associated work packages have not yet been planned. All work and effort performed within a control account is documented in a control account plan.
- **Planning Package.** A planning package is a WBS component below the control account, but above the work package. This component is used for planning known work content that does not have detailed schedule activities.

6.1.3 Activity Definition: Outputs

.1 **Activity List**

The activity list is a comprehensive list including all schedule activities that are planned to be performed on the project. The activity list does not include any schedule activities that are not required as part of the project scope. The activity list includes the activity identifier and a scope of work description for each schedule activity in sufficient detail to ensure that project team members understand what work is required to be completed. The schedule activity's scope of work can be in physical terms, such as linear feet of pipe to be installed, designated placement of concrete, number of drawings, lines of computer program code, or chapters in a book. The activity list is used in the schedule model and is a component of the project management plan (Section 4.3). The schedule activities are discrete components of the project schedule, but are not components of the WBS.

.2 Activity Attributes

These activity attributes are an extension of the activity attributes in the activity list and identify the multiple attributes associated with each schedule activity. Activity attributes for each schedule activity include the activity identifier, activity codes, activity description, predecessor activities, successor activities, logical relationships, leads and lags, resource requirements, imposed dates, constraints, and assumptions. Activity attributes can also include the person responsible for executing the work, geographic area or place where the work has to be performed, and schedule activity type such as level of effort, discrete effort, and apportioned effort. These attributes are used for project schedule development and for selecting, ordering, and sorting the planned schedule activities in various ways within reports. The number of attributes varies by application area. The activity attributes are used in the schedule model.

.3 Milestone List

The list of schedule milestones identifies all milestones and indicates whether the milestone is mandatory (required by the contract) or optional (based upon project requirements or historical information). The milestone list is a component of the project management plan (Section 4.3) and the milestones are used in the schedule model.

.4 Requested Changes

The Activity Definition process can generate requested changes (Section 4.4.3.2) that can affect the project scope statement and WBS. Requested changes are processed for review and disposition through the Integrated Change Control process (Section 4.6).

6.2 Activity Sequencing

Activity sequencing involves identifying and documenting the logical relationships among schedule activities. Schedule activities can be logically sequenced with proper precedence relationships, as well as leads and lags to support later development of a realistic and achievable project schedule. Sequencing can be performed by using project management software or by using manual techniques. Manual and automated techniques can also be used in combination.

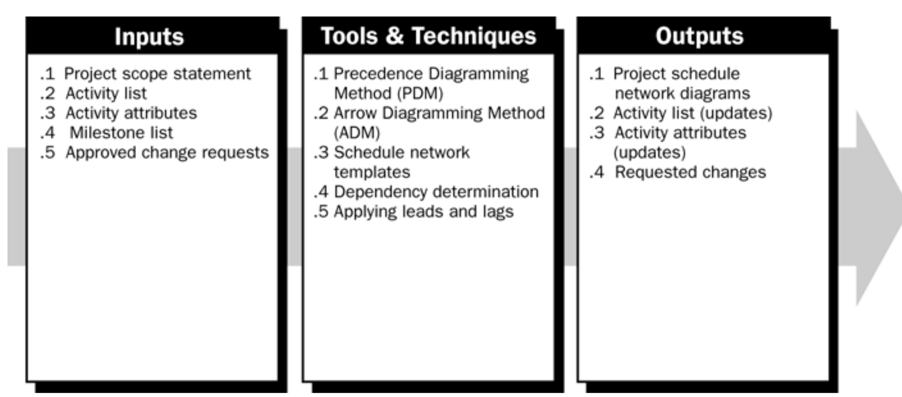

Figure 6-4. Activity Sequencing: Inputs, Tools & Techniques, and Outputs

6.2.1 Activity Sequencing: Inputs

.1 Project Scope Statement

The project scope statement (Section 5.2.3.1) contains the product scope description, which includes product characteristics that often can affect activity sequencing, such as the physical layout of a plant to be constructed or subsystem interfaces on a software project. While these effects are often apparent in the activity list, the product scope description is generally reviewed to ensure accuracy.

.2 Activity List

Described in Section 6.1.3.1.

.3 Activity Attributes

Described in Section 6.1.3.2.

.4 Milestone List

Described in Section 6.1.3.3.

.5 Approved Change Requests

Described in Section 4.4.1.4.

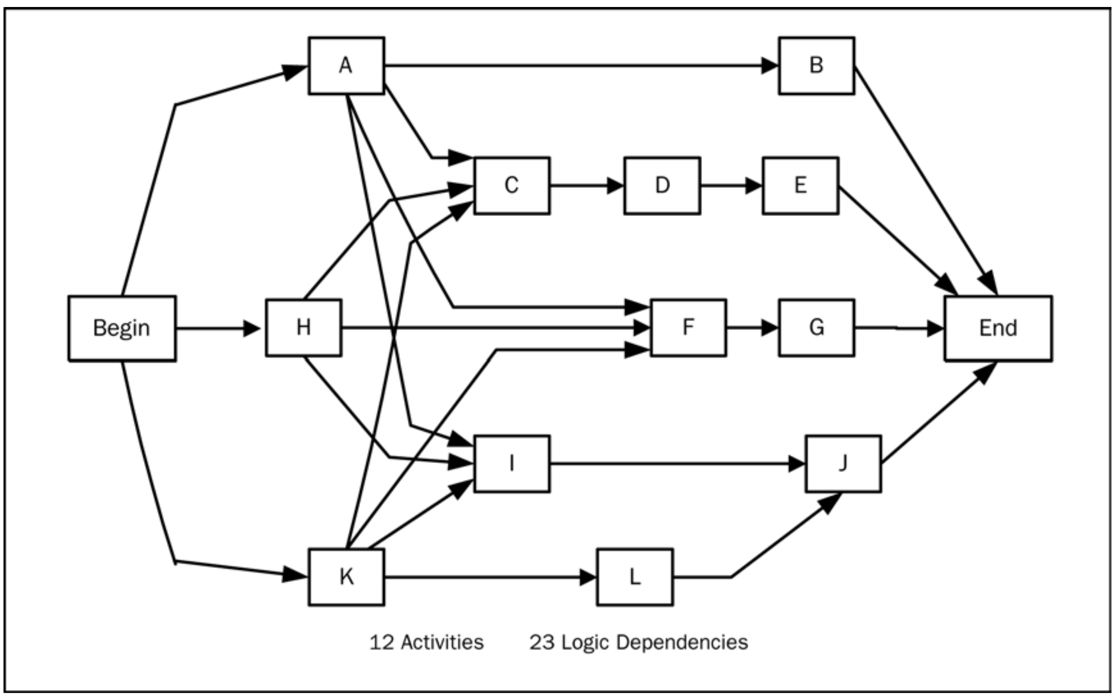

Figure 6-5. Precedence Diagram Method

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6.2.2 Activity Sequencing: Tools and Techniques

.1 Precedence Diagramming Method (PDM)

PDM is a method of constructing a project schedule network diagram that uses boxes or rectangles, referred to as nodes, to represent activities and connects them with arrows that show the dependencies. Figure 6-5 shows a simple project schedule network diagram drawn using PDM. This technique is also called activity-on-node (AON), and is the method used by most project management software packages.

PDM includes four types of dependencies or precedence relationships:

- **Finish-to-Start.** The initiation of the successor activity depends upon the completion of the predecessor activity.
- **Finish-to-Finish.** The completion of the successor activity depends upon the completion of the predecessor activity.
- **Start-to-Start.** The initiation of the successor activity depends upon the initiation of the predecessor activity.
- **Start-to-Finish.** The completion of the successor activity depends upon the initiation of the predecessor activity.

In PDM, finish-to-start is the most commonly used type of precedence relationship. Start-to-finish relationships are rarely used.

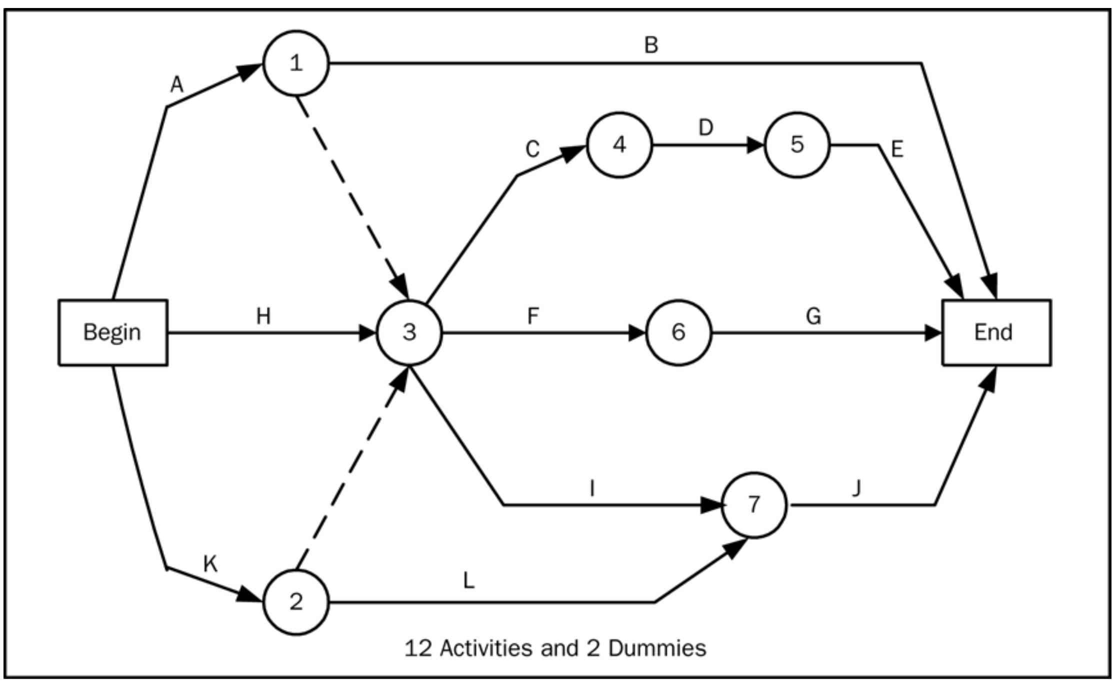

Figure 6-6. Arrow Diagram Method

.2 Arrow Diagramming Method (ADM)

ADM is a method of constructing a project schedule network diagram that uses arrows to represent activities and connects them at nodes to show their dependencies. Figure 6-6 shows a simple network logic diagram drawn using ADM. This technique is also called activity-on-arrow (AOA) and, although less prevalent than PDM, it is still used in teaching schedule network theory and in some application areas.

ADM uses only finish-to-start dependencies and can require the use of "dummy" relationships called dummy activities, which are shown as dashed lines, to define all logical relationships correctly. Since dummy activities are not actual schedule activities (they have no work content), they are given a zero value duration for schedule network analysis purposes. For example, in Figure 6-6 schedule activity "F" is dependent upon the completion of schedule activities "A" and "K," in addition to the completion of schedule activity "H."

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.3 Schedule Network Templates

Standardized project schedule network diagram templates can be used to expedite the preparation of networks of project schedule activities. They can include an entire project or only a portion of it. Portions of a project schedule network diagram are often referred to as a subnetwork or a fragment network. Subnetwork templates are especially useful when a project includes several identical or nearly identical deliverables, such as floors on a high-rise office building, clinical trials on a pharmaceutical research project, coding program modules on a software project, or the start-up phase of a development project.

.4 Dependency Determination

Three types of dependencies are used to define the sequence among the activities.

- **Mandatory dependencies.** The project management team determines which dependencies are mandatory during the process of establishing the sequence of activities. Mandatory dependencies are those that are inherent in the nature of the work being done. Mandatory dependencies often involve physical limitations, such as on a construction project, where it is impossible to erect the superstructure until after the foundation has been built, or on an electronics project, where a prototype must be built before it can be tested. Mandatory dependencies are also sometimes referred to as hard logic.

- **Discretionary dependencies.** The project management team determines which dependencies are discretionary during the process of establishing the sequence of activities. Discretionary dependencies are fully documented since they can create arbitrary total float values and can limit later scheduling options. Discretionary dependencies are sometimes referred to as preferred logic, preferential logic or soft logic. Discretionary dependencies are usually established based on knowledge of best practices within a particular application area or some unusual aspect of the project where a specific sequence is desired, even though there are other acceptable sequences. Some discretionary dependencies include preferred schedule activity sequences based upon previous experience on a successful project performing the same type of work.
- **External dependencies.** The project management team identifies external dependencies during the process of establishing the sequence of activities. External dependencies are those that involve a relationship between project activities and non-project activities. For example, the testing schedule activity in a software project can be dependent on delivery of hardware from an external source, or governmental environmental hearings may need to be held before site preparation can begin on a construction project. This input can be based on historical information (Section 4.1.1.4) from previous projects of a similar nature or from seller contracts or proposals (Section 12.4.3.2).

.5 Applying Leads and Lags

The project management team determines the dependencies (Section 6.2.2.4) that may require a lead or a lag to accurately define the logical relationship. The use of leads and lags and their related assumptions are documented.

A lead allows an acceleration of the successor activity. For example, a technical writing team can begin writing the second draft of a large document (the successor activity) fifteen days before they finish writing the entire first draft (the predecessor activity). This could be accomplished by a finish-to-start relationship with a fifteen-day lead time.

A lag directs a delay in the successor activity. For example, to account for a ten-day curing period for concrete, a ten-day lag on a finish-to-start relationship could be used, which means the successor activity cannot start until ten days after the predecessor is completed.

6.2.3 Activity Sequencing: Outputs

.1 Project Schedule Network Diagrams

Project schedule network diagrams are schematic displays of the project's schedule activities and the logical relationships among them, also referred to as dependencies. Figures 6-5 and 6-6 illustrate two different approaches to drawing a project schedule network diagram. A project schedule network diagram can be produced manually or by using project management software. The project schedule network diagram can include full project details, or have one or more summary activities. A summary narrative accompanies the diagram and describes the basic approach used to sequence the activities. Any unusual activity sequences within the network are fully described within the narrative.

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.2 Activity List (Updates)

If approved change requests (Section 4.4.1.4) result from the Activity Sequencing process, then the activity list (Section 6.1.3.1) is updated to include those approved changes.

.3 Activity Attributes (Updates)

The activity attributes (Section 6.1.3.2) are updated to include the defined logical relationships and any associated leads and lags. If approved change requests (Section 4.4.1.4) resulting from the Activity Sequencing process affect the activity list, then the related items in the activity attributes are updated to include those approved changes.

.4 Requested Changes

Preparation of project logical relationships, leads, and lags might reveal instances that can generate a requested change (Section 4.4.3.2) to the activity list or the activity attributes. Examples include where a schedule activity can be divided or otherwise redefined, where dependencies can be refined, or where a lead or lag is adjusted to adequately diagram the correct logical relationships. Requested changes are processed for review and disposition through the Integrated Change Control process (Section 4.6).

6.3 Activity Resource Estimating

Estimating schedule activity resources involves determining what resources (persons, equipment, or materiel) and what quantities of each resource will be used, and when each resource will be available to perform project activities. The Activity Resource Estimating process is closely coordinated with the Cost Estimating process (Section 7.1). For example:

- A construction project team will need to be familiar with local building codes. Such knowledge is often readily available from local sellers. However, if the local labor pool lacks experience with unusual or specialized construction techniques, the additional cost for a consultant might be the most effective way to secure knowledge of the local building codes.

- An automotive design team will need to be familiar with the latest in automated assembly techniques. The requisite knowledge might be obtained by hiring a consultant, by sending a designer to a seminar on robotics, or by including someone from manufacturing as a member of the project team.

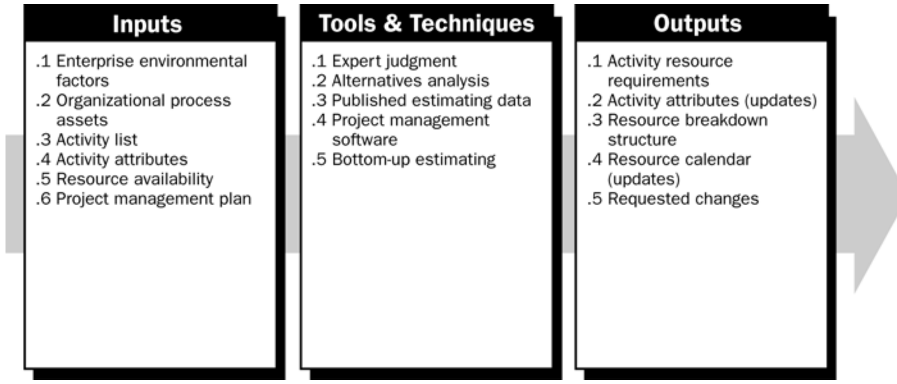

Figure 6-7. Activity Resource Estimating: Inputs, Tools & Techniques, and Outputs

6.3.1 Activity Resource Estimating: Inputs

.1 Enterprise Environmental Factors

The Activity Resource Estimating process uses the infrastructure resource availability information included in enterprise environmental factors (Section 4.1.1.3).

.2 Organizational Process Assets

Organizational process assets (Section 4.1.1.4) provide the policies of the performing organization regarding staffing and the rental or purchase of supplies and equipment that are considered during activity resource estimating. If available, historical information regarding what types of resources were required for similar work on previous projects are reviewed.

.3 Activity List

The activity list (Section 6.1.3.1) identifies the schedule activities for resources that are estimated.

.4 Activity Attributes

The activity attributes (Section 6.1.3.2) developed during the activity definition process provide the primary data input for use in estimating those resources required for each schedule activity in the activity list.

.5 **Resource Availability**

Information on which resources (such as people, equipment, and materiel) are potentially available (Sections 9.2.3.2 and 12.4.3.4) is used for estimating the resource types. This knowledge includes consideration of various geographical locations from which the resources originate and when they may be available. For example, during the early phases of an engineering design project, the pool of resources might include junior and senior engineers in large numbers. During later phases of the same project, however, the pool can be limited to those individuals who are knowledgeable about the project as a result of having worked on the earlier phases of the project.

.6 **Project Management Plan**

The schedule management plan is a component part of the project management plan (Section 4.3) that is used in Activity Resource Estimating.

6.3.2 Activity Resource Estimating: Tools and Techniques

.1 **Expert Judgment**

Expert judgment is often required to assess the resource-related inputs to this process. Any group or person with specialized knowledge in resource planning and estimating can provide such expertise.

.2 **Alternatives Analysis**

Many schedule activities have alternative methods of accomplishment. They include using various levels of resource capability or skills, different size or type of machines, different tools (hand versus automated), and make-or-buy decisions regarding the resource (Section 12.1.3.3).

.3 **Published Estimating Data**

Several companies routinely publish updated production rates and unit costs of resources for an extensive array of labor trades, materiel, and equipment for different countries and geographical locations within countries.

.4 **Project Management Software**

Project management software has the capability to help plan, organize, and manage resource pools and develop resource estimates. Depending upon the sophistication of the software, resource breakdown structures, resource availabilities, and resource rates can be defined, as well as various resource calendars.

.5 **Bottom-up Estimating**

When a schedule activity cannot be estimated with a reasonable degree of confidence, the work within the schedule activity is decomposed into more detail. The resource needs of each lower, more detailed piece of work are estimated, and these estimates are then aggregated into a total quantity for each of the schedule activity's resources. Schedule activities may or may not have dependencies between them that can affect the application and use of resources. If there are dependencies, this pattern of resource usage is reflected in the estimated requirements of the schedule activity and is documented.

6.3.3 Activity Resource Estimating: Outputs

.1 Activity Resource Requirements

The output of the Activity Resource Estimating process is an identification and description of the types and quantities of resources required for each schedule activity in a work package. These requirements can then be aggregated to determine the estimated resources for each work package. The amount of detail and the level of specificity of the resource requirement descriptions can vary by application area. The resource requirements documentation for each schedule activity can include the basis of estimate for each resource, as well as the assumptions that were made in determining which types of resources are applied, their availability, and what quantity are used. The Schedule Development process (Section 6.5) determines when the resources are needed.

.2 Activity Attributes (Updates)

The types and quantities of resources required for each schedule activity are incorporated into the activity attributes. If approved change requests (Section 4.6.3.1) result from the Activity Resource Estimating process, then the activity list (Section 6.2.3.2) and activity attributes (Section 6.2.3.3) are updated to include those approved changes.

.3 Resource Breakdown Structure

The resource breakdown structure (RBS) is a hierarchical structure of the identified resources by resource category and resource type.

.4 Resource Calendar (Updates)

A composite resource calendar for the project documents working days and nonworking days that determine those dates on which a specific resource, whether a person or materiel, can be active or is idle. The project resource calendar typically identifies resource-specific holidays and resource availability periods. The project resource calendar identifies the quantity of each resource available during each availability period.

.5 Requested Changes

The Activity Resource Estimating process can result in requested changes (Section 4.4.3.2) to add or delete planned schedule activities within the activity list. Requested changes are processed for review and disposition through the Integrated Change Control process (Section 4.6).

6.4 Activity Duration Estimating

The process of estimating schedule activity durations uses information on schedule activity scope of work, required resource types, estimated resource quantities, and resource calendars with resource availabilities. The inputs for the estimates of schedule activity duration originate from the person or group on the project team who is most familiar with the nature of the work content in the specific schedule activity. The duration estimate is progressively elaborated, and the process considers the quality and availability of the input data. For example, as the project engineering and design work evolves, more detailed and precise data is available, and the accuracy of the duration estimates improves. Thus, the duration estimate can be assumed to be progressively more accurate and of better quality.

The Activity Duration Estimating process requires that the amount of work effort required to complete the schedule activity is estimated, the assumed amount of resources to be applied to complete the schedule activity is estimated, and the number of work periods needed to complete the schedule activity is determined. All data and assumptions that support duration estimating are documented for each activity duration estimate.

Estimating the number of work periods required to complete a schedule activity can require consideration of elapsed time as a requirement related to a specific type of work. Most project management software for scheduling will handle this situation by using a project calendar and alternative work-period resource calendars that are usually identified by the resources that require specific work periods. The schedule activities will be worked according to the project calendar, and the schedule activities to which the resources are assigned will also be worked according to the appropriate resource calendars.

Overall project duration is calculated as an output of the Schedule Development process (Section 6.5).

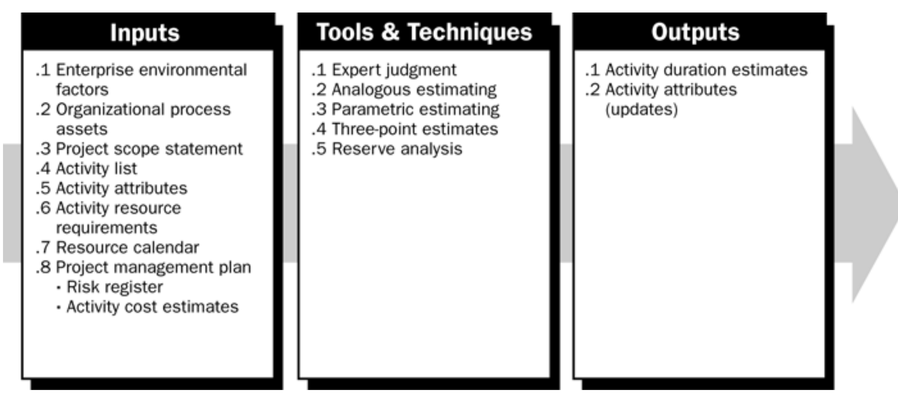

Figure 6-8. Activity Duration Estimating: Inputs, Tools & Techniques, and Outputs

6.4.1 Activity Duration Estimating: Inputs

.1 Enterprise Environmental Factors

One or more of the organizations involved in the project may maintain duration estimating databases and other historical reference data. This type of reference information is also available commercially. These databases tend to be especially useful when activity durations are not driven by the actual work content (e.g., how long it takes concrete to cure or how long a government agency usually takes to respond to certain types of requests).

.2 Organizational Process Assets

Historical information (Section 4.1.1.4) on the likely durations of many categories of activities is often available. One or more of the organizations involved in the project may maintain records of previous project results that are detailed enough to aid in developing duration estimates. In some application areas, individual team members may maintain such records. The organizational process assets (Section 4.1.1.4) of the performing organization may have some asset items that can be used in Activity Duration Estimating, such as the project calendar (a calendar of working days or shifts on which schedule activities are worked, and nonworking days on which schedule activities are idle).

.3 Project Scope Statement

The constraints and assumptions from the project scope statement (Section 5.2.3.1) are considered when estimating the schedule activity durations. An example of an assumption would be the length of the reporting periods for the project that could dictate maximum schedule activity durations. An example of a constraint would be document submittals, reviews, and similar non-deliverable schedule activities that often have frequency and durations specified by contract or within the performing organization's policies.

.4 Activity List

Described in Section 6.1.3.1.

.5 Activity Attributes

Described in Section 6.1.3.2.

.6 Activity Resource Requirements

The estimated activity resource requirements (Section 6.3.3.1) will have an effect on the duration of the schedule activity, since the resources assigned to the schedule activity, and the availability of those resources, will significantly influence the duration of most activities. For example, if a schedule activity requires two engineers working together to efficiently complete a design activity, but only one person is applied to the work, the schedule activity will generally take at least twice as much time to complete. However, as additional resources are added or lower skilled resources are applied to some schedule activities, projects can experience a reduction in efficiency. This inefficiency, in turn, could result in a work production increase of less than the equivalent percentage increase in resources applied.

.7 Resource Calendar

The composite resource calendar (Section 6.3), developed as part of the Activity Resource Estimating process, includes the availability, capabilities, and skills of human resources (Section 9.2). The type, quantity, availability, and capability, when applicable, of both equipment and materiel resources (Section 12.4) that could significantly influence the duration of schedule activities are also considered. For example, if a senior and junior staff member are assigned full time, a senior staff member can generally be expected to complete a given schedule activity in less time than a junior staff member.

.8 Project Management Plan

The project management plan contains the risk register (Sections 11.2 through 11.6) and project cost estimates (Section 7.1).

- **Risk Register.** The risk register has information on identified project risks that the project team considers when producing estimates of activity durations and adjusting those durations for risks. The project team considers the extent to which the effects of risks are included in the baseline duration estimate for each schedule activity, in particular those risks with ratings of high probability or high impact.
- **Activity Cost Estimates.** The project activity cost estimates, if already completed, can be developed in sufficient detail to provide estimated resource quantities for each schedule activity in the project activity list.

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6.4.2 Activity Duration Estimating: Tools and Techniques

.1 Expert Judgment

Activity durations are often difficult to estimate because of the number of factors that can influence them, such as resource levels or resource productivity. Expert judgment, guided by historical information, can be used whenever possible. The individual project team members may also provide duration estimate information or recommended maximum activity durations from prior similar projects. If such expertise is not available, the duration estimates are more uncertain and risky.

.2 Analogous Estimating

Analogous duration estimating means using the actual duration of a previous, similar schedule activity as the basis for estimating the duration of a future schedule activity. It is frequently used to estimate project duration when there is a limited amount of detailed information about the project for example, in the early phases of a project. Analogous estimating uses historical information (Section 4.1.1.4) and expert judgment.

Analogous duration estimating is most reliable when the previous activities are similar in fact and not just in appearance, and the project team members preparing the estimates have the needed expertise.

.3 Parametric Estimating

Estimating the basis for activity durations can be quantitatively determined by multiplying the quantity of work to be performed by the productivity rate. For example, productivity rates can be estimated on a design project by the number of drawings times labor hours per drawing, or a cable installation in meters of cable times labor hours per meter. The total resource quantities are multiplied by the labor hours per work period or the production capability per work period, and divided by the number of those resources being applied to determine activity duration in work periods.

.4 Three-Point Estimates

The accuracy of the activity duration estimate can be improved by considering the amount of risk in the original estimate. Three-point estimates are based on determining three types of estimates:

- **Most likely.** The duration of the schedule activity, given the resources likely to be assigned, their productivity, realistic expectations of availability for the schedule activity, dependencies on other participants, and interruptions.
- **Optimistic.** The activity duration is based on a best-case scenario of what is described in the most likely estimate.
- **Pessimistic.** The activity duration is based on a worst-case scenario of what is described in the most likely estimate.

An activity duration estimate can be constructed by using an average of the three estimated durations. That average will often provide a more accurate activity duration estimate than the single point, most-likely estimate.

.5 Reserve Analysis

Project teams can choose to incorporate additional time referred to as contingency reserves, time reserves or buffers, into the overall project schedule as recognition of schedule risk. The contingency reserve can be a percentage of the estimated activity duration, a fixed number of work periods, or developed by quantitative schedule risk analysis (Section 11.4.2.2.). The contingency reserve can be used completely or partially, or can later be reduced or eliminated, as more precise information about the project becomes available. Such contingency reserve is documented along with other related data and assumptions.

6.4.3 Activity Duration Estimating: Outputs

.1 Activity Duration Estimates

Activity duration estimates are quantitative assessments of the likely number of work periods that will be required to complete a schedule activity. Activity duration estimates include some indication of the range of possible results. For example:

- 2 weeks ± 2 days to indicate that the schedule activity will take at least eight days and no more than twelve (assuming a five-day workweek).
- 15 percent probability of exceeding three weeks to indicate a high probability—85 percent—that the schedule activity will take three weeks or less.

.2 Activity Attributes (Updates)

The activity attributes (Section 6.1.3.2) are updated to include the durations for each schedule activity, the assumptions made in developing the activity duration estimates, and any contingency reserves.

6.5 Schedule Development

Project schedule development, an iterative process, determines planned start and finish dates for project activities. Schedule development can require that duration estimates and resource estimates are reviewed and revised to create an approved project schedule that can serve as a baseline against which progress can be tracked. Schedule development continues throughout the project as work progresses, the project management plan changes, and anticipated risk events occur or disappear as new risks are identified.

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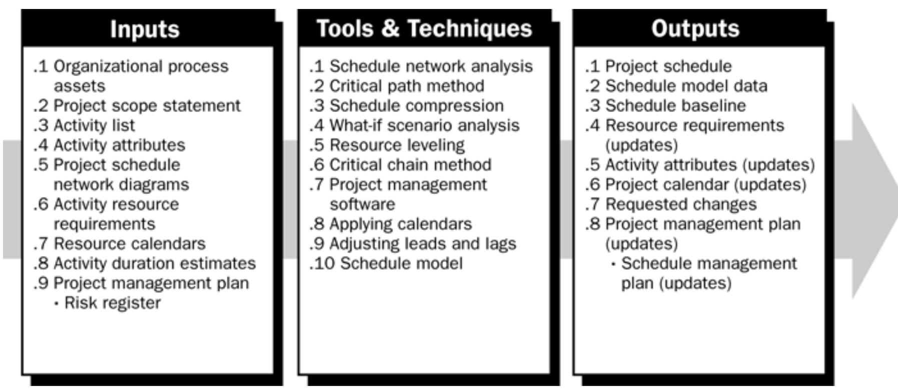

Figure 6-9. Schedule Development Overview: Inputs, Tools & Techniques, and Outputs

6.5.1 Schedule Development: Inputs

.1 Organizational Process Assets

The organizational process assets (Section 4.1.1.4) of the performing organization may have some asset items that can be used in Schedule Development, such as a project calendar (a calendar of working days or shifts that establishes dates on which schedule activities are worked, and nonworking days on which schedule activities are idle).

.2 Project Scope Statement

The project scope statement (Section 5.2.3.1) contains assumptions and constraints that can impact the development of the project schedule. Assumptions are those documented schedule-related factors that, for schedule development purposes, are considered to be true, real, or certain. Constraints are factors that will limit the project management team's options when performing schedule network analysis.

There are two major categories of time constraints considered during schedule development:

- Imposed dates on activity starts or finishes can be used to restrict the start or finish to occur either no earlier than a specified date or no later than a specified date. While several constraints are typically available in project management software, the "Start No Earlier Than" and the "Finish No Later Than" constraints are the most commonly used. Date constraints include such situations as agreed-upon contract dates, a market window on a technology project, weather restrictions on outdoor activities, government-mandated compliance with environmental remediation, and delivery of materiel from parties not represented in the project schedule.
- The project sponsor, project customer, or other stakeholders often dictate key events or major milestones affecting the completion of certain deliverables by a specified date. Once scheduled, these dates become expected and can be moved only through approved changes. Milestones can also be used to indicate interfaces with work outside of the project. Such work is typically not in the project database and milestones with constraint dates can provide the appropriate schedule interface.

.3 Activity List
Described in Section 6.1.3.1.

.4 Activity Attributes
Described in Section 6.1.3.2.

.5 Project Schedule Network Diagrams
Described in Section 6.2.3.1.

.6 Activity Resource Requirements
Described in Section 6.3.3.1.

.7 Resource Calendars
Described in Sections 6.3.3.4.

.8 Activity Duration Estimates
Described in Section 6.4.3.1.

.9 Project Management Plan
The project management plan contains the schedule management plan, cost management plan, project scope management plan, and risk management plan. These plans guide the schedule development, as well as components that directly support the Schedule Development process. One such component is the risk register.

- **Risk Register.** The risk register (Sections 11.1 through 11.5) identifies the project risks and associated risk response plans that are needed to support the Schedule Development process.

6.5.2 Schedule Development: Tools and Techniques

.1 Schedule Network Analysis

Schedule network analysis is a technique that generates the project schedule. It employs a schedule model and various analytical techniques, such as critical path method, critical chain method, what-if analysis, and resource leveling to calculate the early and late start and finish dates, and scheduled start and finish dates for the uncompleted portions of project schedule activities. If the schedule network diagram used in the model has any network loops or network open ends, then those loops and open ends are adjusted before one of the analytical techniques is applied. Some network paths may have points of path convergence or path divergence that can be identified and used in schedule compression analysis or other analyses.

.2 Critical Path Method

The critical path method is a schedule network analysis technique that is performed using the schedule model. The critical path method calculates the theoretical early start and finish dates, and late start and finish dates, for all schedule activities without regard for any resource limitations, by performing a forward pass analysis and a backward pass analysis through the project schedule network paths. The resulting early and late start and finish dates are not necessarily the project schedule; rather, they indicate the time periods within which the schedule activity should be scheduled, given activity durations, logical relationships, leads, lags, and other known constraints.

Calculated early start and finish dates, and late start and finish dates, may or may not be the same on any network path since total float, which provides schedule flexibility, may be positive, negative, or zero. On any network path, the schedule flexibility is measured by the positive difference between early and late dates, and is termed "total float." Critical paths have either a zero or negative total float, and schedule activities on a critical path are called "critical activities." Adjustments to activity durations, logical relationships, leads and lags, or other schedule constraints may be necessary to produce network paths with a zero or positive total float. Once the total float for a network path is zero or positive, then the free float — the amount of time that a schedule activity can be delayed without delaying the early start date of any immediate successor activity within the network path — can also be determined.

.3 Schedule Compression

Schedule compression shortens the project schedule *without* changing the project scope, to meet schedule constraints, imposed dates, or other schedule objectives. Schedule compression techniques include:

- **Crashing.** Schedule compression technique in which cost and schedule tradeoffs are analyzed to determine how to obtain the greatest amount of compression for the least incremental cost. Crashing does not always produce a viable alternative and can result in increased cost.

- **Fast tracking.** A schedule compression technique in which phases or activities that normally would be done in sequence are performed in parallel. An example would be to construct the foundation for a building before all the architectural drawings are complete. Fast tracking can result in rework and increased risk. This approach can require work to be performed without completed detailed information, such as engineering drawings. It results in trading cost for time, and increases the risk of achieving the shortened project schedule.

.4 What-If Scenario Analysis

This is an analysis of the question "What if the situation represented by scenario 'X' happens?" A schedule network analysis is performed using the schedule model to compute the different scenarios, such as delaying a major component delivery, extending specific engineering durations, or introducing external factors, such as a strike or a change in the permitting process. The outcome of the what-if scenario analysis can be used to assess the feasibility of the project schedule under adverse conditions, and in preparing contingency and response plans to overcome or mitigate the impact of unexpected situations. Simulation involves calculating multiple project durations with different sets of activity assumptions. The most common technique is Monte Carlo Analysis (Section 11.4.2.2), in which a distribution of possible activity durations is defined for each schedule activity and used to calculate a distribution of possible outcomes for the total project.

.5 Resource Leveling

Resource leveling is a schedule network analysis technique applied to a schedule model that has already been analyzed by the critical path method. Resource leveling is used to address schedule activities that need to be performed to meet specified delivery dates, to address the situation where shared or critical required resources are only available at certain times or are only available in limited quantities, or to keep selected resource usage at a constant level during specific time periods of the project work. This resource usage leveling approach can cause the original critical path to change.

The critical path method calculation (Section 6.5.2.2) produces a preliminary early start schedule and late start schedule that can require more resources during certain time periods than are available, or can require changes in resource levels that are not manageable. Allocating scarce resources to critical path activities first can be used to develop a project schedule that reflects such constraints. Resource leveling often results in a projected duration for the project that is longer than the preliminary project schedule. This technique is sometimes called the resource-based method, especially when implemented using schedule optimization project management software. Resource reallocation from non-critical to critical activities is a common way to bring the project back on track, or as close as possible, to its originally intended overall duration. Utilization of extended hours, weekends, or multiple shifts for selected resources can also be considered using different resource calendars to reduce the durations of critical activities. Resource productivity increases are another way to shorten durations that have extended the preliminary project schedule. Different technologies or machinery, such as reuse of computer code, automatic welding, electric pipe cutters, and automated processes, can all have an impact on resource productivity. Some projects can have a finite and critical project resource. In this case, the resource is scheduled in reverse from the project ending date, which is known as reverse resource allocation scheduling, and may not result in an optimal project schedule. The resource leveling technique produces a resource-limited schedule, sometimes called a resource-constrained schedule, with scheduled start dates and scheduled finish dates.

.6 Critical Chain Method

Critical chain is another schedule network analysis technique that modifies the project schedule to account for limited resources. Critical chain combines deterministic and probabilistic approaches. Initially, the project schedule network diagram is built using non-conservative estimates for activity durations within the schedule model, with required dependencies and defined constraints as inputs. The critical path is then calculated. After the critical path is identified, resource availability is entered and the resource-limited schedule result is determined. The resulting schedule often has an altered critical path.

The critical chain method adds duration buffers that are non-work schedule activities to maintain focus on the planned activity durations. Once the buffer schedule activities are determined, the planned activities are scheduled to their latest possible planned start and finish dates. Consequently, in lieu of managing the total float of network paths, the critical chain method focuses on managing the buffer activity durations and the resources applied to planned schedule activities.

.7 Project Management Software

Project management scheduling software is widely used to assist with schedule development. Other software might be capable of interacting directly or indirectly with project management software to carry out the requirements of other Knowledge Areas, such as cost estimating by time period (Section 7.1.2.5) and schedule simulation in quantitative risk analysis (Section 11.4.2.2). These products automate the calculation of the mathematical forward pass and backward pass critical path analysis and resource leveling, and, thus, allow for rapid consideration of many schedule alternatives. They are also widely used to print or display the outputs of developed schedules.

.8 Applying Calendars

Project calendars (Section 4.1.1.4) and resource calendars (Section 6.3.3.4) identify periods when work is allowed. Project calendars affect all activities. For example, it may not be possible to work on the site during certain periods of the year because of weather. Resource calendars affect a specific resource or category of resources. Resource calendars reflect how some resources work only during normal business hours, while others work three full shifts, or a project team member might be unavailable, such as on vacation or in a training program, or a labor contract can limit certain workers to certain days of the week.

.9 Adjusting Leads and Lags

Since the improper use of leads or lags can distort the project schedule, the leads or lags are adjusted during schedule network analysis to develop a viable project schedule.

.10 Schedule Model

Schedule data and information are compiled into the schedule model for the project. The schedule model tool and the supporting schedule model data are used in conjunction with manual methods or project management software to perform schedule network analysis to generate the project schedule.

6.5.3 Schedule Development: Outputs

.1 Project Schedule

The project schedule includes at least a planned start date and planned finish date for each schedule activity. If resource planning is done at an early stage, then the project schedule would remain preliminary until resource assignments have been confirmed, and scheduled start dates and finish dates are established. This process usually happens no later than completion of the project management plan (Section 4.3). A project target schedule may also be developed with defined target start dates and target finish dates for each schedule activity. The project schedule can be presented in summary form, sometimes referred to as the master schedule or milestone schedule, or presented in detail. Although a project schedule can be presented in tabular form, it is more often presented graphically, using one or more of the following formats:

- **Project schedule network diagrams.** These diagrams, with activity date information, usually show both the project network logic and the project's critical path schedule activities. These diagrams can be presented in the activity-on-node diagram format, as shown in Figure 6-5, or presented in a time-scaled schedule network diagram format that is sometimes called a logic bar chart, as shown for the detailed schedule in Figure 6-10. This example also shows how each work package is planned as a series of related schedule activities.
- **Bar charts.** These charts, with bars representing activities, show activity start and end dates, as well as expected durations. Bar charts are relatively easy to read, and are frequently used in management presentations. For control and management communication, the broader, more comprehensive summary activity, sometimes referred to as a hammock activity, is used between milestones or across multiple interdependent work packages, and is displayed in bar chart reports. An example is the summary schedule portion of Figure 6-10 that is presented in a WBS structured format.
- **Milestone charts.** These charts are similar to bar charts, but only identify the scheduled start or completion of major deliverables and key external interfaces. An example is the milestone schedule portion of Figure 6-10.

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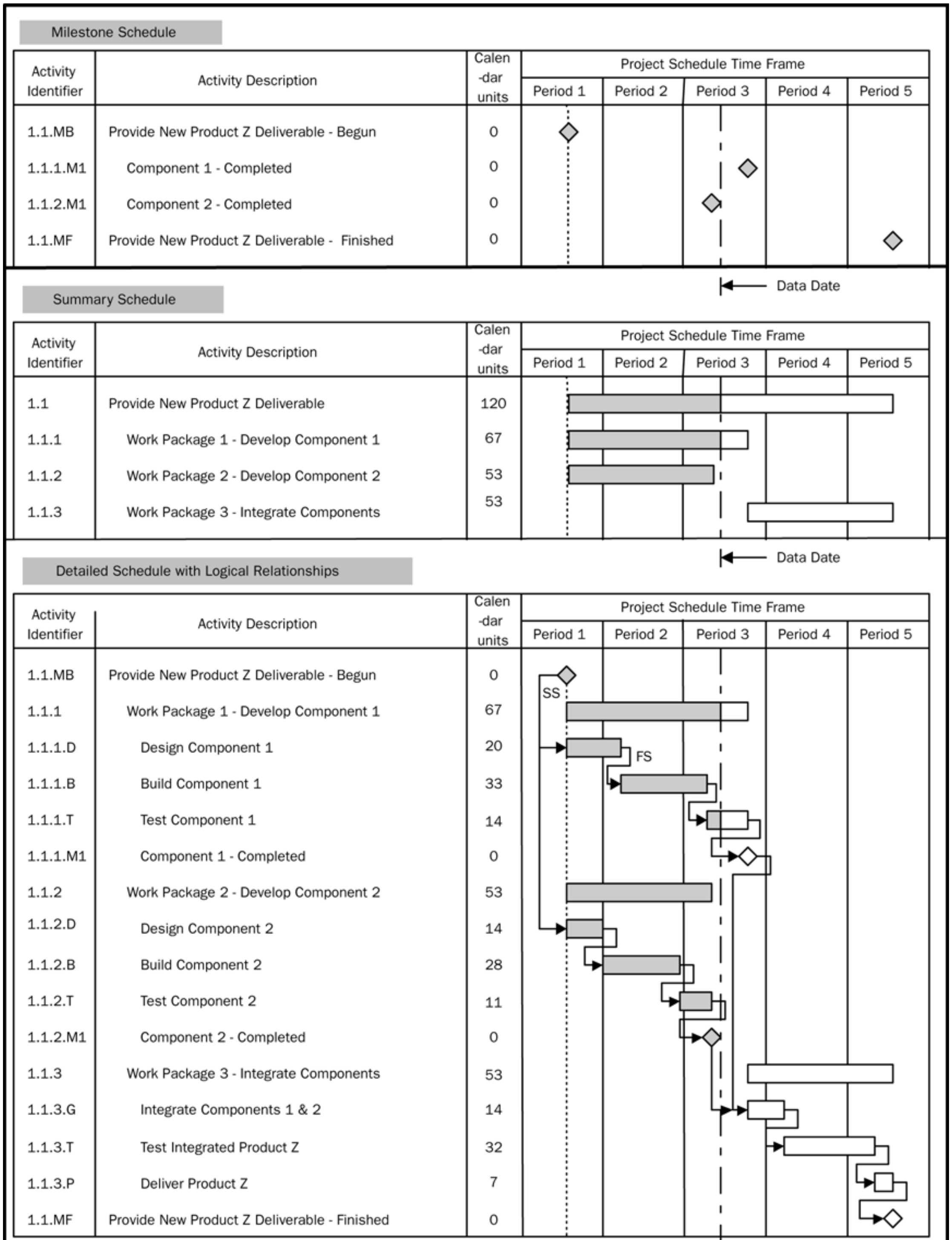

Figure 6-10. Project Schedule - Graphical Examples

Figure 6-10. Project Schedule – Graphic Examples

Figure 6-10 shows the schedule for a sample project being executed, with the work in progress reported through the data date, which is sometimes also called the as-of date or time now date. The figure shows the actual start date, actual duration, and actual finish date for completed schedule activities, the actual start date, remaining duration, and current finish date for schedule activities with work in progress, and the current start date, original duration, and current finish date for schedule activities where work has not yet started. For a simple project schedule, Figure 6-10 gives a graphic display of a Milestone Schedule, a Summary Schedule, and a Detailed Schedule. Figure 6-10 also visually shows the relationships among the three different levels of schedule presentation.

.2 Schedule Model Data

Supporting data for the project schedule includes at least the schedule milestones, schedule activities, activity attributes and documentation of all identified assumptions and constraints. The amount of additional data varies by application area. Information frequently supplied as supporting detail includes, but is not limited to:

- Resource requirements by time period, often in the form of a resource histogram
- Alternative schedules, such as best-case or worst-case, not resource leveled, resource leveled, with or without imposed dates
- Schedule contingency reserves.

For example, on an electronics design project, the schedule model data might include such items as human resource histograms, cash-flow projections, and order and delivery schedules.

.3 Schedule Baseline

A schedule baseline is a specific version of the project schedule developed from the schedule network analysis of the schedule model. It is accepted and approved by the project management team as the schedule baseline with baseline start dates and baseline finish dates.

.4 Resource Requirements (Updates)

Resource leveling can have a significant effect on preliminary estimates of the types and quantities of resources required. If the resource-leveling analysis changes the project resource requirements, then the resource requirements are updated.

.5 Activity Attributes (Updates)

The activity attributes (Section 6.2.3.3) are updated to include any revised resource requirements and any other related approved changes (Section 4.4.1.4) generated by the Schedule Development process.

.6 Project Calendar (Updates)

A project calendar is a calendar of working days or shifts that establishes those dates on which schedule activities are worked. It also establishes nonworking days that determine dates on which schedule activities are idle, such as holidays, weekends, and non-shift hours. The calendar for each project may use different calendar units as the basis for scheduling the project.

.7 Requested Changes

The Schedule Development process can create requested changes (Section 4.4.3.2) that are processed for review and disposition through the Integrated Change Control process (Section 4.6).

.8 Project Management Plan (Updates)

The project management plan (Section 4.3) is updated to reflect any approved changes in how the project schedule will be managed.

- **Schedule Management Plan (Updates).** If approved change requests (Section 4.4.1.4) result from the Project Time Management processes, then the schedule management plan (Chapter 6 introductory material) component of the project management plan (Section 4.3) may need to be updated to include those approved changes.

6.6 Schedule Control

Schedule control is concerned with:

- Determining the current status of the project schedule
- Influencing the factors that create schedule changes
- Determining that the project schedule has changed
- Managing the actual changes as they occur.

Schedule control is a portion of the Integrated Change Control process (Section 4.6).

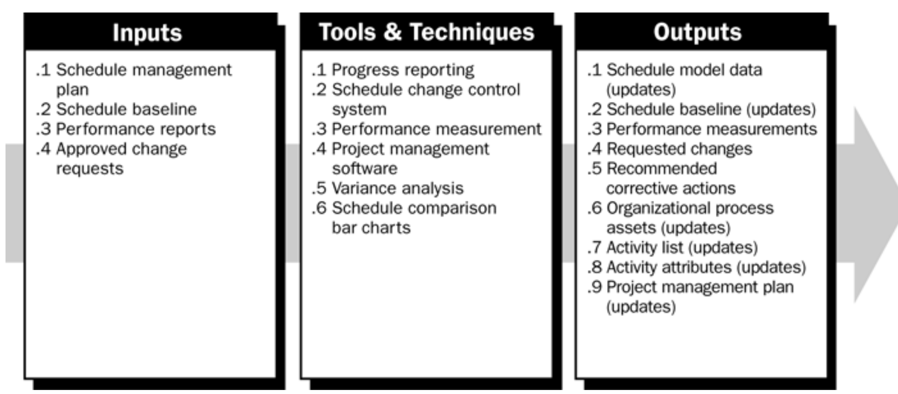

Figure 6-11. Schedule Control Overview: Inputs, Tools & Techniques, and Outputs

6.6.1 Schedule Control: Inputs

.1 Schedule Management Plan

The project management plan (Section 4.3) contains the schedule management plan (Chapter 6 introductory material) that establishes how the project schedule will be managed and controlled.

.2 Schedule Baseline

The project schedule (Section 6.5.3.1) used for control is the approved project schedule, which is referred to as the schedule baseline (Section 6.5.3.3). The schedule baseline is a component of the project management plan (Section 4.3). It provides the basis for measuring and reporting schedule performance as part of the performance measurement baseline.

.3 Performance Reports

Performance reports (Section 10.3.3.1) provide information on schedule performance, such as which planned dates have been met and which have not. Performance reports may also alert the project team to issues that may cause schedule performance problems in the future.

.4 Approved Change Requests

Only approved change requests (Section 4.4.1.4) that have been previously processed through the Integrated Change Control process (Section 4.6) are used to update the project schedule baseline or other components of the project management plan (Section 4.3).

6.6.2 Schedule Control: Tools and Techniques

.1 Progress Reporting

The progress reporting and current schedule status includes information such as actual start and finish dates, and the remaining durations for unfinished schedule activities. If progress measurement such as earned value is also used, then the percent complete of in-progress schedule activities can also be included. To facilitate the periodic reporting of project progress, a template created for consistent use across various project organizational components can be used throughout the project life cycle. The template can be paper-based or electronic.

.2 Schedule Change Control System

The schedule change control system defines the procedures by which the project schedule can be changed. It includes the paperwork, tracking systems, and approval levels necessary for authorizing changes. The schedule change control system is operated as part of the Integrated Change Control process (Section 4.6).

.3 Performance Measurement

Performance measurement techniques produce the Schedule Variance (SV) (Section 7.3.2.2) and Schedule Performance Index (SPI) (Section 7.3.2.2), which are used to assess the magnitude of any project schedule variations that do occur. An important part of schedule control is to decide if the schedule variation requires corrective action. For example, a major delay on any schedule activity not on the critical path may have little effect on the overall project schedule, while a much shorter delay on a critical or near-critical activity may require immediate action.

.4 Project Management Software

Project management software for scheduling provides the ability to track planned dates versus actual dates, and to forecast the effects of project schedule changes, real or potential, which makes it a useful tool for schedule control.

.5 Variance Analysis

Performing the schedule variance analysis during the schedule monitoring process is a key function of schedule control. Comparing target schedule dates with the actual/forecast start and finish dates provides useful information for the detection of deviations, and for the implementation of corrective actions in case of delays. The total float variance is also an essential planning component to evaluate project time performance.

.6 Schedule Comparison Bar Charts

To facilitate analysis of schedule progress, it is convenient to use a comparison bar chart, which displays two bars for each schedule activity. One bar shows the current actual status and the other shows the status of the approved project schedule baseline. This shows graphically where the schedule has progressed as planned or where slippage has occurred.

6.6.3 Schedule Control: Outputs

.1 Schedule Model Data (Updates)

A project schedule update is any modification to the project schedule model information that is used to manage the project. Appropriate stakeholders are notified of significant modifications as they occur.

New project schedule network diagrams are developed to display approved remaining durations and modifications to the work plan. In some cases, project schedule delays can be so severe that development of a new target schedule with revised target start and finish dates is needed to provide realistic data for directing the work, and for measuring performance and progress.

.2 Schedule Baseline (Updates)

Schedule revisions are a special category of project schedule updates. Revisions are changes to the schedule's start and finish dates in the approved schedule baseline. These changes are generally incorporated in response to approved change requests (Section 4.4.1.4) related to project scope changes or changes to estimates. Development of a revised schedule baseline can only occur as a result of approved changes. The original schedule baseline and schedule model are saved before creating the new schedule baseline to prevent loss of historical data for the project schedule.

.3 Performance Measurements

The calculated schedule variance (SV) and schedule performance index (SPI) values for WBS components, in particular the work packages and control accounts, are documented and communicated (Section 10.3.3.1) to stakeholders.

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.4 Requested Changes

Schedule variance analysis, along with review of progress reports, results of performance measures, and modifications to the project schedule model can result in requested changes (Section 4.4.3.2) to the project schedule baseline. Project schedule changes might or might not require adjustments to other components of the project management plan. Requested changes are processed for review and disposition through the Integrated Change Control process (Section 4.6).

.5 Recommended Corrective Actions

A corrective action is anything done to bring expected future project schedule performance in line with the approved project schedule baseline. Corrective action in the area of time management often involves expediting, which includes special actions taken to ensure completion of a schedule activity on time or with the least possible delay. Corrective action frequently requires root cause analysis to identify the cause of the variation. The analysis may address schedule activities other than the schedule activity actually causing the deviation; therefore, schedule recovery from the variance can be planned and executed using schedule activities delineated later in the project schedule.

.6 Organizational Process Assets (Updates)

Lessons learned documentation of the causes of variance, the reasoning behind the corrective actions chosen, and other types of lessons learned from schedule control are documented in the organizational process assets (Section 4.1.1.4), so that they become part of the historical database for both the project and other projects of the performing organization.

.7 Activity List (Updates)
Described in Section 6.1.3.1.

.8 Activity Attributes (Updates)
Described in Section 6.1.3.2.

.9 Project Management Plan (Updates)
The schedule management plan (Chapter 6 introductory material) component of the project management plan (Section 4.3) is updated to reflect any approved changes resulting from the Schedule Control process, and how the project schedule will be managed.

CHAPTER 7

Project Cost Management

7

Project Cost Management includes the processes involved in planning, estimating, budgeting, and controlling costs so that the project can be completed within the approved budget. Figure 7-1 provides an overview of the following three processes, while Figure 7-2 provides a process flow view of these processes and their inputs, outputs, and other related Knowledge Area processes:

7.1 Cost Estimating – developing an approximation of the costs of the resources needed to complete project activities.

7.2 Cost Budgeting – aggregating the estimated costs of individual activities or work packages to establish a cost baseline.

7.3 Cost Control – influencing the factors that create cost variances and controlling changes to the project budget.

These processes interact with each other and with processes in the other Knowledge Areas as well. Each process can involve effort from one or more persons or groups of persons based upon the needs of the project. Each process occurs at least once in every project and occurs in one or more project phases, if the project is divided into phases. Although the processes are presented here as discrete elements with well-defined interfaces, in practice they may overlap and interact in ways not detailed here. Process interactions are discussed in detail in Chapter 3.

Project Cost Management is primarily concerned with the cost of the resources needed to complete schedule activities. However, Project Cost Management should also consider the effect of project decisions on the cost of using, maintaining, and supporting the product, service, or result of the project. For example, limiting the number of design reviews can reduce the cost of the project at the expense of an increase in the customer's operating costs. This broader view of Project Cost Management is often called life-cycle costing. Life-cycle costing, together with value engineering techniques, can improve decision-making and is used to reduce cost and execution time and to improve the quality and performance of the project deliverable.

In many application areas, predicting and analyzing the prospective financial performance of the project's product is done outside the project. In others, such as a capital facilities project, Project Cost Management can include this work. When such predictions and analyses are included, Project Cost Management will address additional processes and numerous general management techniques such as return on investment, discounted cash flow, and investment payback analysis.

Project Cost Management considers the information requirements of the project stakeholders. Different stakeholders will measure project costs in different ways and at different times. For example, the cost of an acquired item can be measured when the acquisition decision is made or committed, the order is placed, the item is delivered, and the actual cost is incurred or recorded for project accounting purposes.

On some projects, especially ones of smaller scope, cost estimating and cost budgeting are so tightly linked that they are viewed as a single process that can be performed by a single person over a relatively short period of time. These processes are presented here as distinct processes because the tools and techniques for each are different. The ability to influence cost is greatest at the early stages of the project, and this is why early scope definition is critical (Section 5.2).

Although not shown here as a discrete process, the work involved in performing the three processes of Project Cost Management is preceded by a planning effort by the project management team. This planning effort is part of the Develop Project Management Plan process (Section 4.3), which produces a cost management plan that sets out the format and establishes the criteria for planning, structuring, estimating, budgeting, and controlling project costs. The cost management processes and their associated tools and techniques vary by application area, are usually selected during the project life cycle (Section 2.1) definition, and are documented in the cost management plan.

For example, the cost management plan can establish:

- **Precision level.** Schedule activity cost estimates will adhere to a rounding of the data to a prescribed precision (e.g., \$100, \$1,000), based on the scope of the activities and magnitude of the project, and may include an amount for contingencies.
- **Units of measure.** Each unit used in measurements is defined, such as staff hours, staff days, week, lump sum, etc., for each of the resources.
- **Organizational procedures links.** The WBS component used for the project cost accounting is called a control account (CA). Each control account is assigned a code or account number that is linked directly to the performing organization's accounting system. If cost estimates for planning packages are included in the control account, then the method for budgeting planning packages is included.
- **Control thresholds.** Variance thresholds for costs or other indicators (e.g., person-days, volume of product) at designated time points over the duration of the project can be defined to indicate the agreed amount of variation allowed.

- **Earned value rules.** Three examples are: 1) Earned value management computation formulas for determining the estimate to complete are defined, 2) Earned value credit criteria (e.g., 0-100, 0-50-100, etc.) are established, and 3) Define the WBS level at which earned value technique analysis will be performed.
- **Reporting formats.** The formats for the various cost reports are defined.
- **Process descriptions.** Descriptions of each of the three cost management processes are documented.

All of the above, as well as other information, are included in the cost management plan, either as text within the body of the plan or as appendices. The cost management plan is contained in, or is a subsidiary plan of, the project management plan (Section 4.3) and may be formal or informal, highly detailed or broadly framed, based upon the needs of the project.

The cost management planning effort occurs early in project planning and sets the framework for each of the cost management processes, so that performance of the processes will be efficient and coordinated.

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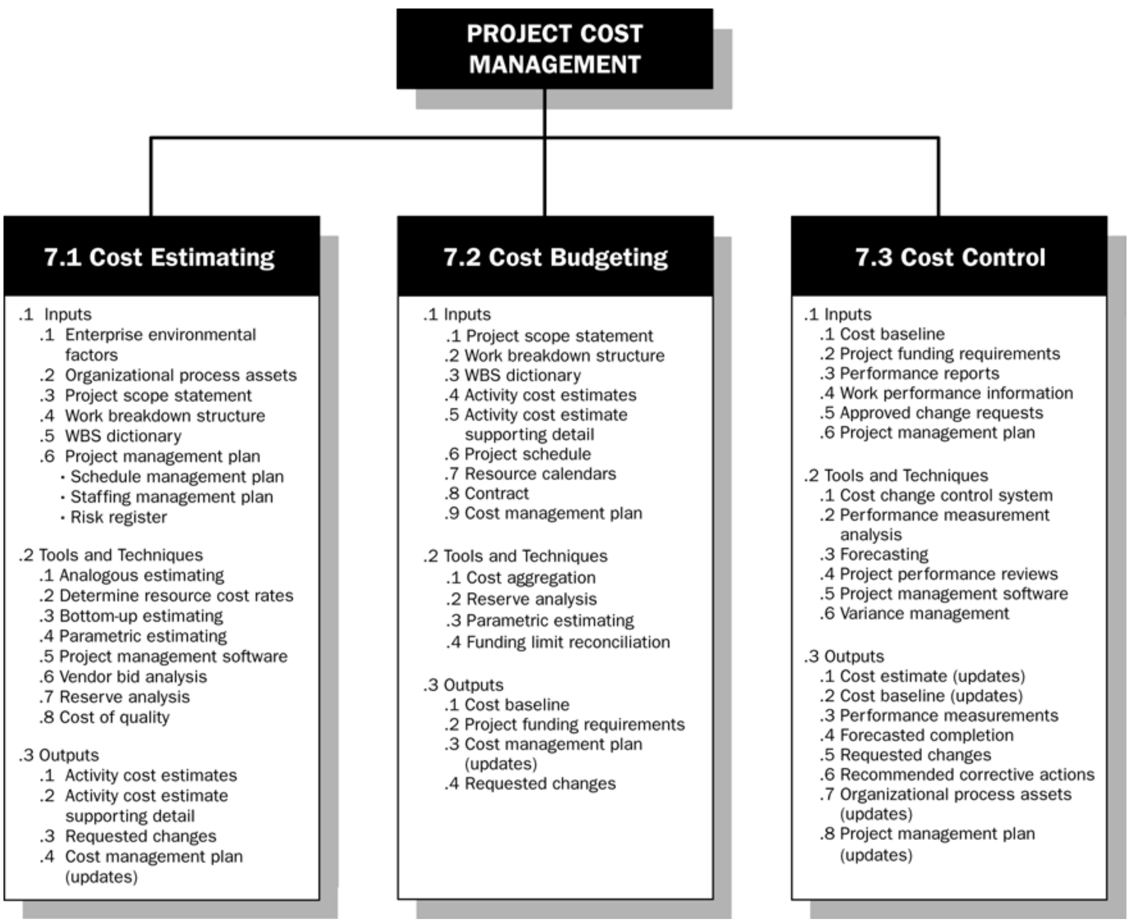
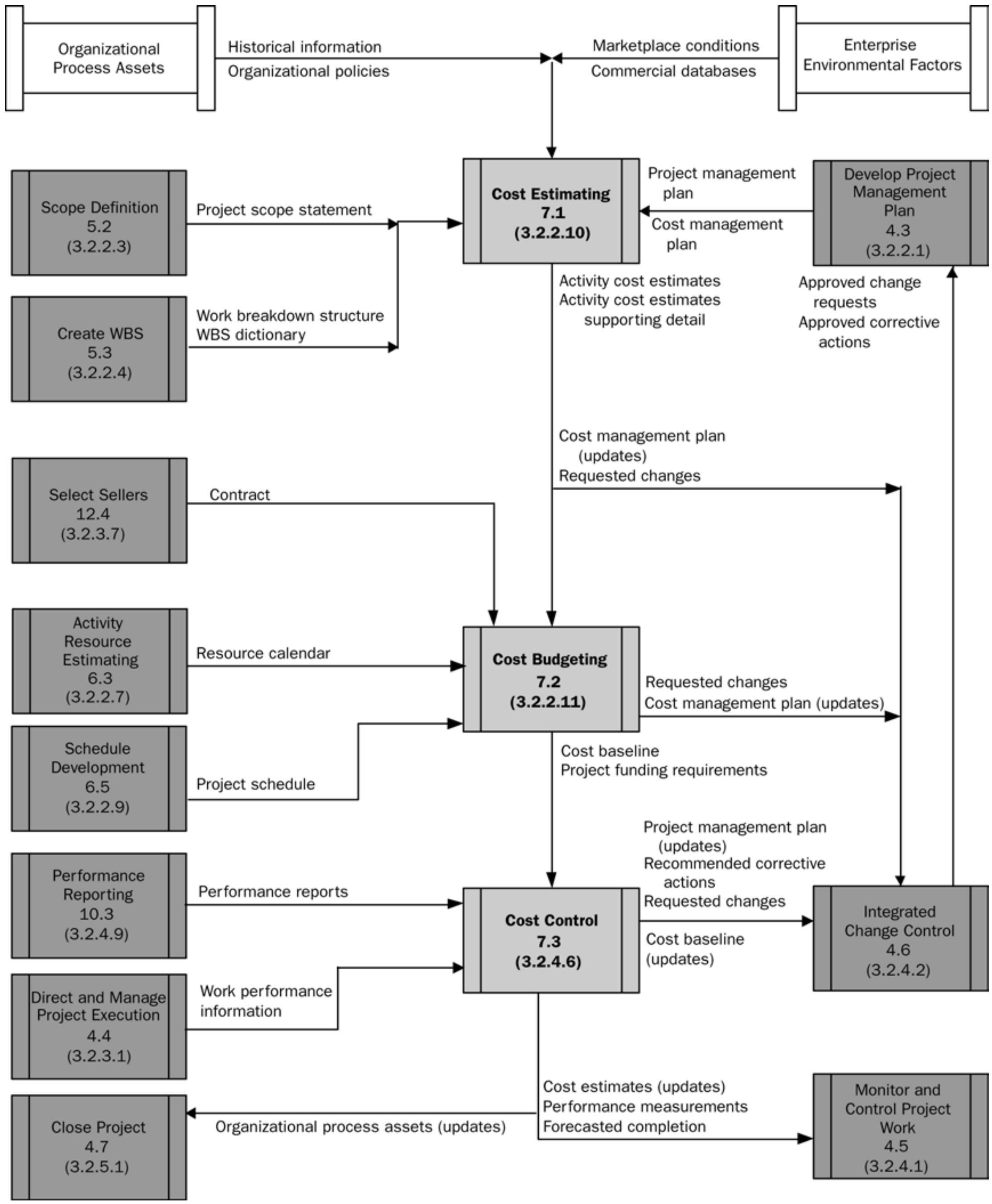


Figure 7-1. Project Cost Management Overview



Note: Not all process interactions and data flow among the processes are shown.

Figure 7-2. Project Cost Management Process Flow Diagram

7.1 Cost Estimating

Estimating schedule activity costs involves developing an approximation of the costs of the resources needed to complete each schedule activity. In approximating costs, the estimator considers the possible causes of variation of the cost estimates, including risks.

Cost estimating includes identifying and considering various costing alternatives. For example, in most application areas, additional work during a design phase is widely held to have the potential for reducing the cost of the execution phase and product operations. The cost estimating process considers whether the expected savings can offset the cost of the additional design work.

Cost estimates are generally expressed in units of currency (dollars, euro, yen, etc.) to facilitate comparisons both within and across projects. In some cases, the estimator can use units of measure to estimate cost, such as staff hours or staff days, along with their cost estimates, to facilitate appropriate management control.

Cost estimates can benefit from refinement during the course of the project to reflect the additional detail available. 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 could have a rough order of magnitude (ROM) estimate in the range of -50 to +100%. Later in the project, as more information is known, estimates could narrow to a range of -10 to +15%. In some application areas, there are guidelines for when such refinements are made and for what degree of accuracy is expected.

Sources of input information come in the form of outputs from the project processes in Chapters 4 through 6 and 9 through 12. Once received, all of this information will remain available as inputs to all three of the cost management processes.

The costs for schedule activities 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 or a contingency cost. A schedule activity cost estimate is a quantitative assessment of the likely costs of the resources required to complete the schedule activity.

If the performing organization does not have formally trained project cost estimators, then the project team will need to supply both the resources and the expertise to perform project cost estimating activities.

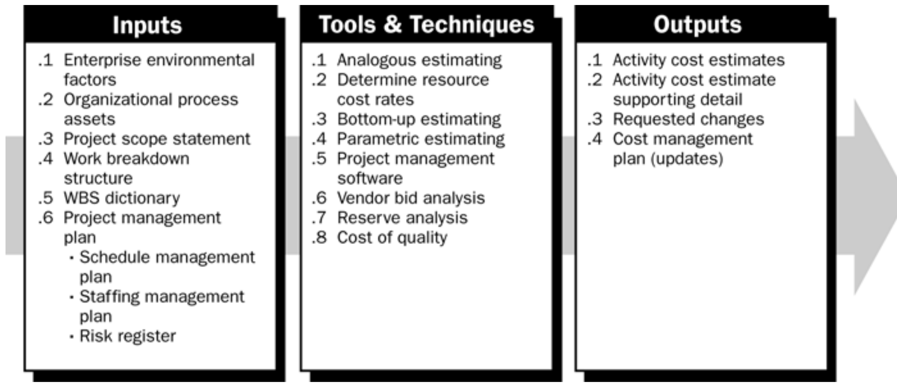


Figure 7-3. Cost Estimating: Inputs, Tools & Techniques, and Outputs

7.1.1 Cost Estimating: Inputs

.1 Enterprise Environmental Factors

The Cost Estimating process considers:

- **Marketplace conditions.** What products, services, and results are available in the marketplace, from whom, and under what terms and conditions (Section 4.1.1.3).
- **Commercial databases.** 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.

.2 Organizational Process Assets

Existing formal and informal cost estimating-related policies, procedures, and guidelines (Section 4.1.1) are considered in developing the cost management plan, selecting the cost estimating tools, and monitoring and reporting methods to be used.

- **Cost estimating policies.** Some organizations have predefined approaches to cost estimating. Where these exist, the project operates within the boundaries defined by these policies.
- **Cost estimating templates.** Some organizations have developed templates (or a pro forma standard) for use by the project team. The organization can continuously improve the template based on its application and usefulness in prior projects.
- **Historical information.** Information that pertains to the project's product or service, and is obtained from various sources within the organization, can influence the cost of the project.
- **Project files.** One or more of the organizations involved in the project will maintain records of previous project performance that are detailed enough to aid in developing cost estimates. In some application areas, individual team members may maintain such records.

- **Project team knowledge.** Members of the project team may recall previous actual costs or cost estimates. While such recollections can be useful, they are generally far less reliable than documented performance.
- **Lessons learned.** Lessons learned could include cost estimates obtained from previous projects that are similar in scope and size.

.3 Project Scope Statement

The project scope statement (Section 5.2.3.1) describes the business need, justification, requirements, and current boundaries for the project. It provides important information about project requirements that is considered during cost estimating. The project scope statement includes constraints, assumptions, and requirements. Constraints are specific factors that can limit cost estimating options. One of the most common constraints for many projects is a limited project budget. Other constraints can involve required delivery dates, available skilled resources, and organizational policies. Assumptions are factors that will be considered to be true, real, or certain. Requirements with contractual and legal implications can include health, safety, security, performance, environmental, insurance, intellectual property rights, equal employment opportunity, licenses, and permits – all of which are considered when developing the cost estimates.

The project scope statement also provides the list of deliverables, and acceptance criteria for the project and its products, services, and results. All factors are considered when developing the project cost estimate. The product scope description, within the project scope statement, provides product and service descriptions, and important information about any technical issues or concerns that are considered during cost estimating.

.4 Work Breakdown Structure

The project's work breakdown structure (WBS) (Section 5.3.3.2) provides the relationship among all the components of the project and the project deliverables (Section 4.4.3.1).

.5 WBS Dictionary

The WBS dictionary (Section 5.3.3.3) and related detailed statements of work provide an identification of the deliverables and a description of the work in each WBS component required to produce each deliverable.

.6 Project Management Plan

The project management plan (Section 4.3) provides the overall plan for executing, monitoring, and controlling the project, and includes subsidiary plans that provide guidance and direction for cost management planning and control. To the extent that other planning outputs are available, they are considered during cost estimating.

- **Schedule management plan.** The type and quantity of resources and the amount of time those resources are applied to complete the work of the project is a major part of determining the project cost. Schedule activity resources and their respective durations are used as key inputs to this process. Activity Resource Estimating (Section 6.3) involves determining the availability and quantities required of staff, equipment, and materiel needed to perform schedule activities. It is closely coordinated with cost estimating. Activity Duration Estimating (Section 6.4) 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 schedule activity. Schedule 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, materials with seasonal cost variations, or cost estimates with time-related costs, such as time-related field overhead costs during construction of a project.
- **Staffing management plan.** Project staffing attributes and personnel rates (Section 9.1.3.3) are necessary components for developing the schedule cost estimates.
- **Risk register.** The cost estimator considers information on risk responses (Section 11.2.3.1) when producing cost estimates. Risks, which can be either threats or opportunities, typically have an impact on both schedule activity and project costs. As a general rule, when the project experiences a negative risk event, the cost of the project will nearly always increase, and there will be a delay in the project schedule.

7.1.2 Cost Estimating: Tools and Techniques

.1 Analogous Estimating

Analogous cost estimating means using the actual cost of previous, similar projects as the basis for estimating the cost of the current project. Analogous cost estimating is frequently used to estimate costs when there is a limited amount of detailed information about the project (e.g., in the early phases). Analogous cost estimating uses expert judgment.

Analogous cost estimating is generally less costly than other techniques, but it is also generally less accurate. It is most reliable when previous projects are similar in fact, and not just in appearance, and the persons or groups preparing the estimates have the needed expertise.

.2 Determine Resource Cost Rates

The person determining the rates or the group preparing the estimates must know the unit cost rates, such as staff cost per hour and bulk material cost per cubic yard, for each resource to estimate schedule activity costs. Gathering quotes (Section 12.3) is one method of obtaining rates. For products, services, or results to be obtained under contract, standard rates with escalation factors can be included in the contract. Obtaining data from commercial databases and seller published price lists is another source of cost rates. If the actual rates are not known, then the rates themselves will have to be estimated.

.3 Bottom-up Estimating

This technique involves estimating the cost of individual work packages or individual schedule activities with the lowest level of detail. This detailed cost is then summarized or "rolled up" to higher levels for reporting and tracking purposes. The cost and accuracy of bottom-up cost estimating is typically motivated by the size and complexity of the individual schedule activity or work package. Generally, activities with smaller associated effort increase the accuracy of the schedule activity cost estimates.

.4 Parametric Estimating

Parametric estimating is a technique that uses a statistical relationship between historical data and other variables (e.g., square footage in construction, lines of code in software development, required labor hours) to calculate a cost estimate for a schedule activity resource. This technique can produce higher levels of accuracy depending upon the sophistication, as well as the underlying resource quantity and cost data built into the model. A cost-related example involves multiplying the planned quantity of work to be performed by the historical cost per unit to obtain the estimated cost.

.5 Project Management Software

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

.6 Vendor Bid Analysis

Other cost estimating methods include vendor bid analysis and an analysis of what the project should cost. In cases where projects are won under competitive processes, additional cost estimating work can be required of the project team to examine the price of individual deliverables, and derive a cost that supports the final total project cost.

.7 Reserve Analysis

Many cost estimators include reserves, also called contingency allowances, as costs in many schedule activity cost estimates. This has the inherent problem of potentially overstating the cost estimate for the schedule activity. Contingency reserves are estimated costs to be used at the discretion of the project manager to deal with anticipated, but not certain, events. These events are "known unknowns" and are part of the project scope and cost baselines.

One option to manage cost contingency reserves is to aggregate each schedule activity's cost contingency reserve for a group of related activities into a single contingency reserve that is assigned to a schedule activity. This schedule activity may be a zero duration activity that is placed across the network path for that group of schedule activities, and is used to hold the cost contingency reserve. An example of this solution to managing cost contingency reserves is to assign them at the work package level to a zero duration activity, which spans from the start to the end of the work package subnetwork. As the schedule activities progress, the contingency reserve, as measured by resource consumption of the non-zero duration schedule activities, can be adjusted. As a result, the activity cost variances for the related group of schedule activities are more accurate because they are based on cost estimates that are not pessimistic.

Alternatively, the schedule activity may be a buffer activity in the critical chain method, and is intentionally placed directly at the end of the network path for that group of schedule activities. As the schedule activities progress, the contingency reserve, as measured by resource consumption of the non-buffer schedule activities, can be adjusted. As a result, the activity cost variances for the related group of schedule activities are more accurate because they are based on cost estimates that are not pessimistic.

.8 Cost of Quality

Cost of quality (Section 8.1.2.4) can also be used to prepare the schedule activity cost estimate.

7.1.3 Cost Estimating: Outputs

.1 Activity Cost Estimates

An activity cost estimate is a quantitative assessment of the likely costs of the resources required to complete schedule activities. This type of estimate 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, labor, materials, equipment, services, facilities, information technology, and special categories such as an inflation allowance or cost contingency reserve.

.2 Activity Cost Estimate Supporting Detail

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

Supporting detail for the activity cost estimates should include:

- Description of the schedule activity's project scope of work
- Documentation of the basis for the estimate (i.e., how it was developed)
- Documentation of any assumptions made
- Documentation of any constraints
- Indication of the range of possible estimates (e.g., $10,000 (-10% / +15%) to indicate that the item is expected to cost between $9,000 and $11,500).

.3 Requested Changes

The Cost Estimating process may generate requested changes (Section 4.4.3.2) that may affect the cost management plan (Chapter 7 introductory material), activity resource requirements (Section 6.3.3.1), and other components of the project management plan. Requested changes are processed for review and disposition through the Integrated Change Control process (Section 4.6).

.4 Cost Management Plan (Updates)

If approved change requests (Section 4.4.1.4) result from the Cost Estimating process, then the cost management plan component of the project management plan (Chapter 7 introductory material) is updated if those approved changes impact the management of costs.

7.2 Cost Budgeting

Cost budgeting involves aggregating the estimated costs of individual schedule activities or work packages to establish a total cost baseline for measuring project performance. The project scope statement provides the summary budget. However, schedule activity or work package cost estimates are prepared prior to the detailed budget requests and work authorization.

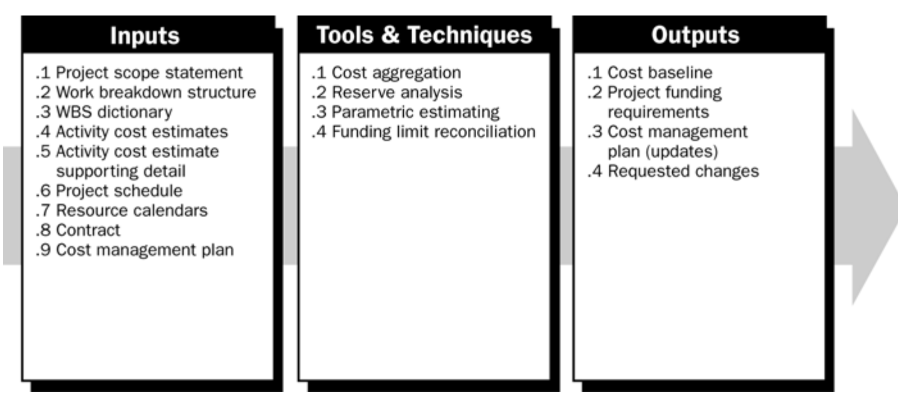


Figure 7-4. Cost Budgeting: Inputs, Tools & Techniques, and Outputs

7.2.1 Cost Budgeting: Inputs

.1 Project Scope Statement

Formal periodic limitations of the expenditure of project funds can be given in the project charter (Section 4.1.3.1) or contract. These funding constraints are reflected in the project scope statement, and can be due to annual funding authorizations by the buyer's organization or other entities like government agencies.

.2 Work Breakdown Structure

The project work breakdown structure (WBS) (Section 5.3.3.2) provides the relationship among all the components of the project and the project deliverables (Section 4.4.3.1).

.3 WBS Dictionary

The WBS dictionary (Section 5.3.3.3) and related detailed statements of work provide an identification of the deliverables and a description of the work in each WBS component required to produce each deliverable.

.4 Activity Cost Estimates

The cost estimates (Section 7.1.3.1) for each schedule activity within a work package are aggregated to obtain a cost estimate for each work package.

.5 Activity Cost Estimate Supporting Detail

Described in Section 7.1.3.2.

.6 Project Schedule

The project schedule (Section 6.5.3.1) includes planned start and finish dates for the project's schedule activities, schedule milestones, work packages, planning packages, and control accounts. This information is used to aggregate costs to the calendar periods when the costs are planned to be incurred.

.7 Resource Calendars

Described in Section 6.3.3.4.

.8 Contract

Contract (Section 12.4.3.2) information related to what products, services, or results have been purchased — and their costs — are used in developing the budget.

.9 Cost Management Plan

The cost management plan component of the project management plan and other subsidiary plans are considered during cost budgeting.

7.2.2 Cost Budgeting: Tools and Techniques

.1 Cost Aggregation

Schedule activity 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.

.2 Reserve Analysis

Reserve analysis (Section 11.6.2.5) establishes contingency reserves, such as the management contingency reserve, that are allowances for unplanned, but potentially required, changes. Such changes may result from risks identified in the risk register

Management contingency reserves are budgets reserved for unplanned, but potentially required, changes to project scope and cost. These are "unknown unknowns," and the project manager must obtain approval before obligating or spending this reserve. Management contingency reserves are not a part of the project cost baseline, but are included in the budget for the project. They are not distributed as budget and, therefore, are not a part of the earned value calculations.

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.3 Parametric Estimating

The parametric estimating technique involves using project characteristics (parameters) in a mathematical model to predict total project costs. Models can be simple (e.g., residential home construction will cost a certain amount per square foot of living space) or complex (e.g., one model of software development costs uses thirteen separate adjustment factors, each of which has five to seven points within it).

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

- The historical information used to develop the model is accurate
- The parameters used in the model are readily quantifiable
- The model is scalable, such that it works for a large project as well as a small one.

.4 Funding Limit Reconciliation

Large variations in the periodic expenditure of funds are usually undesirable for organizational operations. Therefore, the expenditure of funds is reconciled with the funding limits set by the customer or performing organization on the disbursement of funds for the project. Reconciliation will necessitate the scheduling of work to be adjusted to smooth or regulate those expenditures, which is accomplished by placing imposed date constraints for some work packages, schedule milestones, or WBS components into the project schedule. Rescheduling can impact the allocation of resources. If funds were used as a limiting resource in the Schedule Development process, then the process is repeated using the new imposed date constraints. The final product of these planning iterations is a cost baseline.

7.2.3 Cost Budgeting: Outputs

.1 Cost Baseline

The cost baseline is a time-phased budget that is used as a basis against which to measure, monitor, and control overall cost performance on the project. It is developed by summing estimated costs by period and is usually displayed in the form of an S-curve, as illustrated in Figure 7-5. The cost baseline is a component of the project management plan.

Many projects, especially large ones, have multiple cost or resource baselines, and consumables production baselines (e.g., cubic yards of concrete per day) to measure different aspects of project performance. For example, management may require that the project manager track internal costs (labor) separately from external costs (contractors and construction materials) or total labor hours.

.2 Project Funding Requirements

Funding requirements, total and periodic (e.g., annual or quarterly), are derived from the cost baseline and can be established to exceed, usually by a margin, to allow for either early progress or cost overruns. Funding usually occurs in incremental amounts that are not continuous, and, therefore, appears as a step function in Figure 7-5. The total funds required are those included in the cost baseline plus the management contingency reserve amount. Some portion of the management contingency reserve can be included incrementally in each funding step or funded when needed, depending on organizational policies.

Although Figure 7-5 shows the management reserve amount at the end of the project, in reality, the cost baseline and cash flow lines would increase when a portion of the management reserve is authorized and when it is spent. Any gap at the end of a project between the funds allocated and the cost baseline and cash flow amounts shows the amount of the management reserve that was not used.

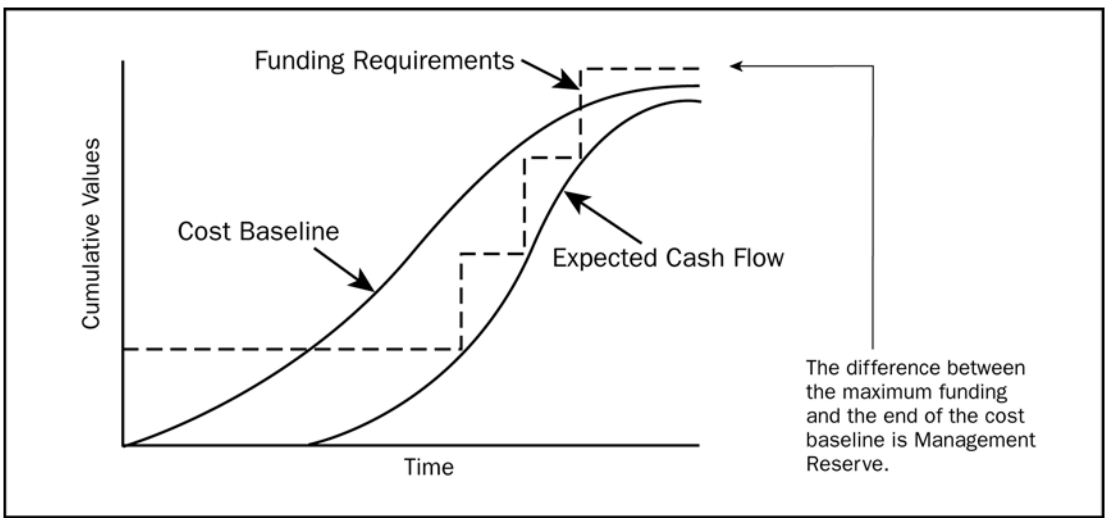

Figure 7-5. Cash Flow, Cost Baseline and Funding Display

.3 Cost Management Plan (Updates)

If approved change requests (Section 4.4.1.4) result from the Cost Budgeting process, then the cost management plan component of the project management plan is updated if those approved changes impact the management of costs.

.4 Requested Changes

The Cost Budgeting process can generate requested changes (Section 4.4.3.2) that affect the cost management plan or other components of the project management plan. Requested changes are processed for review and disposition through the Integrated Change Control process (Section 4.6).

7.3 Cost Control

Project cost control includes:

- Influencing the factors that create changes to the cost baseline
- Ensuring requested changes are agreed upon
- Managing the actual changes when and as they occur
- Assuring that potential cost overruns do not exceed the authorized funding periodically and in total for the project
- Monitoring cost performance to detect and understand variances from the cost baseline
- Recording all appropriate changes accurately against the cost baseline
- Preventing incorrect, inappropriate, or unapproved changes from being included in the reported cost or resource usage
- Informing appropriate stakeholders of approved changes
- Acting to bring expected cost overruns within acceptable limits.

Project cost control searches out the causes of positive and negative variances and is part of Integrated Change Control (Section 4.6). For example, inappropriate responses to cost variances can cause quality or schedule problems or produce an unacceptable level of risk later in the project.

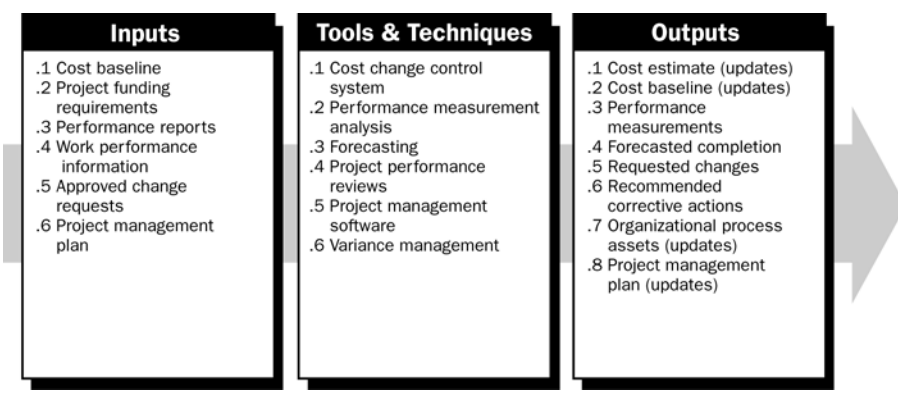

Figure 7-6. Cost Control: Inputs, Tools & Techniques, and Outputs

7.3.1 Cost Control: Inputs

.1 Cost Baseline
Described in Section 7.2.3.1.

.2 Project Funding Requirements
Described in Section 7.2.3.2.

.3 Performance Reports
Performance reports (Section 10.3.3.1) provide information on cost and resource performance as a result of actual work progress.

.4 Work Performance Information
Work performance information (Section 4.4.3.7) pertaining to the status and cost of project activities being performed is collected. This information includes, but is not limited to:

- Deliverables that have been completed and those not yet completed
- Costs authorized and incurred
- Estimates to complete the schedule activities
- Percent physically complete of the schedule activities.

.5 Approved Change Requests
Approved change requests (Section 4.4.1.4) from the Integrated Change Control process (Section 4.6) can include modifications to the cost terms of the contract, project scope, cost baseline, or cost management plan.

.6 Project Management Plan
The project management plan and its cost management plan component and other subsidiary plans are considered when performing the Cost Control process.

7.3.2 Cost Control: Tools and Techniques

.1 Cost Change Control System
A cost change control system, documented in the cost management plan, defines the procedures by which the cost baseline can be changed. It includes the forms, documentation, tracking systems, and approval levels necessary for authorizing changes. The cost change control system is integrated with the integrated change control process (Section 4.6).

.2 Performance Measurement Analysis
Performance measurement techniques help to assess the magnitude of any variances that will invariably occur. The earned value technique (EVT) compares the cumulative value of the budgeted cost of work performed (earned) at the original allocated budget amount to both the budgeted cost of work scheduled (planned) and to the actual cost of work performed (actual). This technique is especially useful for cost control, resource management, and production.

An important part of cost control is to determine the cause of a variance, the magnitude of the variance, and to decide if the variance requires corrective action. The earned value technique uses the cost baseline (Section 7.2.3.1) contained in the project management plan (Section 4.3) to assess project progress and the magnitude of any variations that occur.

The earned value technique involves developing these key values for each schedule activity, work package, or control account:

- **Planned value (PV).** PV is the budgeted cost for the work scheduled to be completed on an activity or WBS component up to a given point in time.
- **Earned value (EV).** EV is the budgeted amount for the work actually completed on the schedule activity or WBS component during a given time period.
- **Actual cost (AC).** AC is the total cost incurred in accomplishing work on the schedule activity or WBS component during a given time period. This AC must correspond in definition and coverage to whatever was budgeted for the PV and the EV (e.g., direct hours only, direct costs only, or all costs including indirect costs).
- **Estimate to complete (ETC) and estimate at completion (EAC).** See ETC and EAC development, described in the following technique on forecasting.

The PV, EV, and AC values are used in combination to provide performance measures of whether or not work is being accomplished as planned at any given point in time. The most commonly used measures are cost variance (CV) and schedule variance (SV). The amount of variance of the CV and SV values tend to decrease as the project reaches completion due to the compensating effect of more work being accomplished. Predetermined acceptable variance values that will decrease over time as the project progresses towards completion can be established in the cost management plan.

- **Cost variance (CV).** CV equals earned value (EV) minus 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. Formula: CV= EV – AC
- **Schedule variance (SV).** SV equals earned value (EV) minus planned value (PV). Schedule variance will ultimately equal zero when the project is completed because all of the planned values will have been earned. Formula: SV = EV – PV

These two values, the CV and SV, can be converted to efficiency indicators to reflect the cost and schedule performance of any project.

- **Cost performance index (CPI).** A CPI value less than 1.0 indicates a cost overrun of the estimates. A CPI value greater than 1.0 indicates a cost underrun of the estimates. CPI equals the ratio of the EV to the AC. The CPI is the most commonly used cost-efficiency indicator. Formula: CPI = EV/AC

- **Cumulative CPI (CPI^C).** The cumulative CPI is widely used to forecast project costs at completion**.** CPI^C equals the sum of the periodic earned values (EV^C) divided by the sum of the individual actual costs (AC^C). Formula: $CPI^C = EV^C/AC^C$
- **Schedule performance index (SPI).** The SPI is used, in addition to the schedule status (Section 6.6.2.1), to predict the completion date and is sometimes used in conjunction with the CPI to forecast the project completion estimates. SPI equals the ratio of the EV to the PV. Formula: SPI = EV/PV

Figure 7-7 uses S-curves to display cumulative EV data for a project that is over budget and behind the work plan.

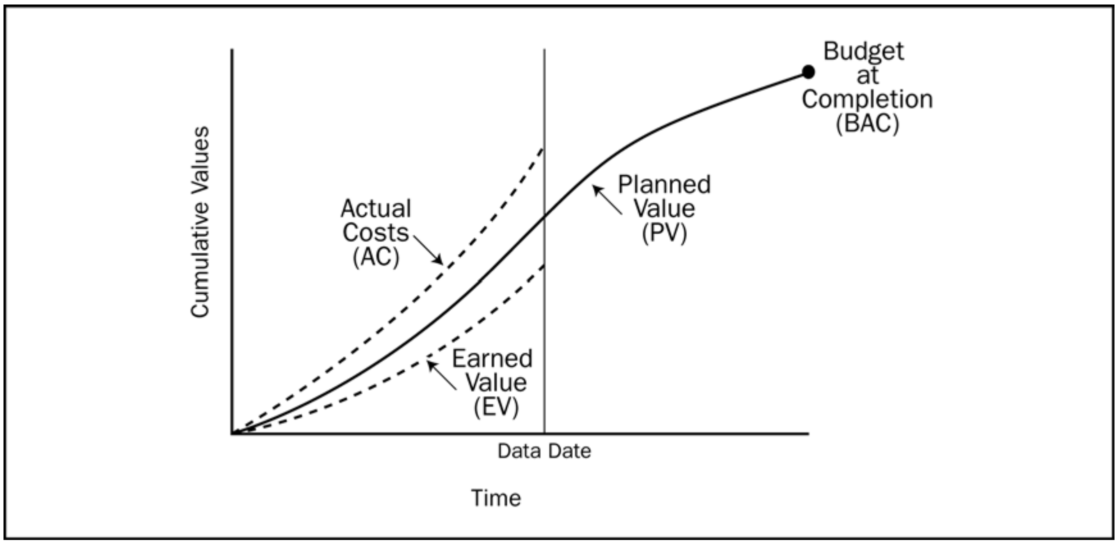

Figure 7-7. Illustrative Graphic Performance Report

The earned value technique in its various forms is a commonly used method of performance measurement. It integrates project scope, cost (or resource) and schedule measures to help the project management team assess project performance.

.3 Forecasting

Forecasting includes making estimates or predictions of conditions in the project's future based on information and knowledge available at the time of the forecast. Forecasts are generated, updated, and reissued based on work performance information (Section 4.4.3.7) provided as the project is executed and progressed. The work performance information is about the project's past performance and any information that could impact the project in the future, for example, estimate at completion and estimate to complete.

The earned value technique parameters of BAC, actual cost (AC^C) to date, and the cumulative CPIC efficiency indicator are used to calculate ETC and EAC, where the BAC is equal to the total PV at completion for a schedule activity, work package, control account, or other WBS component. Formula: BAC = total cumulative PV at completion

Forecasting techniques help to assess the cost or the amount of work to complete schedule activities, which is called the EAC. Forecasting techniques also help to determine the ETC, which is the estimate for completing the remaining work for a schedule activity, work package, or control account. While the earned value technique of determining EAC and ETC is quick and automatic, it is not as valuable or accurate as a manual forecasting of the remaining work to be done by the project team. The ETC forecasting technique based upon the performing organization providing the estimate to complete is:

- **ETC based on new estimate.** ETC equals the revised estimate for the work remaining, as determined by the performing organization. This more accurate and comprehensive completion estimate is an independent, non-calculated estimate to complete for all the work remaining, and considers the performance or production of the resource(s) to date.

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Alternatively, to calculate ETC using earned value data, one of two formulas is typically used:

- **ETC based on atypical variances.** This approach is most often used when current variances are seen as atypical and the project management team expectations are that similar variances will not occur in the future. ETC equals the BAC minus the cumulative earned value to date (EV^C). Formula: $ETC = (BAC - EV^C)$
- **ETC based on typical variances.** This approach is most often used when current variances are seen as typical of future variances. ETC equals the BAC minus the cumulative EV^C (the remaining PV) divided by the cumulative cost performance index (CPI^C). Formula: $ETC = (BAC - EV^C) / CPI^C$

An EAC is a forecast of the most likely total value based on project performance (Section 4.4) and risk quantification (Section 11.4). EAC is the projected or anticipated total final value for a schedule activity, WBS component, or project when the defined work of the project is completed. One EAC forecasting technique is based upon the performing organization providing an estimate at completion:

- **EAC using a new estimate.** EAC equals the actual costs to date (AC^C) plus a new ETC that is provided by the performing organization. This approach is most often used when past performance shows that the original estimating assumptions were fundamentally flawed or that they are no longer relevant due to a change in conditions. Formula: $EAC = AC^C + ETC$

The two most common forecasting techniques for calculating EAC using earned value data are some variation of:

- **EAC using remaining budget.** EAC equals AC^C plus the budget required to complete the remaining work, which is the budget at completion (BAC) minus the earned value (EV). This approach is most often used when current variances are seen as atypical and the project management team expectations are that similar variances will not occur in the future. Formula: $EAC = AC^C + BAC - EV$
- **EAC using CPI^C.** EAC equals actual costs to date (AC^C) plus the budget required to complete the remaining project work, which is the BAC minus the EV, modified by a performance factor (often the CPI^C). This approach is most often used when current variances are seen as typical of future variances. Formula: $EAC = AC^C + ((BAC - EV) / CPI^C)$

Each of these approaches can be the correct approach for any given project and will provide the project management team with a signal if the EAC forecasts are not within acceptable tolerances.

.4 Project Performance Reviews

Performance reviews compare cost performance over time, schedule activities or work packages overrunning and underrunning budget (planned value), milestones due, and milestones met.

Performance reviews are meetings held to assess schedule activity, work package, or cost account status and progress, and are typically used in conjunction with one or more of the following performance-reporting techniques:

- **Variance analysis.** Variance analysis involves comparing actual project performance to planned or expected performance. Cost and schedule variances are the most frequently analyzed, but variances from plan in the areas of project scope, resource, quality, and risk are often of equal or greater importance.
- **Trend analysis.** Trend analysis involves examining project performance over time to determine if performance is improving or deteriorating.
- **Earned value technique.** The earned value technique compares planned performance to actual performance.

.5 Project Management Software

Project management software, such as computerized spreadsheets, is often used to monitor PV versus AC, and to forecast the effects of changes or variances.

.6 Variance Management

The cost management plan (Section 7.1.3.4) describes how cost variances will be managed, for example, having different responses to major or minor problems. The amount of variance tends to decrease as more work is accomplished. The larger variances allowed at the start of the project can be decreased as the project nears completion.

7.3.3 Cost Control: Outputs

.1 Cost Estimates (Updates)

Revised schedule activity cost estimates are modifications to the cost information used to manage the project. Appropriate stakeholders are notified as needed. Revised cost estimates may require adjustments to other aspects of the project management plan.

.2 Cost Baseline (Updates)

Budget updates are changes to an approved cost baseline. These values are generally revised only in response to approved changes in project scope. However, in some cases, cost variances can be so severe that a revised cost baseline is needed to provide a realistic basis for performance measurement.

.3 Performance Measurements

The calculated CV, SV, CPI, and SPI values for WBS components, in particular the work packages and control accounts, are documented and communicated (Section 10.3.3.1) to stakeholders.

.4 Forecasted Completion

Either a calculated EAC value or a performing organization-reported EAC value is documented and the value communicated (Section 10.3.3.1) to stakeholders. Either a calculated ETC value or a reported ETC value provided by the performing organization is documented and the value communicated to stakeholders.

.5 Requested Changes

Analysis of project performance can generate a request for a change to some aspect of the project. Identified changes can require increasing or decreasing the budget. Requested changes (Section 4.4.3.2) are processed for review and disposition through the Integrated Change Control process (Section 4.6).

.6 Recommended Corrective Actions

A corrective action is anything done to bring expected future performance of the project in line with the project management plan. Corrective action in the area of cost management often involves adjusting schedule activity budgets, such as special actions taken to balance cost variances.

.7 Organizational Process Assets (Updates)

Lessons learned are documented so they can become part of the historical databases for both the project and the performing organization. Lessons learned documentation includes the root causes of variances, the reasoning behind the corrective action chosen, and other types of lessons learned from cost, resource, or resource production control.

.8 Project Management Plan (Updates)

Schedule activity, work package, or planning package cost estimates (Chapter 7 introductory material), as well as the cost baseline (Section 7.2.3.1), cost management plan, and project budget documents are components of the project management plan. All approved change requests (Section 4.4.1.4) affecting those documents are incorporated as updates to those documents.

CHAPTER 8

Project Quality Management

Project Quality Management processes include all the 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. It implements the quality management system through the policy, procedures, and processes of quality planning, quality assurance, and quality control, with continuous process improvement activities conducted throughout, as appropriate. Figure 8-1 provides an overview of the Project Quality Management processes, and Figure 8-2 provides a process flow diagram of those processes and their inputs, outputs, and other related Knowledge Area processes. The Project Quality Management processes include the following:

8.1 Quality Planning – identifying which quality standards are relevant to the project and determining how to satisfy them.

8.2 Perform Quality Assurance – applying the planned, systematic quality activities to ensure that the project employs all processes needed to meet requirements.

8.3 Perform Quality Control – monitoring specific project results to determine whether they comply with relevant quality standards and identifying ways to eliminate causes of unsatisfactory performance.

These processes interact with each other and with the processes in the other Knowledge Areas as well. Each process can involve effort from one or more persons or groups of persons based on the needs of the project. Each process occurs at least once in every project and occurs in one or more project phases, if the project is divided into phases. Although the processes are presented here as discrete elements with well-defined interfaces, in practice they may overlap and interact in ways not detailed here. Process interactions are discussed in detail in Chapter 3.

The basic approach to quality management described in this section is intended to be compatible with that of the International Organization for Standardization (ISO). This generalized approach should also be compatible with proprietary approaches to quality management such as those recommended by Deming, Juran, Crosby and others, and non-proprietary approaches such as Total Quality Management (TQM), Six Sigma, Failure Mode and Effect Analysis, Design Reviews, Voice of the Customer, Cost of Quality (COQ), and Continuous Improvement.

Project Quality Management must address the management of the project and the product of the project. While Project Quality Management applies to all projects, regardless of the nature of their product, product quality measures and techniques are specific to the particular type of product produced by the project. For example, quality management of software products entails different approaches and measures than nuclear power plants, while Project Quality Management approaches apply to both. In either case, failure to meet quality requirements in either dimension can have serious negative consequences for any or all of the project stakeholders. For example:

- Meeting customer requirements by overworking the project team may produce negative consequences in the form of increased employee attrition, unfounded errors, or rework
- Meeting project schedule objectives by rushing planned quality inspections may produce negative consequences when errors go undetected.

Quality is "the degree to which a set of inherent characteristics fulfill requirements"[6]. Stated and implied needs are the inputs to developing project requirements. A critical element of quality management in the project context is to turn stakeholder needs, wants, and expectations into requirements through Stakeholder Analysis (Section 5.2.2.4), performed during Project Scope Management.

Quality and grade are not the same. Grade is a category assigned to products or services having the same functional use but different technical characteristics[7]. Low quality is always a problem; low grade may not be. For example, a software product can be of high quality (no obvious defects, readable manual) and low grade (a limited number of features), or of low quality (many defects, poorly organized user documentation) and high grade (numerous features). The project manager and the project management team are responsible for determining and delivering the required levels of both quality and grade.

Precision and accuracy are not equivalent. Precision is consistency that the value of repeated measurements are clustered and have little scatter. Accuracy is correctness that the measured value is very close to the true value. Precise measurements are not necessarily accurate. A very accurate measurement is not necessarily precise. The project management team must determine how much accuracy or precision or both are required.

Modern quality management complements project management. For example, both disciplines recognize the importance of:

- **Customer satisfaction.** Understanding, evaluating, defining,and managing expectations so that customer requirements are met. This requires a combination of conformance to requirements (the project must produce what it said it would produce) and fitness for use (the product or service must satisfy real needs).
- **Prevention over inspection.** The cost of preventing mistakes is generally much less than the cost of correcting them, as revealed by inspection.
- **Management responsibility.** Success requires the participation of all members of the team, but it remains the responsibility of management to provide the resources needed to succeed.
- **Continuous improvement.** The plan-do-check-act cycle is the basis for quality improvement (as defined by Shewhart and modified by Deming, in the ASQ Handbook, pages 13–14, American Society for Quality, 1999). In addition, quality improvement initiatives undertaken by the performing organization, such as TQM and Six Sigma, can improve the quality of the project's management as well as the quality of the project's product. Process improvement models include Malcolm Baldrige, CMM®, and CMMI℠.

The cost of quality refers to the total cost of all efforts related to quality. Project decisions can impact operational costs of quality as a result of product returns, warranty claims, and recall campaigns. However, the temporary nature of the project means that investments in product quality improvement, especially defect prevention and appraisal, can often be borne by the acquiring organization, rather than the project, since the project may not last long enough to reap the rewards.

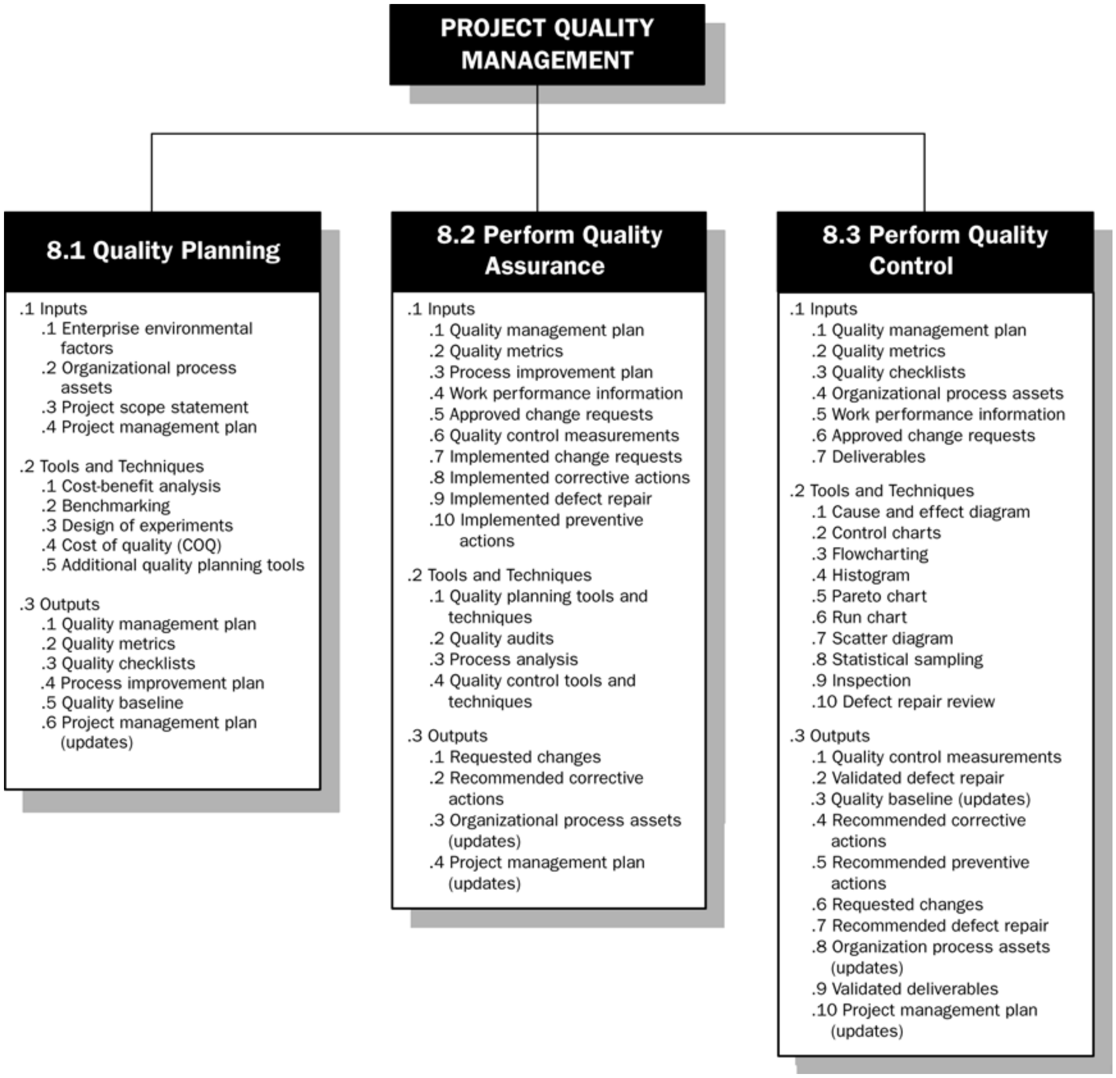
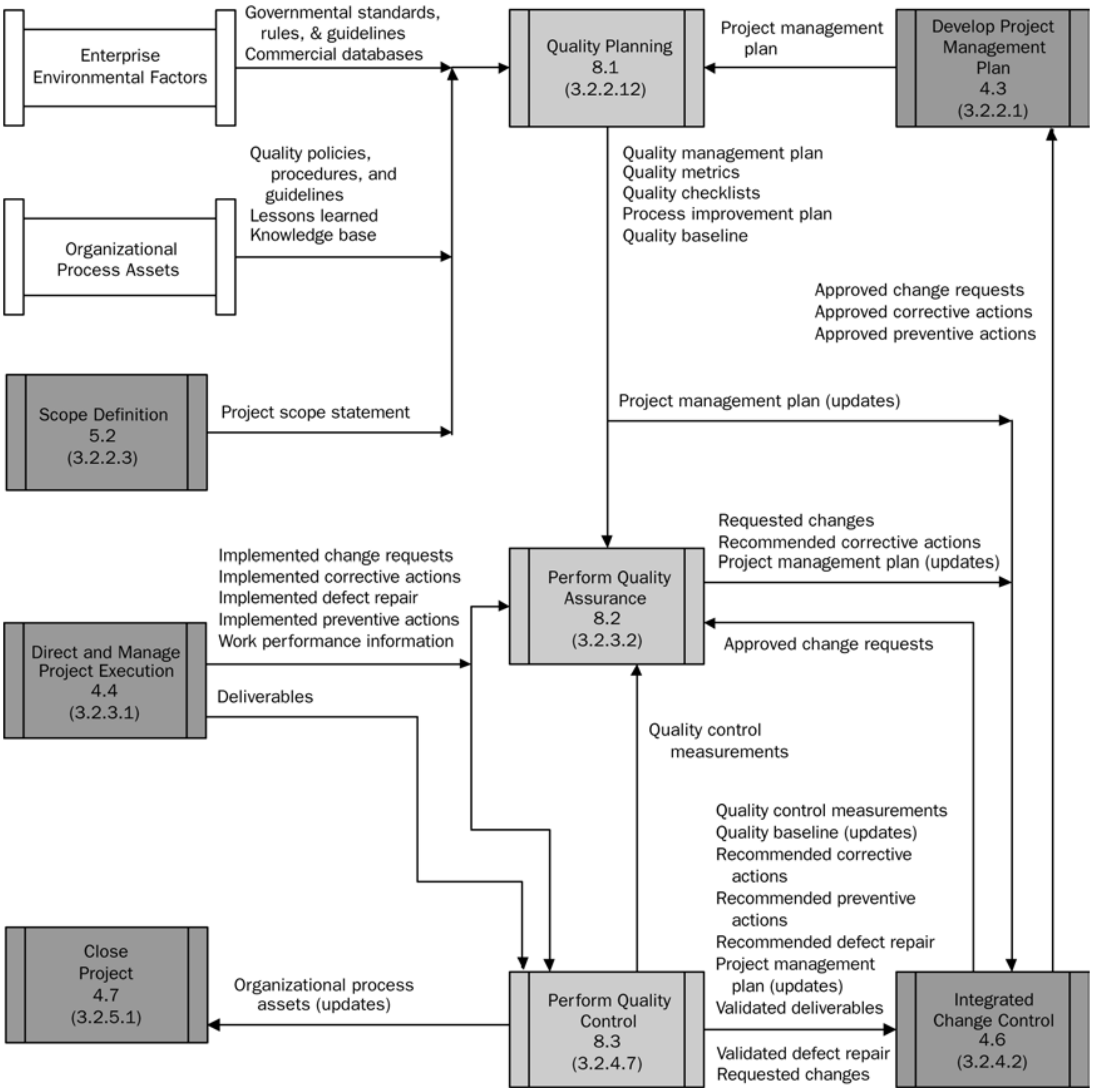


Figure 8-1. Project Quality Management Overview



Note: Not all process interactions and data flow among the processes are shown.

Figure 8-2. Project Quality Management Process Flow Diagram

8.1 Quality Planning

Quality planning involves identifying which quality standards are relevant to the project and determining how to satisfy them. It is one of the key processes when doing the Planning Process Group (Section 3.3) and during development of the project management plan (Sections 4.3), and should be performed in parallel with the other project planning processes. For example, the required changes in the product to meet identified quality standards may require cost or schedule adjustments, or the desired product quality may require a detailed risk analysis of an identified problem.

The quality planning techniques discussed here are those techniques most frequently used on projects. There are many others that may be useful on certain projects or in some application areas. One of the fundamental tenets of modern quality management is: quality is planned, designed, and built in—not inspected in.

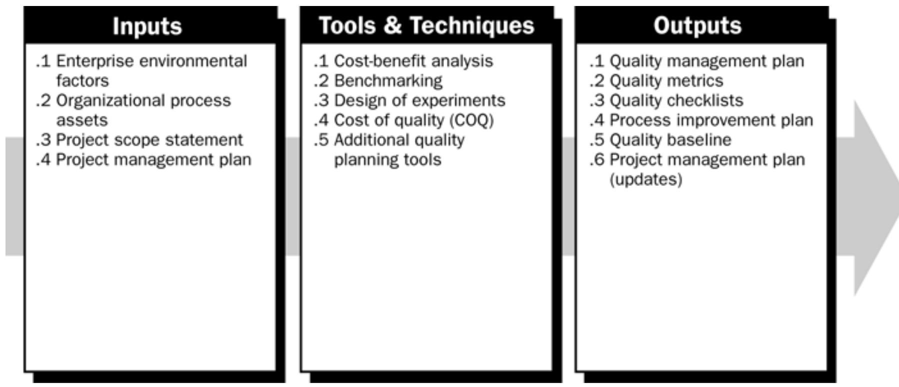


Figure 8-3. Quality Planning: Inputs, Tools & Techniques, and Outputs

8.1.1 Quality Planning: Inputs

.1 Enterprise Environmental Factors

Governmental agency regulations, rules, standards, and guidelines specific to the application area may affect the project (Section 4.1.1.3).

.2 Organizational Process Assets

Organizational quality policies, procedures and guidelines, historical databases and lessons learned from previous projects specific to the application area may affect the project (Section 4.1.1.4).

The quality policy, as endorsed by senior management, is the intended direction of a performing organization with regard to quality. The quality policy of the performing organization for their products often can be adopted "as is" for use by the project. However, if the performing organization lacks a formal quality policy, or if the project involves multiple performing organizations (as with a joint venture), then the project management team will need to develop a quality policy for the project.

Regardless of the origin of the quality policy, the project management team is responsible for ensuring that the project stakeholders are fully aware of the policy through the appropriate distribution of information (Section 10.2.3.1).

.3 Project Scope Statement

The project scope statement (Section 5.2.3.1) is a key input to quality planning since it documents major project deliverables, the project objectives that serve to define requirements (which were derived from stakeholder needs, wants, and expectations), thresholds, and acceptance criteria.

Thresholds, which are defined as cost, time, or resource values used as parameters, can be part of the project scope statement. If these threshold values are exceeded, it will require action from the project management team.

Acceptance criteria include performance requirements and essential conditions that must be achieved before project deliverables are accepted. The definition of acceptance criteria can significantly increase or decrease project quality costs. The result of the deliverables satisfying all acceptance criteria implies that the needs of the customer have been met. Formal acceptance (Section 5.4.3.1) validates that the acceptance criteria have been satisfied. The product scope description, embodied in the project scope statement (Section 5.2.3.1), will often contain details of technical issues and other concerns that can affect quality planning.

.4 Project Management Plan
Described in Section 4.3.

8

8.1.2 Quality Planning: Tools and Techniques

.1 Cost-Benefit Analysis
Quality planning must consider cost-benefits tradeoffs. The primary benefit of meeting quality requirements is less rework, which means higher productivity, lower costs, and increased stakeholder satisfaction. The primary cost of meeting quality requirements is the expense associated with Project Quality Management activities.

.2 Benchmarking
Benchmarking involves comparing actual or planned project practices to those of other projects to generate ideas for improvement and to provide a basis by which to measure performance. These other projects can be within the performing organization or outside of it, and can be within the same or in another application area.

.3 Design of Experiments
Design of experiments (DOE) is a statistical method that helps identify which factors may influence specific variables of a product or process under development or in production. It also plays a role in the optimization of products or processes. An example is where an organization can use DOE to reduce the sensitivity of product performance to sources of variations caused by environmental or manufacturing differences. The most important aspect of this technique is that it provides a statistical framework for systematically changing all of the important factors, instead of changing the factors one at a time. The analysis of the experimental data should provide the optimal conditions for the product or process, highlighting the factors that influence the results, and revealing the presence of interactions and synergisms 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.

.4 Cost of Quality (COQ)

Quality costs are the total costs incurred 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 and external. Failure costs are also called cost of poor quality.

.5 Additional Quality Planning Tools

Other quality planning tools are also often used to help better define the situation and help plan effective quality management activities. These include brainstorming, affinity diagrams, force field analysis, nominal group techniques, matrix diagrams, flowcharts, and prioritization matrices.

8.1.3 Quality Planning: Outputs

.1 Quality Management Plan

The quality management plan describes how the project management team will implement the performing organization's quality policy. The quality management plan is a component or a subsidiary plan of the project management plan (Section 4.3).

The quality management plan provides input to the overall project management plan and must address quality control (QC), quality assurance (QA), and continuous process improvement for the project.

The quality management plan may be formal or informal, highly detailed or broadly framed, based on the requirements of the project. The quality management plan should include efforts at the front end of a project to ensure that the earlier decisions, for example on concepts, designs and tests, are correct. These efforts should be performed through an independent peer review and not include individuals that worked on the material being reviewed. The benefits of this review can include reduction of cost and schedule overruns caused by rework.

.2 Quality Metrics

A metric is an operational definition that describes, in very specific terms, what something is and how the quality control process measures it. A measurement is an actual value. For example, it is not enough to say that meeting the planned schedule dates is a measure of management quality. The project management team must also indicate whether every activity must start on time or only finish on time and whether individual activities will be measured, or only certain deliverables and if so, which ones. Quality metrics are used in the QA and QC processes. Some examples of quality metrics include defect density, failure rate, availability, reliability, and test coverage.

.3 Quality Checklists

A checklist is a structured tool, usually component-specific, used to verify that a set of required steps has been performed. Checklists may be simple or complex. They are usually phrased as imperatives ("Do this!") or interrogatories ("Have you done this?"). 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 are used in the quality control process.

.4 Process Improvement Plan

The process improvement plan is a subsidiary of the project management plan (Section 4.3). The process improvement plan details the steps for analyzing processes that will facilitate the identification of waste and non-value added activity, thus increasing customer value, such as:

- **Process boundaries.** Describes the purpose, start, and end of processes, their inputs and outputs, data required, if any, and the owner and stakeholders of processes.
- **Process configuration.** A flowchart of processes to facilitate analysis with interfaces identified.
- **Process metrics.** Maintain control over status of processes.
- **Targets for improved performance.** Guides the process improvement activities.

8

.5 Quality Baseline

The quality baseline records the quality objectives of the project. The quality baseline is the basis for measuring and reporting quality performance as part of the performance measurement baseline.

.6 Project Management Plan (Updates)

The project management plan will be updated through the inclusion of a subsidiary quality management plan and process improvement plan (Section 4.3). Requested changes (additions, modifications, deletions) to the project management plan and its subsidiary plans are processed by review and disposition through the Integrated Change Control process (Section 4.6).

8.2 Perform Quality Assurance

Quality assurance (QA) is the application of planned, systematic quality activities to ensure that the project will employ all processes needed to meet requirements.

A quality assurance department, or similar organization, often oversees quality assurance activities. QA 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. QA also provides an umbrella for another important quality activity, continuous process improvement. Continuous process improvement provides an iterative means for improving the quality of all processes.

Continuous process improvement reduces waste and non-value-added activities, which allows processes to operate at increased levels of efficiency and effectiveness. Process improvement is distinguished by its identification and review of organizational business processes. It may be applied to other processes within an organization as well, from micro processes, such as the coding of modules within a software program, to macro processes, such as the opening of new markets.

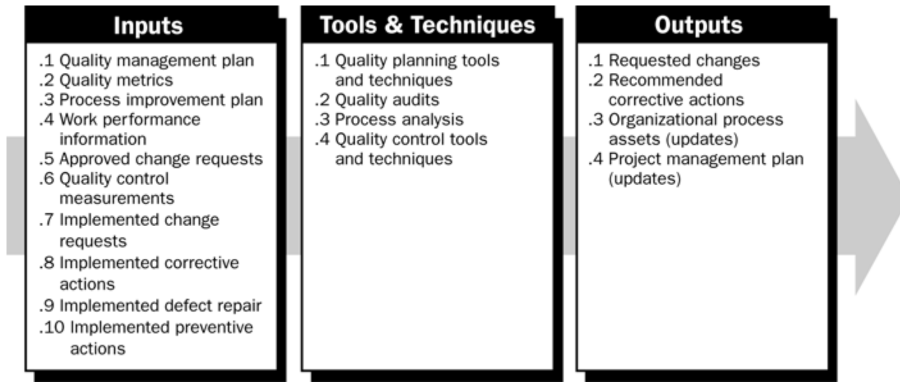


Figure 8-4. Perform Quality Assurance: Inputs, Tools & Techniques, and Outputs

8.2.1 Perform Quality Assurance: Inputs

.1 Quality Management Plan

The quality management plan describes how QA will be performed within the project (Section 8.1.3.1).

.2 Quality Metrics

Described in Section 8.1.3.2.

.3 Process Improvement Plan

Described in Section 8.1.3.4.

.4 Work Performance Information

Work performance information (Section 4.4.3.7), including technical performance measures, project deliverables status, required corrective actions, and performance reports (Section 10.3.3.1) are important inputs to QA and can be used in areas such as audits, quality reviews, and process analyses.

.5 Approved Change Requests

Approved change requests (Section 4.4.1.4) can include modifications to work methods, product requirements, quality requirements, scope, and schedule. Approved changes need to be analyzed for any effects upon the quality management plan, quality metrics, or quality checklists. Approved changes are important inputs to QA and can be used in areas such as audits, quality reviews, and process analyses. All changes should be formally documented in writing and any verbally discussed, but undocumented, changes should not be processed or implemented.

.6 Quality Control Measurements
Quality control measurements (Section 8.3.3.1) are the results of quality control activities that are fed back to the QA process for use in re-evaluating and analyzing the quality standards and processes of the performing organization.

.7 Implemented Change Requests
Described in Section 4.4.3.3.

.8 Implemented Corrective Actions
Described in Section 4.4.3.4.

.9 Implemented Defect Repair
Described in Section 4.4.3.6.

.10 Implemented Preventive Actions
Described in Section 4.4.3.5.

8.2.2 Perform Quality Assurance: Tools and Techniques

8

.1 Quality Planning Tools and Techniques
The quality planning tools and techniques (Section 8.1.2) also can be used for QA activities.

.2 Quality Audits
A quality audit is a structured, independent review to determine whether project activities comply with organizational and project policies, processes, and procedures. The objective of a quality audit is to identify inefficient and ineffective policies, processes, and procedures in use on the project. The subsequent effort to correct these deficiencies should result in a reduced cost of quality and an increase in the percentage of acceptance of the product or service by the customer or sponsor within the performing organization. Quality audits may be scheduled or at random, and may be carried out by properly trained in-house auditors or by third parties, external to the performing organization.

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

.3 Process Analysis
Process analysis follows the steps outlined in the process improvement plan to identify needed improvements from an organizational and technical standpoint. 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 to analyze a problem/situation, determine the underlying causes that lead to it, and create preventive actions for similar problems.

.4 Quality Control Tools and Techniques
Described in Section 8.3.2.

8.2.3 Perform Quality Assurance: Outputs

.1 Requested Changes

Quality improvement includes taking action to increase the effectiveness and efficiency of the policies, processes, and procedures of the performing organization, which should provide added benefits to the stakeholders of all projects (Section 4.4.3.2).

.2 Recommended Corrective Actions

Quality improvement includes recommending actions to increase the effectiveness and efficiency of the performing organization. Corrective action is an action that is recommended immediately as a result of quality assurance activities, such as audits and process analyses.

.3 Organizational Process Assets (Updates)

Updated quality standards provide validation of the effectiveness and efficiency of the performing organization's quality standards and processes to meet requirements. These quality standards are used during the Perform Quality Control process (Section 8.3).

.4 Project Management Plan (Updates)

The project management plan (Section 4.3) will be updated from changes to the quality management plan that result from changes to the Perform Quality Assurance process. These updates can include incorporation of processes that have been through continuous process improvement and are ready to repeat the cycle, and improvements to processes that have been identified and measured, and are ready to be implemented. Requested changes (additions, modifications, deletions) to the project management plan and its subsidiary plans are processed by review and disposition through the Integrated Change Control process (Section 4.6).

8.3 Perform Quality Control

Performing quality control (QC) involves monitoring specific project results to determine whether they comply with relevant quality standards and identifying ways to eliminate causes of unsatisfactory results. It should be performed throughout the project. Quality standards include project processes and product goals. Project results include deliverables and project management results, such as cost and schedule performance. QC is often performed by a quality control department or similarly titled organizational unit. QC can include taking action to eliminate causes of unsatisfactory project performance.

The project management team should have a working knowledge of statistical quality control, especially sampling and probability, to help evaluate QC 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 conforms, or it does not) and variables sampling (the result is rated on a continuous scale that measures the degree of conformity).
- Special causes (unusual events) and common causes (normal process variation). Common causes are also called random causes.
- Tolerances (the result is acceptable if it falls within the range specified by the tolerance) and control limits (the process is in control if the result falls within the control limits).

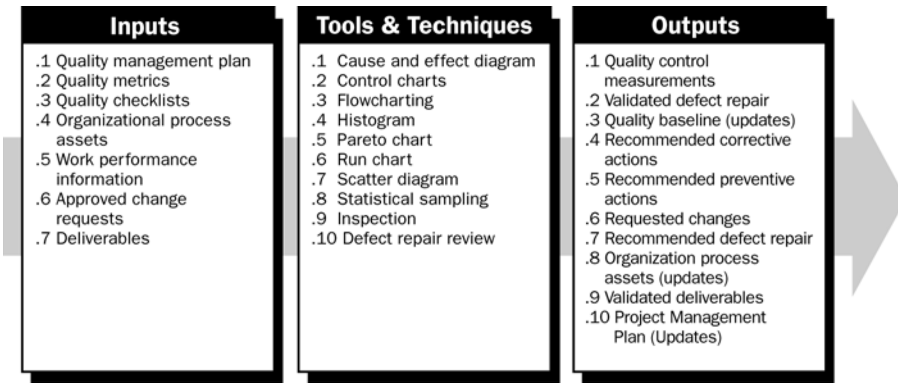


Figure 8-5. Perform Quality Control: Inputs, Tools & Techniques, and Outputs

8.3.1 Perform Quality Control: Inputs

.1 Quality Management Plan
Described in Section 8.1.3.1.

.2 Quality Metrics
Described in Section 8.1.3.2.

.3 Quality Checklists
Described in Section 8.1.3.3.

.4 Organizational Process Assets
Described in Section 4.1.1.4.

.5 Work Performance Information
Work performance information (Section 4.4.3.7), including technical performance measures, project deliverables completion status, and the implementation of required corrective actions, are important inputs to QC. Information from the project management plan about the planned or expected results should be available along with information about the actual results and implemented change requests.

.6 Approved Change Requests

Approved change requests (Section 4.4.1.4) can include modifications such as revised work methods and revised schedule. The timely correct implementation of approved changes needs to be verified.

.7 Deliverables

Described in Section 4.4.3.1.

8.3.2 Perform Quality Control: Tools and Techniques

The first seven of these are known as the Seven Basic Tools of Quality.

.1 Cause and Effect Diagram

Cause and effect diagrams, also called Ishikawa diagrams or fishbone diagrams, illustrate how various factors might be linked to potential problems or effects. Figure 8-6 is an example of a cause and effect diagram.

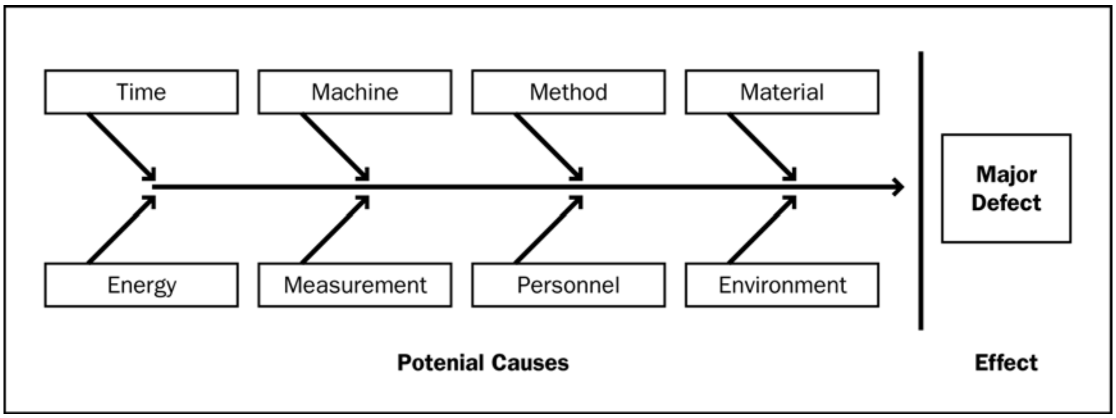


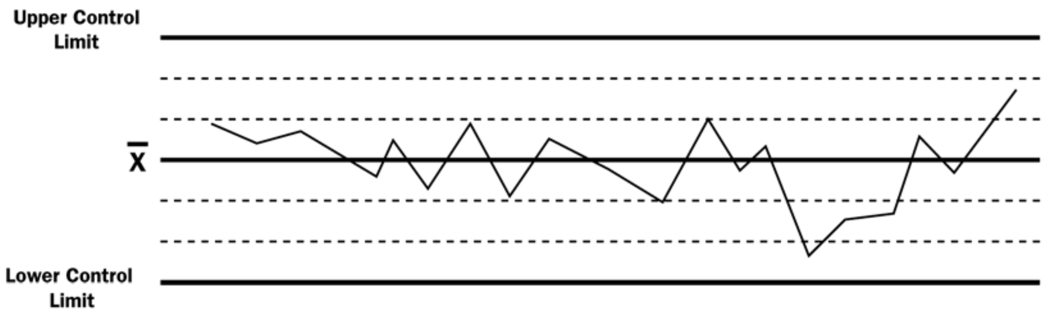
Figure 8-6. Cause and Effect Diagram

.2 Control Charts

A control chart's purpose is to determine whether or not a process is stable or has predictable performance. Control charts may serve as a data gathering tool to show when a process is subject to special cause variation, which creates an out-of-control condition. Control charts also illustrate how a process behaves over time. They are a graphic display of the interaction of process variables on a process to answer the question: Are the process variables within acceptable limits? Examination of the non-random pattern of data points on a control chart may reveal wildly fluctuating values, sudden process jumps or shifts, or a gradual trend in increased variation. By monitoring the output of a process over time, a control chart can be employed to assess whether the application of process changes resulted in the desired improvements. When a process is within acceptable limits, the process need not be adjusted. When a process is outside acceptable limits, the process should be adjusted. The upper control limit and lower control limit are usually set at +/- 3 sigma (i.e., standard deviation).

Control charts can be used for both project and product life cycle processes. An example of project use of control charts is determining whether cost variances or schedule variances are outside of acceptable limits (for example, +/- 10 percent). An example of product use of control charts is evaluating whether the number of defects found during testing are acceptable or unacceptable in relation to the organization's standards for quality.

Control charts can be used to monitor any type of output variable. Although used most frequently to track repetitive activities, such as manufactured lots, control charts also can be used to monitor cost and schedule variances, volume and frequency of scope changes, errors in project documents, or other management results to help determine if the project management process is in control. Figure 8-7 is an example of a control chart of project schedule performance.



The x axis of all control charts consists of sample numbers (usually the time of the sample).

Control charts have three common lines:
1. A center line, designated with an "$\bar{x}$" which provides the average (x) of the process data.
2. An upper line designating the upper control limit (UCL), drawn at a calculated distance above the center line, showing the upper range of acceptable dates.
3. The lower line designating the lower control limit (LCL), which shows the lower range of an acceptable date. Points outside of the UCL and LCL are indicative that the process is out of control and/or unstable.

Figure 8-7. Example of a Control Chart of Project Schedule Performance

.3 Flowcharting

Flowcharting helps to analyze how problems occur. A flowchart is a graphical representation of a process. There are many styles, but all process flowcharts show activities, decision points, and the order of processing. Flowcharts show how various elements of a system interrelate. Figure 8-8 is an example of a process flowchart for design reviews. Flowcharting can help the project team anticipate what and where quality problems might occur and, thus, can help develop approaches for dealing with them.

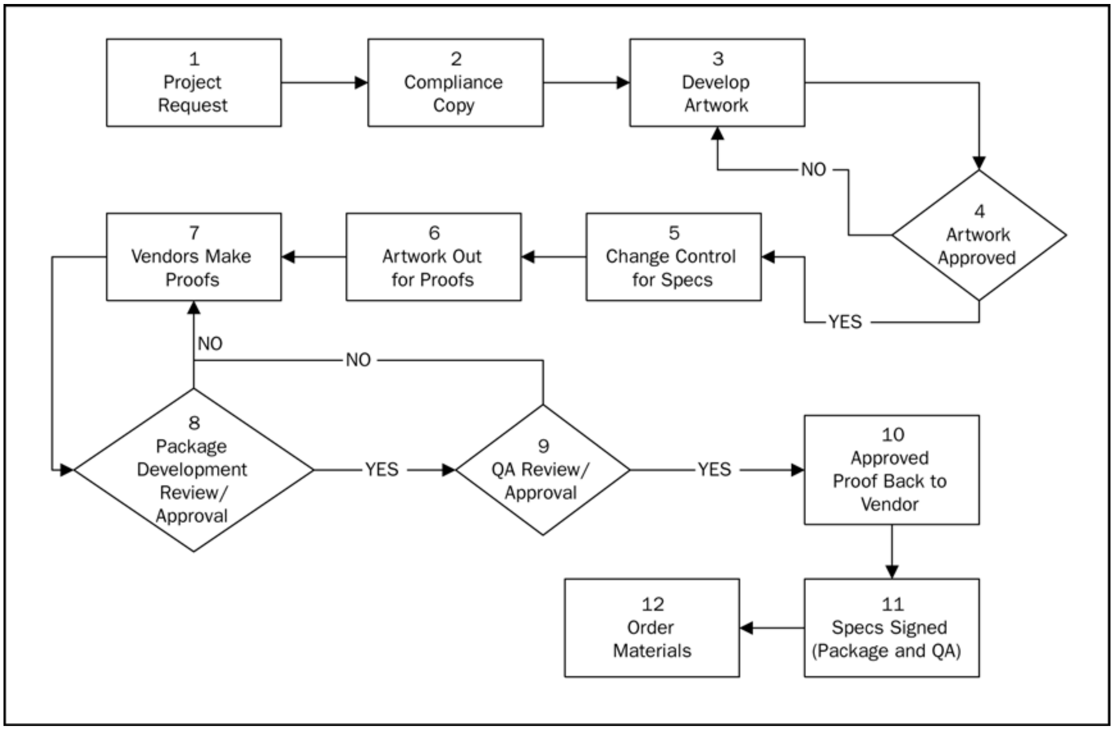


Figure 8-8. Sample Process Flowchart

.4 Histogram

A histogram is a bar chart showing a distribution of variables. Each column represents an attribute or characteristic of a problem/situation. The height of each column represents the relative frequency of the characteristic. This tool helps identify the cause of problems in a process by the shape and width of the distribution.

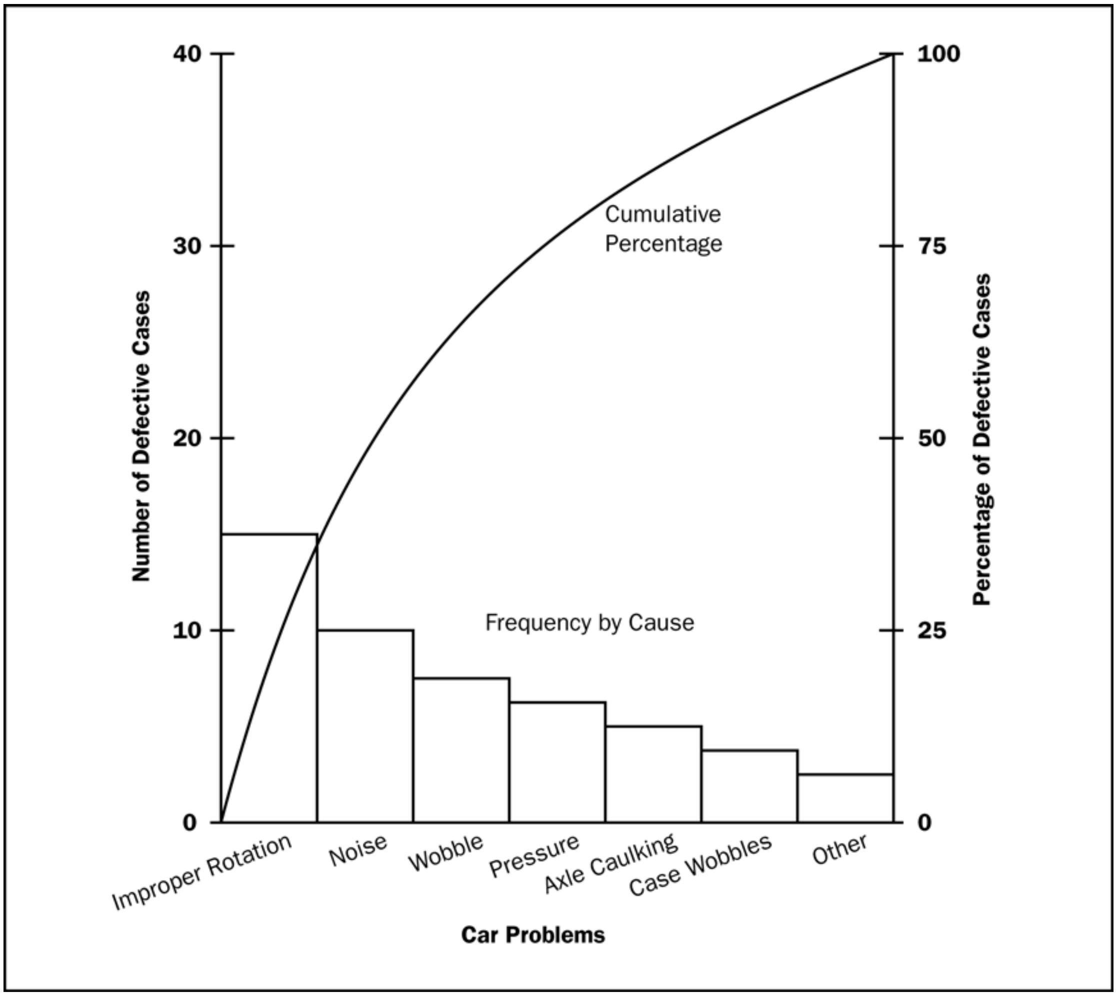


Figure 8-9. Pareto Diagram (Chart)

.5 Pareto Chart

A Pareto chart is a specific type of histogram, ordered by frequency of occurrence, which shows how many defects were generated by type or category of identified cause (Figure 8-9). The Pareto technique is used primarily to identify and evaluate nonconformities.

In Pareto diagrams, rank ordering is used to guide corrective action. The project team should take action to fix the problems that are causing the greatest number of defects first. Pareto diagrams are conceptually related to Pareto's Law, which holds that a relatively small number of causes will typically produce a large majority of the problems or defects. This is commonly referred to as the 80/20 principle, where 80 percent of the problems are due to 20 percent of the causes. Pareto diagrams also can be used to summarize all types of data for 80/20 analyses.

.6 Run Chart

A run chart shows the history and pattern of variation. A run chart is a line graph that shows data points plotted in the order in which they occur. Run charts show trends in a process over time, variation over time, or declines or improvements in a process over time. Trend analysis is performed using run charts. Trend analysis involves using mathematical techniques to forecast future outcomes based on historical results. Trend analysis is often used to monitor:

- **Technical performance.** How many errors or defects have been identified, how many remain uncorrected?
- **Cost and schedule performance.** How many activities per period were completed with significant variances?

.7 Scatter Diagram

A scatter diagram shows the pattern of relationship between two variables. This tool allows the quality team to study and identify the possible relationship between changes observed in two variables. Dependent variables versus independent variables are plotted. The closer the points are to a diagonal line, the more closely they are related.

.8 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). Appropriate sampling can often reduce the cost of quality control. 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.

.9 Inspection

An inspection is the examination of a work product to determine whether it conforms to standards. Generally, the results of an inspection include measurements. Inspections can 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 are also called reviews, peer reviews, audits, and walkthroughs. In some application areas, these terms have narrow and specific meanings. Inspections are also used to validate defect repairs.

.10 Defect Repair Review

Defect repair review is an action taken by the quality control department or similarly titled organization to ensure that product defects are repaired and brought into compliance with requirements or specifications.

8.3.3 Perform Quality Control: Outputs

.1 Quality Control Measurements

Quality control measurements represent the results of QC activities that are fed back to QA (Section 8.2) to reevaluate and analyze the quality standards and processes of the performing organization.

.2 Validated Defect Repair

The repaired items are reinspected and will be either accepted or rejected before notification of the decision is provided (Section 4.4). Rejected items may require further defect repair.

.3 Quality Baseline (Updates)

Described in Section 8.1.3.5.

.4 Recommended Corrective Actions

Corrective action (Section 4.5.3.1) involves actions taken as a result of a QC measurement that indicates that the manufacturing or development process exceeds established parameters.

.5 Recommended Preventive Actions

Preventive action (Section 4.5.3.2) involves action taken to forestall a condition that may exceed established parameters in a manufacturing or development process, which may have been indicated through a QC measurement.

.6 Requested Changes

If the recommended corrective or preventive actions require a change to the project, a change request (Section 4.4.3.2) should be initiated in accordance with the defined Integrated Change Control process.

.7 Recommended Defect Repair

A defect is where a component does not meet its requirements or specifications, and needs to be repaired or replaced. Defects are identified and recommended for repair by the QC department or similarly titled organization. The project team should make every reasonable effort to minimize the errors that cause the need for defect repair. A defect log can be used to collect the set of recommended repairs. This is often implemented in an automated problem-tracking system.

.8 Organization Process Assets (Updates)

- **Completed checklists.** When checklists are used, the completed checklists should become part of the project's records (Section 4.1.1.4).
- **Lessons learned documentation.** The causes of variances, the reasoning behind the corrective action chosen, and other types of lessons learned from quality control should be documented so that they become part of the historical database for both this project and the performing organization. Lessons learned are documented throughout the project life cycle, but, at a minimum, during project closure (Section 4.1.1.4).

.9 Validated Deliverables

A goal of quality control is to determine the correctness of deliverables. The results of the execution quality control processes are validated deliverables.

.10 Project Management Plan (Updates)

The project management plan is updated to reflect changes to the quality management plan that result from changes in performing the QC process. Requested changes (additions, modifications, or deletions) to the project management plan and its subsidiary plans are processed by review and disposition through the Integrated Change Control process (Section 4.6).

CHAPTER 9

Project Human Resource Management

Project Human Resource Management includes the processes that organize and manage the project team. The project team is comprised of the people who have assigned roles and responsibilities for completing the project. While it is common to speak of roles and responsibilities being assigned, team members should be involved in much of the project's planning and decision-making. Early involvement of team members adds expertise during the planning process and strengthens commitment to the project. The type and number of project team members can often change as the project progresses. Project team members can be referred to as the project's staff.

The project management team is a subset of the project team and is responsible for project management activities such as planning, controlling, and closing. This group can be called the core, executive, or leadership team. For smaller projects, the project management responsibilities can 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 questions, and influencing others in order to benefit the project.

Figure 9-1 provides an overview of the Project Human Resource Management processes, and Figure 9-2 provides a process flow diagram of those processes and their inputs, outputs, and other related Knowledge Area processes. The Project Human Resource Management processes include the following:

9.1 Human Resource Planning – Identifying and documenting project roles, responsibilities, and reporting relationships, as well as creating the staffing management plan.

9.2 Acquire Project Team – Obtaining the human resources needed to complete the project.

9.3 Develop Project Team – Improving the competencies and interaction of team members to enhance project performance.

9.4 Manage Project Team – Tracking team member performance, providing feedback, resolving issues, and coordinating changes to enhance project performance.

These processes interact with each other and with processes in the other Knowledge Areas as well. Each process can involve effort from one or more persons or groups of persons based on the needs of the project. Each process occurs at least once in every project, and occurs in one or more project phases, if the project is divided into phases. Although the processes are presented here as discrete elements with well-defined interfaces, in practice they may overlap and interact in ways not detailed here. Process interactions are discussed in detail in Chapter 3.

Figure 9-2 illustrates the primary ways that Project Human Resource Management interacts with other project processes. Examples of interactions that require additional planning include the following situations:

- After initial team members create a work breakdown structure, additional team members may need to be acquired
- As additional project team members are acquired, their experience level could increase or decrease project risk, creating the need for additional risk planning
- When activity durations are estimated before all project team members are known, actual competency levels of the acquired team members can cause the activity durations and schedule to change.

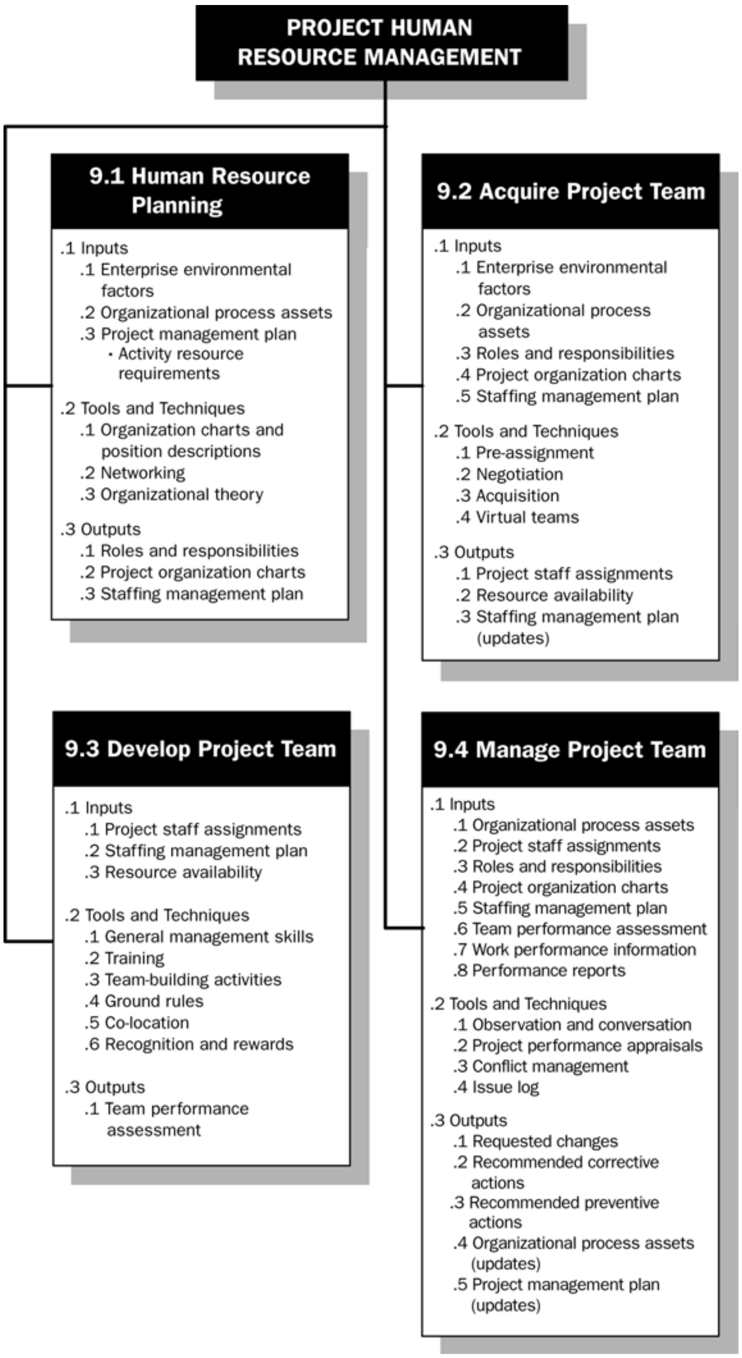


Figure 9-1. Project Human Resource Management Overview

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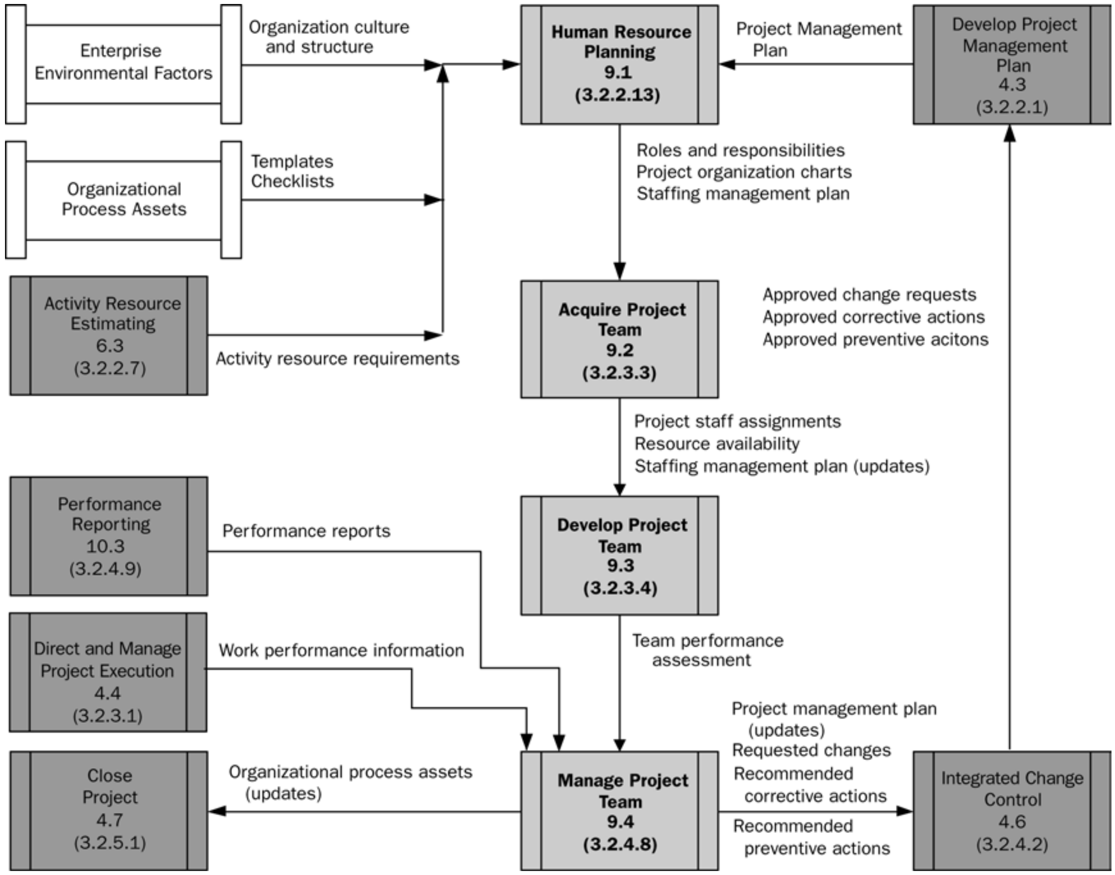

Note: Not all process interactions and data flow among the processes are shown.

Figure 9-2. Project Human Resource Management Process Flow Diagram

9.1 Human Resource Planning

Human Resource Planning determines project roles, responsibilities, and reporting relationships, and creates the staffing management plan. Project roles can be designated for persons or groups. Those persons or groups can be from inside or outside the organization performing the project. The staffing management plan can include how and when project team members will be acquired, the criteria for releasing them from the project, identification of training needs, plans for recognition and rewards, compliance considerations, safety issues, and the impact of the staffing management plan on the organization.

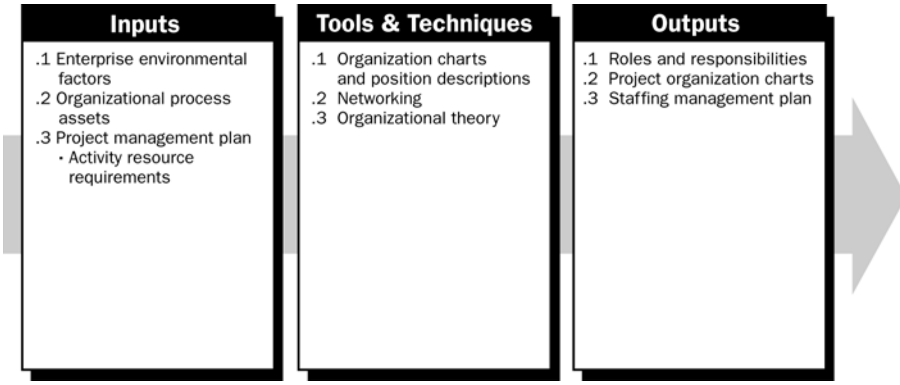

Figure 9-3. Human Resource Planning: Inputs, Tools & Techniques, and Outputs

9.1.1 Human Resource Planning: Inputs

.1 Enterprise Environmental Factors

The definition of project roles and responsibilities is developed with an understanding of the ways that existing organizations will be involved and how the technical disciplines and people currently interact with one another. Some of the relevant enterprise environmental factors (Section 4.1.1.3) involving organizational culture and structure are:

- **Organizational.** Which organizations or departments will be involved in the project? What are the current working arrangements among them? What formal and informal relationships exist among them?
- **Technical.** What are the different disciplines and specialties that will be needed to complete this project? Are there different types of software languages, engineering approaches, or kinds of equipment that will need to be coordinated? Do the transitions from one life cycle phase to the next present any unique challenges?
- **Interpersonal.** What types of formal and informal reporting relationships exist among people who are candidates for the project team? What are the candidates' job descriptions? What are their supervisor-subordinate relationships? What are their supplier-customer relationships? What cultural or language differences will affect working relationships among team members? What levels of trust and respect currently exist?
- **Logistical.** How much distance separates the people and units that will be part of the project? Are people in different buildings, time zones, or countries?
- **Political.** What are the individual goals and agendas of the potential project stakeholders? Which groups and people have informal power in areas important to the project? What informal alliances exist?

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In addition to the factors listed above, constraints limit the project team's options. Examples of constraints that can limit flexibility in the Human Resource Planning process are:

- **Organizational structure.** An organization whose basic structure is a weak matrix means a relatively weaker role for the project manager (Section 2.3.3).
- **Collective bargaining agreements.** Contractual agreements with unions or other employee groups can require certain roles or reporting relationships.
- **Economic conditions.** Hiring freezes, reduced training funds, or a lack of travel budget are examples of economic conditions that can restrict staffing options.

.2 Organizational Process Assets

As project management methodology matures within an organization, lessons learned from past Human Resource Planning experiences are available as organizational process assets (Section 4.1.1.4) to help plan the current project. Templates and checklists reduce the amount of planning time needed at the beginning of a project and reduce the likelihood of missing important responsibilities.

- **Templates.** Templates that can be helpful in Human Resource Planning include project organization charts, position descriptions, project performance appraisals, and a standard conflict management approach.
- **Checklists.** Checklists that can be helpful in Human Resource Planning include common project roles and responsibilities, typical competencies, training programs to consider, team ground rules, safety considerations, compliance issues, and reward ideas.

.3 Project Management Plan

The project management plan (Section 4.3) includes the activity resource requirements, plus descriptions of project management activities, such as quality assurance, risk management, and procurement, that will help the project management team identify all of the required roles and responsibilities.

- **Activity Resource Requirements.** Human Resource Planning uses activity resource requirements (Section 6.3.3.1) to determine the human resource needs for the project. The preliminary requirements regarding the required people and competencies for the project team members are refined as part of the Human Resource Planning process.

9.1.2 Human Resource Planning: Tools and Techniques

.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 project plans, such as the risk, quality, or communication plans. Whichever combination of methods is used, 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.

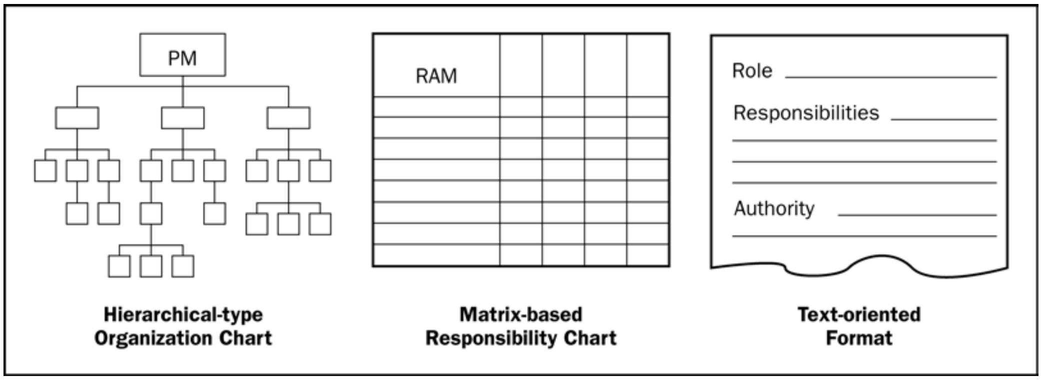

Figure 9-4. Roles and Responsibility Definition Formats

- **Hierarchical-type charts.** The traditional organization chart structure can be used to show positions and relationships in a graphic, top-down format. Work breakdown structures (WBS) that are primarily designed to show how project deliverables are broken down into work packages become one way to show high-level areas of responsibility. The organizational breakdown structure (OBS) looks similar to the WBS, but instead of being arranged according to a breakdown of project deliverables, it is arranged according to an organization's existing departments, units, or teams. The project activities or work packages are listed under each existing department. This way, 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 another hierarchical chart. It is used to break down the project by types of resources. For example, an RBS can depict all of the welders and welding equipment being used in different areas of a ship even though they can be scattered among different branches of the OBS and WBS. The RBS is helpful in tracking project costs, and can be aligned with the organization's accounting system. The RBS can contain resource categories other than human resources.

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- **Matrix-based charts.** A responsibility assignment matrix (RAM) is used to illustrate the connections between work that needs to be done and project team members. On larger projects, RAMs can be developed at various levels. For example, a high-level RAM can define what project team group or unit is responsible for 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, sometimes called a table, allows a person to see all activities associated with one person or to see all people associated with one activity. The matrix shown in Figure 9-5 is a type of RAM called a RACI chart because the names of roles being documented are Responsible, Accountable, Consult, and Inform. The sample chart shows the work to be done in the left column as activities, but RAMs can show responsibilities at various levels of detail. The people can be shown as persons or groups.

RACI Chart	**Person**				
Activity	Ann	Ben	Carlos	Dina	Ed
Define	A	R	I	I	I
Design	I	A	R	C	C
Develop	I	A	R	C	C
Test	A	I	I	R	I

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

Figure 9-5. Responsibility Assignment Matrix (RAM) Using a RACI Format

- **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 descriptions and forms make excellent templates for future projects, especially when the information is updated throughout the current project by applying lessons learned.
- **Other sections of the project management plan.** Some responsibilities related to managing the project are listed and explained in other sections of the project management plan. For example, the risk register lists risk owners, the communication plan lists team members responsible for communication activities, and the quality plan designates people responsible for carrying out quality assurance and quality control activities.

.2 **Networking**

Informal interaction with others in an organization or industry is a constructive way to understand political and interpersonal factors that will impact the effectiveness of various staffing management options. Human resources networking activities include proactive correspondence, luncheon meetings, informal conversations, and trade conferences. While concentrated networking can be a useful technique at the beginning of a project, carrying out networking activities on a regular basis before a project begins is also effective.

.3 **Organizational Theory**

Organizational theory provides information regarding the ways that people, teams, and organizational units behave. Applying proven principles shortens the amount of time needed to create the Human Resource Planning outputs and improves the likelihood that the planning will be effective.

9.1.3 Human Resource Planning: Outputs

.1 **Roles and Responsibilities**

The following items should be addressed when listing the roles and responsibilities needed to complete the project:

- **Role.** The label describing the portion of a project for which a person is accountable. Examples of project roles are civil engineer, court liaison, business analyst, and testing coordinator. Role clarity concerning authority, responsibilities, and boundaries is essential for project success.
- **Authority.** The right to apply project resources, make decisions, and sign approvals. 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 matches their individual responsibilities.
- **Responsibility.** The 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 project activities. 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.

.2 **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.

.3 Staffing Management Plan

The staffing management plan, a subset of the project management plan (Section 4.3), describes when and how human resource requirements will be met. The staffing management plan can be formal or informal, highly detailed or broadly framed, based on 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, will the human resources come from within the organization or from external, contracted sources? Will team members need to work in a central location or can they work from distant locations? What are the costs associated with each level of expertise needed for the project? How much assistance can the organization's human resource department provide to the project management team?
- **Timetable.** 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 (Section 6.5.3.2). This bar chart illustrates the number of hours that a person, department, or entire project team 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 leveling strategy, such as adding more resources or extending the length of the schedule. A sample resource histogram is illustrated in Figure 9-6.

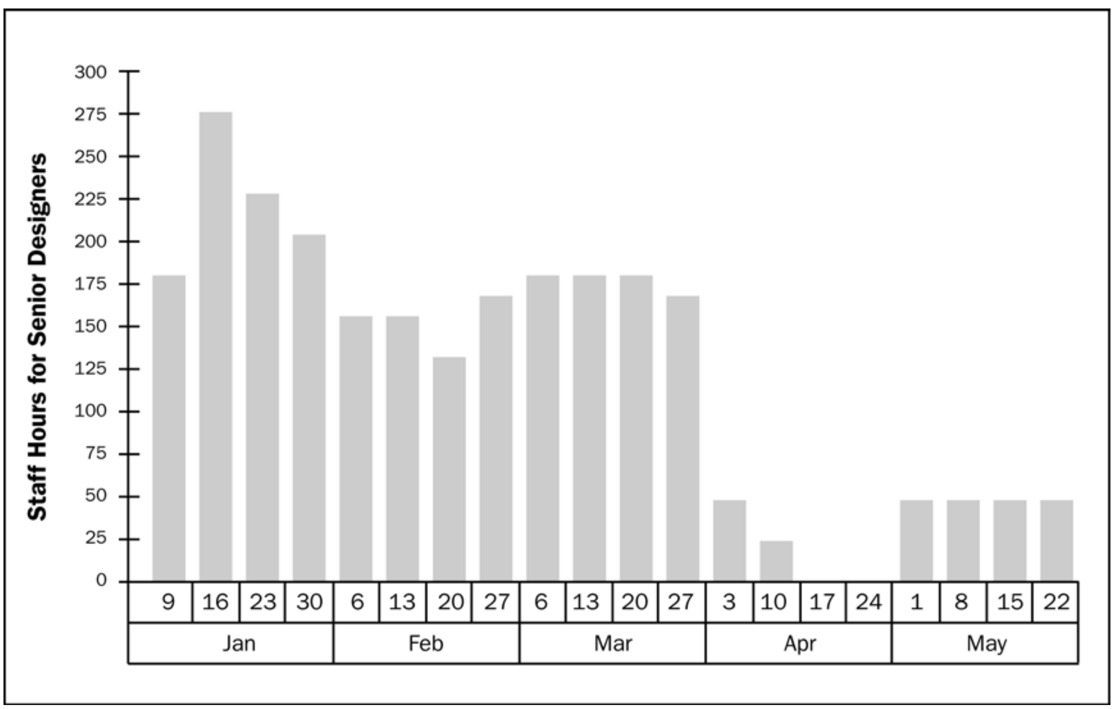


Figure 9-6. Illustrative Resource Histogram

- **Release criteria.** Determining the method and timing of releasing team members benefits both the project and team members. When team members are released from a project at the optimum time, payments made for people who are finished with their responsibilities can be eliminated and the costs reduced. Morale is improved when smooth transitions to upcoming projects are already planned.
- **Training needs.** If the team members to be assigned are not expected to 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 benefit the project.
- **Recognition and rewards.** Clear criteria for rewards and a planned system for their use will 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 rewards ensures that recognition takes place and is not forgotten. Recognition and rewards are awarded as 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 the risk register.

9.2 Acquire Project Team

Acquire Project Team is the process of obtaining the human resources needed to complete the project. The project management team may or may not have control over team members selected for the project.

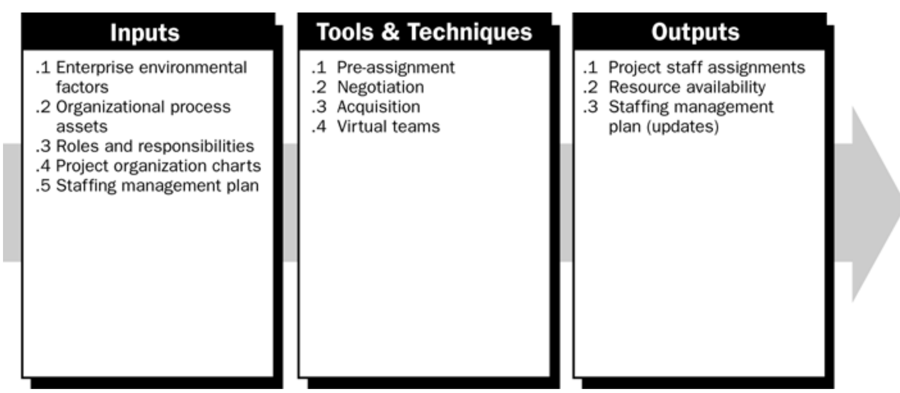


Figure 9-7. Acquire Project Team: Inputs, Tools & Techniques, and Outputs

9.2.1 Acquire Project Team: Inputs

.1 Enterprise Environmental Factors

Project team members are drawn from all available sources, both internal and external. When the project management team is able to influence or direct staff assignments, characteristics to consider include:

- **Availability.** Who is available and when are they available?
- **Ability.** What competencies do people possess?
- **Experience.** Have the people done similar or related work? Have they done it well?
- **Interests.** Are the people interested in working on this project?
- **Cost.** How much will each team member be paid, particularly if they are contracted from outside the organization?

.2 Organizational Process Assets

One or more of the organizations involved in the project may have policies, guidelines, or procedures governing staff assignments (Section 4.1.1.4). The human resource departments also can assist with recruitment, hiring and orientation of project team members.

.3 Roles and Responsibilities

Roles and responsibilities define the positions, skills, and competencies that the project demands (Section 9.1.3.1).

.4 Project Organization Charts

Project organization charts provide an overview regarding the number of people needed for the project (Section 9.1.3.2).

.5 Staffing Management Plan

The staffing management plan, along with the project schedule, identifies the time periods each project team member will be needed and other information important to acquiring the project team (Section 9.1.3.3).

9.2.2 Acquire Project Team: Tools and Techniques

.1 Pre-Assignment

In some cases, project team members are known in advance; that is, they are pre-assigned. This situation can occur if the project is the result of specific people being promised as part of a competitive proposal, if the project is dependent on the expertise of particular persons, or if some staff assignments are defined within the project charter.

.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 project team members will be able to work on the project until their responsibilities are completed
- Other project management teams within the performing organization to appropriately assign scarce or specialized resources.

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 (Section 2.3.3). For example, a functional manager will weigh the benefits and visibility of competing projects when determining where to assign exceptional performers that all project teams desire.

.3 Acquisition

When the performing organization lacks the in-house staff needed to complete the project, the required services can be acquired from outside sources (Section 12.4.3.1). This can involve hiring individual consultants or subcontracting work to another organization.

.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 electronic communication, such as e-mail and video conferencing, has made such teams feasible. The virtual team format makes it possible to:

- Form teams of people from the same company 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 or hours
- Include people with mobility handicaps
- Move forward with projects that would have been ignored due to travel expenses.

Communications Planning (Section 10.1) becomes increasingly important in a virtual team environment. Additional time may be needed to set clear expectations, develop protocols for confronting conflict, include people in decision-making, and share credit in successes.

9.2.3 Acquire Project Team: Outputs

.1 Project Staff Assignments

The project is staffed when appropriate people have been assigned to work on it. Documentation 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.

.2 Resource Availability

Resource availability documents the time periods each project team member can work on the project. Creating a reliable final schedule (Section 6.5.3.1) depends on having a good understanding of each person's schedule conflicts, including vacation time and commitments to other projects.

.3 Staffing Management Plan (Updates)

As specific people fill the project roles and responsibilities, changes in the staffing management plan (Section 9.1.3.3) may be needed because people seldom fit the exact staffing requirements that are planned. Other reasons for changing the staffing management plan include promotions, retirements, illnesses, performance issues, and changing workloads.

9.3 Develop Project Team

Develop Project Team improves the competencies and interaction of team members to enhance project performance. Objectives include:

- Improve skills of team members in order to increase their ability to complete project activities
- Improve feelings of trust and cohesiveness among team members in order to raise productivity through greater teamwork.

Examples of effective teamwork include assisting one another when workloads are unbalanced, communicating in ways that fit individual preferences, and sharing information and resources. Team development efforts have greater benefit when conducted early, but should take place throughout the project life cycle.

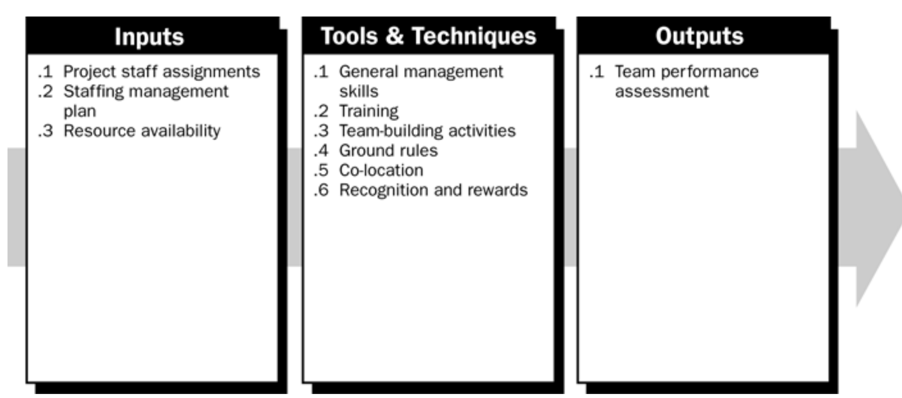


Figure 9-8. Develop Project Team: Inputs, Tools & Techniques, and Outputs

9.3.1 Develop Project Team: Inputs

.1 Project Staff Assignments

Team development starts with a list of the project team members. Project staff assignment documents (Section 9.2.3.1) identify the people who are on the team.

.2 Staffing Management Plan

The staffing management plan (Section 9.1.3.3) identifies training strategies and plans for developing the project team. As the project progresses, items such as rewards, feedback, additional training, and disciplinary actions are added to the plan as a result of ongoing team performance assessments (Section 9.3.3.1) and other forms of project team management (Section 9.4.2).

.3 Resource Availability

Resource availability information (Section 9.2.3.2) identifies times that project team members can participate in team development activities.

9.3.2 Develop Project Team: Tools and Techniques

.1 General Management Skills

Interpersonal skills (Section 1.5.5), sometimes known as "soft skills," are particularly important to team development. By understanding the sentiments of project team members, anticipating their actions, acknowledging their concerns, and following up on their issues, the project management team can greatly reduce problems and increase cooperation. Skills such as empathy, influence, creativity, and group facilitation are valuable assets when managing the project team.

.2 Training

Training includes all activities designed to enhance the competencies of the project team members. Training can be formal or informal. Examples of training methods include classroom, online, computer-based, on-the-job training from another project team member, mentoring, and coaching.

If project team members lack necessary management or technical skills, such skills can be developed as part of the project work. Scheduled training takes place as stated in the staffing management plan. Unplanned training takes place as a result of observation, conversation, and project performance appraisals conducted during the controlling process of managing the project team.

.3 Team-Building Activities

Team-building activities can vary from a five-minute agenda item in a status review meeting to an off-site, professionally facilitated experience designed to improve interpersonal relationships. Some group activities, such as developing the WBS, may not be explicitly designed as team-building activities, but can increase team cohesiveness when that planning activity is structured and facilitated well. It also is important to encourage informal communication and activities because of their role in building trust and establishing good working relationships. Team-building strategies are particularly valuable when team members operate virtually from remote locations, without the benefit of face-to-face contact.

.4 Ground Rules

Ground rules establish clear expectations regarding acceptable behavior by project team members. Early commitment to clear guidelines decreases misunderstandings and increases productivity. The process of discussing ground rules allows team members to discover values that are important to one another. All project team members share responsibility for enforcing the rules once they are established.

.5 Co-Location

Co-location involves placing many or all of the most active project team members in the same physical location to enhance their ability to perform as a team. Co-location can be temporary, such as at strategically important times during the project, or for the entire project. Co-location strategy can include a meeting room, sometimes called a war room, with electronic communication devices, places to post schedules, and other conveniences that enhance communication and a sense of community. While co-location is considered good strategy, the use of virtual teams will reduce the frequency that team members are located together.

.6 Recognition and Rewards

Part of the team development process involves recognizing and rewarding desirable behavior. The original plans concerning ways to reward people are developed during Human Resource Planning (Section 9.1). Award decisions are made, formally or informally, during the process of managing the project team through performance appraisals (Section 9.4.2.2).

Only desirable behavior should be rewarded. For example, the willingness to work overtime to meet an aggressive schedule objective should be rewarded or recognized; needing to work overtime as the result of poor planning should not be rewarded. Win-lose (zero sum) rewards that only a limited number of project team members can achieve, such as team member of the month, can hurt team cohesiveness. Rewarding win-win behavior that everyone can achieve, such as turning in progress reports on time, tends to increase support among team members.

Recognition and rewards should consider cultural differences. For example, developing appropriate team rewards in a culture that encourages individualism can be difficult.

9.3.3 Develop Project Team: Outputs

.1 Team Performance Assessment

As development efforts such as training, team building, and co-location are implemented, the project management team makes informal or formal assessments of the project team's effectiveness. Effective team development strategies and activities are expected to increase the team's performance, which increases the likelihood of meeting project objectives. The evaluation of a team's effectiveness can include indicators such as:

- Improvements in skills that allow a person to perform assigned activities more effectively
- Improvements in competencies and sentiments that help the team perform better as a group
- Reduced staff turnover rate.

9.4 Manage Project Team

Manage Project Team involves tracking team member performance, providing feedback, resolving issues, and coordinating changes to enhance project performance. The project management team observes team behavior, manages conflict, resolves issues, and appraises team member performance. As a result of managing the project team, the staffing management plan is updated, change requests are submitted, issues are resolved, input is given to organizational performance appraisals, and lessons learned are added to the organization's database.

Management of the project team is complicated when team members are accountable to both a functional manager and the project manager within a matrix organization (Section 2.3.3). Effective management of this dual reporting relationship is often a critical success factor for the project, and is generally the responsibility of the project manager.

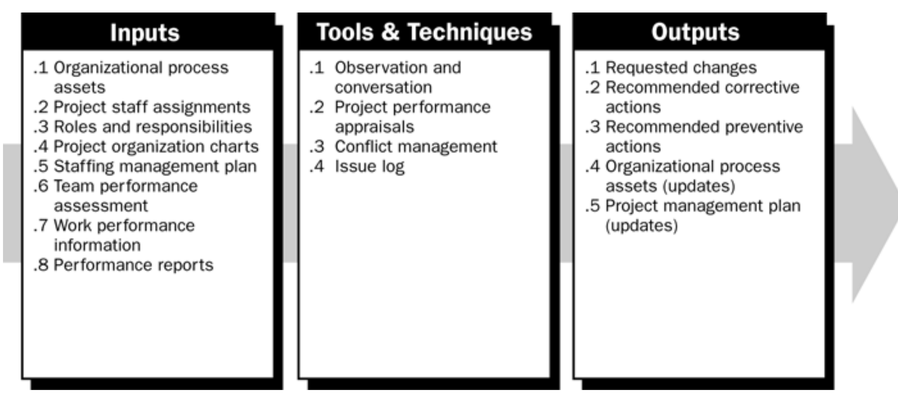


Figure 9-9. Manage Project Team: Inputs, Tools & Techniques, and Outputs

9.4.1 Manage Project Team: Inputs

.1 Organizational Process Assets

The project management team should utilize an organization's policies, procedures, and systems for rewarding employees during the course of a project (Section 4.1.1.4). Organizational recognition dinners, certificates of appreciation, newsletters, bulletin boards, Web sites, bonus structures, corporate apparel, and other organizational perquisites should be available to the project management team as part of the project management process.

.2 Project Staff Assignments

Project staff assignments (Section 9.2.3.1) provide a list of the project team members to be evaluated during this monitoring and controlling process.

.3 Roles and Responsibilities

A list of the staff's roles and responsibilities is used to monitor and evaluate performance (Section 9.1.3.1).

.4 Project Organization Charts

Project organization charts provide a picture of the reporting relationships among project team members (Section 9.1.3.2).

.5 Staffing Management Plan

The staffing management plan lists the time periods that team members are expected to work on the project, along with information such as training plans, certification requirements, and compliance issues (Section 9.1.3.3).

.6 Team Performance Assessment

The project management team makes ongoing formal or informal assessments of the project team's performance (Section 9.3.3.1). By continually assessing the project team's performance, actions can be taken to resolve issues, modify communication, address conflict, and improve team interaction.

.7 Work Performance Information

As part of the Direct and Manage Project Execution process (Section 4.4), the project management team directly observes team member performance as it occurs. Observations related to areas such as a team member's meeting participation, follow-up on action items, and communication clarity are considered when managing the project team.

.8 Performance Reports

Performance reports (Section 10.3.3.1) provide documentation about performance against the project management plan. Examples of performance areas that can help with project team management include results from schedule control, cost control, quality control, scope verification, and procurement audits. The information from performance reports and related forecasts assists in determining future human resource requirements, recognition and rewards, and updates to the staffing management plan.

9.4.2 Manage Project Team: Tools and Techniques

.1 Observation and Conversation

Observation and conversation are used to stay in touch with the work and attitudes of project team members. The project management team monitors indicators such as progress toward project deliverables, accomplishments that are a source of pride for team members, and interpersonal issues.

.2 Project Performance Appraisals

The need for formal or informal project performance appraisals depends on the length of the project, complexity of the project, organizational policy, labor contract requirements, and the amount and quality of regular communication. Project team members receive feedback from the people who supervise their project work. Evaluation information also can be gathered from people who interact with project team members by using 360-degree feedback principles. The term "360-degree" means that feedback regarding performance is provided to the person being evaluated from many sources, including superiors, peers, and subordinates.

Objectives for conducting performance appraisals during the course of a project can include reclarification of roles and responsibilities, structured time to ensure team members receive positive feedback in what might otherwise be a hectic environment, discovery of unknown or unresolved issues, development of individual training plans, and the establishment of specific goals for future time periods.

.3 Conflict Management

Successful conflict management results in greater productivity and positive working relationships. Sources of conflict include scarce resources, scheduling priorities, and personal work styles. Team ground rules, group norms, and solid project management practices, like communication planning and role definition, reduce the amount of conflict. When managed properly, differences of opinion are healthy, and can lead to increased creativity and better decision-making. When the differences become a negative factor, project team members are initially responsible for resolving their own conflicts. If conflict escalates, the project manager should help facilitate a satisfactory resolution. Conflict should be addressed early and usually in private, using a direct, collaborative approach. If disruptive conflict continues, increasingly formal procedures will need to be used, including the possible use of disciplinary actions.

.4 Issue Log

As issues arise in the course of managing the project team, a written log can document persons responsible for resolving specific issues by a target date. The log helps the project team monitor issues until closure. Issue resolution addresses obstacles that can block the team from achieving its goals. These obstacles can include factors such as differences of opinion, situations to be investigated, and emerging or unanticipated responsibilities that need to be assigned to someone on the project team.

9.4.3 Manage Project Team: Outputs

.1 Requested Changes

Staffing changes, whether by choice or by uncontrollable events, can affect the rest of the project plan. When staffing issues are going to disrupt the project plan, such as causing the schedule to be extended or the budget to be exceeded, a change request can be processed through the Integrated Change Control process (Section 4.6).

.2 Recommended Corrective Actions

Corrective action for human resource management includes items such as staffing changes, additional training, and disciplinary actions. Staffing changes can include moving people to different assignments, outsourcing some work, and replacing team members who leave. The project management team also determines how and when to give out recognition and rewards based on the team's performance.

.3 Recommended Preventive Actions

When the project management team identifies potential or emerging human resource issues, preventive action can be developed to reduce the probability and/or impact of problems before they occur. Preventive actions can include cross-training in order to reduce problems during project team member absences, additional role clarification to ensure all responsibilities are fulfilled, and added personal time in anticipation of extra work that may be needed in the near future to meet project deadlines.

.4 Organizational Process Assets (Updates)

- **Input to organizational performance appraisals.** Project staff generally should be prepared to provide input for regular organizational performance appraisals of any project team member with whom they interact in a significant way.

- **Lessons learned documentation.** All knowledge learned during the project should be documented so it becomes part of the historical database of the organization. Lessons learned in the area of human resources can include:
  - ♦ Project organization charts, position descriptions, and staffing management plans that can be saved as templates
  - ♦ Ground rules, conflict management techniques, and recognition events that were particularly useful
  - ♦ Procedures for virtual teams, co-location, negotiation, training, and team building that proved to be successful
  - ♦ Special skills or competencies by team members that were discovered during the project
  - ♦ Issues and solutions documented in the project issue log.

.5 Project Management Plan (Updates)

Approved change requests and corrective actions can result in updates to the staffing management plan, a part of the project management plan. Examples of plan update information include new project team member roles, additional training, and reward decisions.

CHAPTER 10

Project Communications Management

Project Communications Management is the Knowledge Area that employs the processes required to ensure timely and appropriate generation, collection, distribution, storage, retrieval, and ultimate disposition of project information. The Project Communications Management processes provide the critical links among people and information that are necessary for successful communications. Project managers can spend an inordinate amount of time communicating with the project team, stakeholders, customer, and sponsor. Everyone involved in the project should understand how communications affect the project as a whole. Figure 10-1 provides an overview of the Project Communications Management processes, and Figure 10-2 provides a process flow diagram of those processes and their inputs, outputs, and other related Knowledge Area processes. The Project Communications Management processes include the following:

10.1 Communications Planning – determining the information and communications needs of the project stakeholders.

10.2 Information Distribution – making needed information available to project stakeholders in a timely manner.

10.3 Performance Reporting – collecting and distributing performance information. This includes status reporting, progress measurement, and forecasting.

10.4 Manage Stakeholders – managing communications to satisfy the requirements of and resolve issues with project stakeholders.

These processes interact with each other and with the processes in the other Knowledge Areas as well. Each process can involve effort from one or more persons or groups of persons based on the needs of the project. Each process occurs at least once in every project and occurs in one or more project phases, if the project is divided into phases. Although the processes are presented here as discrete elements with well-defined interfaces, in practice they may overlap and interact in ways not detailed here. Process interactions are discussed in detail in Chapter 3.

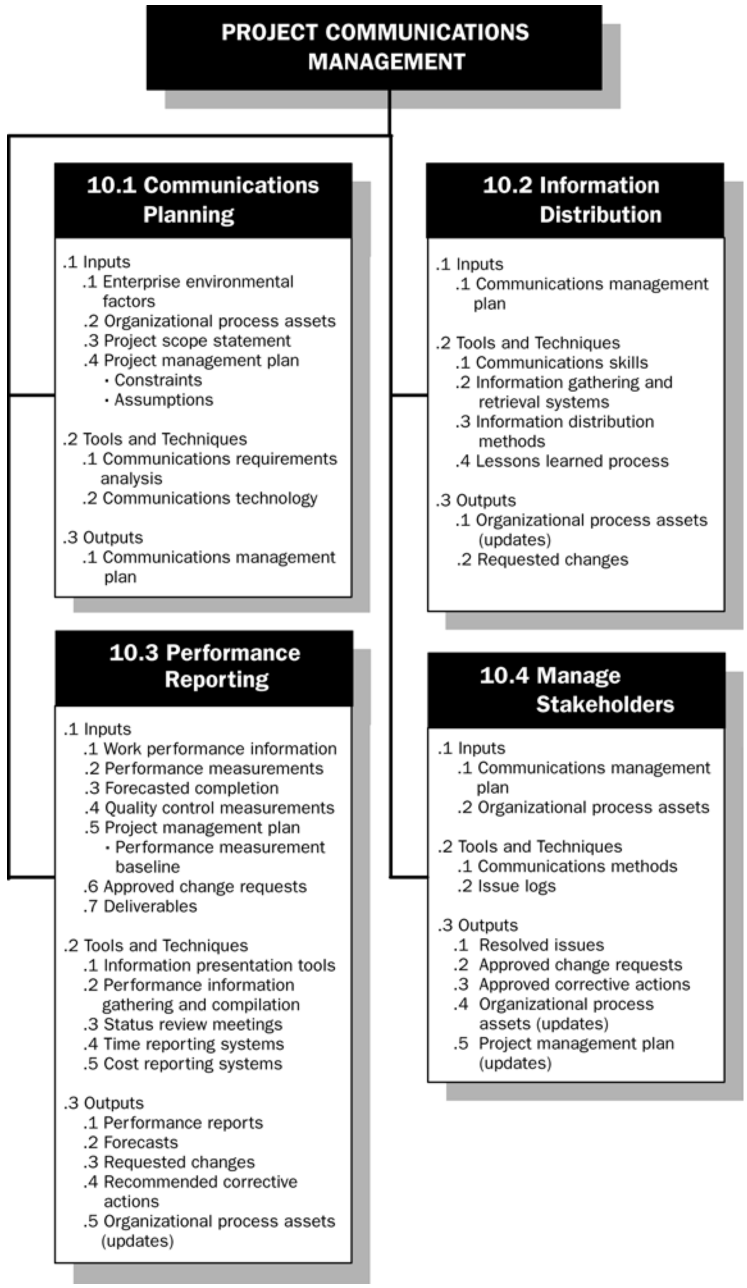
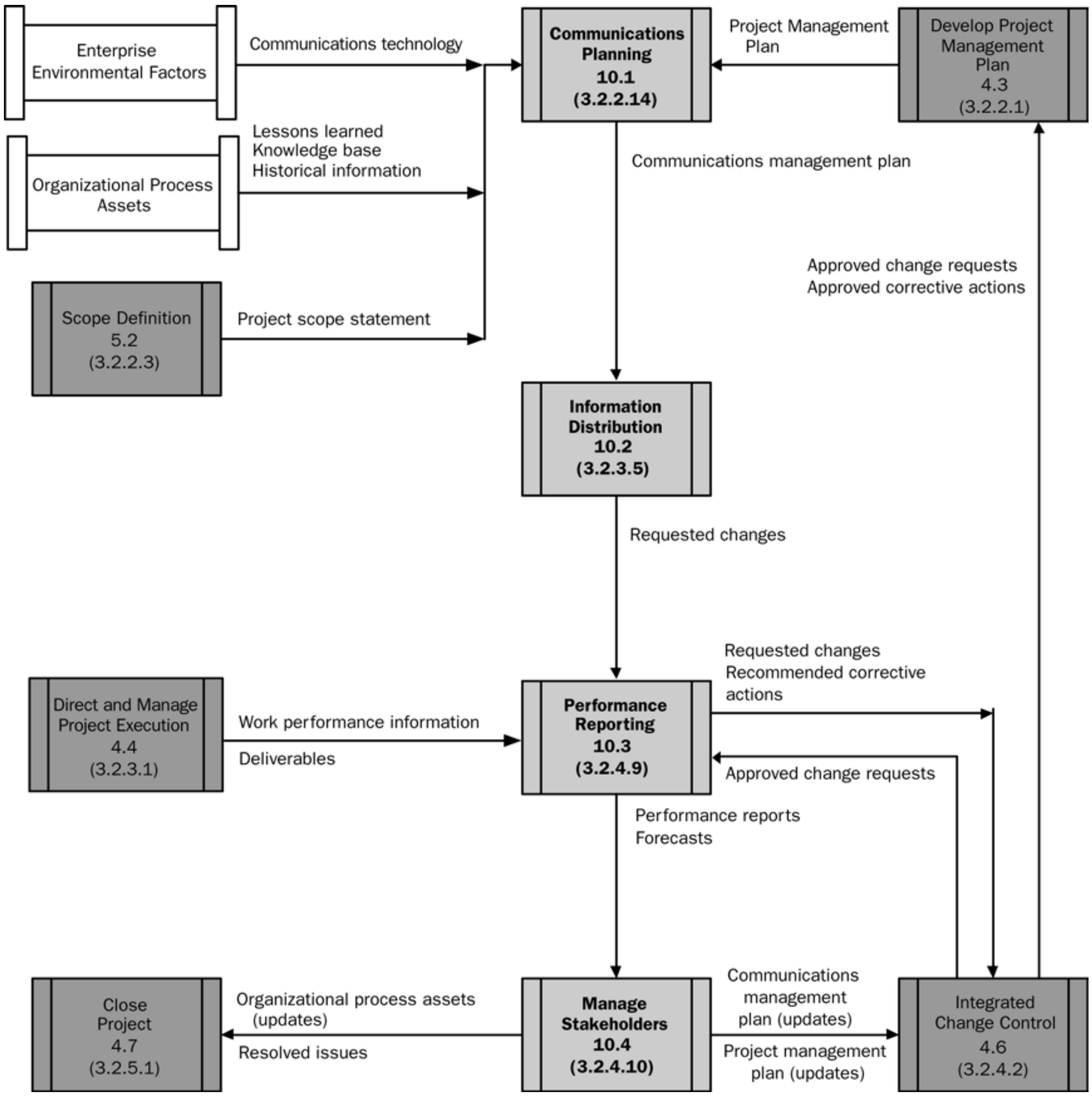


Figure 10-1. Project Communications Management Overview



Note: Not all process interactions and data flow among the processes are shown.

Figure 10-2. Project Communications Management Process Flow Diagram

Communications skills are related to, but are not the same as, project management communications. The art of communications is a broad subject and involves a substantial body of knowledge including:

- **Sender-receiver models.** Feedback loops and barriers to communication.
- **Choice of media.** When to communicate in writing versus orally, when to write an informal memo versus a formal report, and when to communicate face-to-face versus by e-mail. The media chosen for communication activities will depend upon the situation.
- **Writing style.** Active versus passive voice, sentence structure, and word choice.

- **Presentation techniques.** Body language and design of visual aids.
- **Meeting management techniques.** Preparing an agenda and dealing with conflict.

A basic model of communication, shown in Figure 10-3, demonstrates how ideas or information is sent and received between two parties, defined as the sender and the receiver. The key components of the model include:

- **Encode.** To translate thoughts or ideas into a language that is understood by others.
- **Message.** The output of encoding.
- **Medium.** The method used to convey the message.
- **Noise.** Anything that interferes with the transmission and understanding of the message (e.g., distance).
- **Decode.** To translate the message back into meaningful thoughts or ideas.

Inherent in the model shown in Figure 10-3 is an action to acknowledge a message. Acknowledgement means that the receiver signals receipt of the message, but not necessarily agreement with the message. Another action is the response to a message, which means that the receiver has decoded, understands, and is replying to the message.

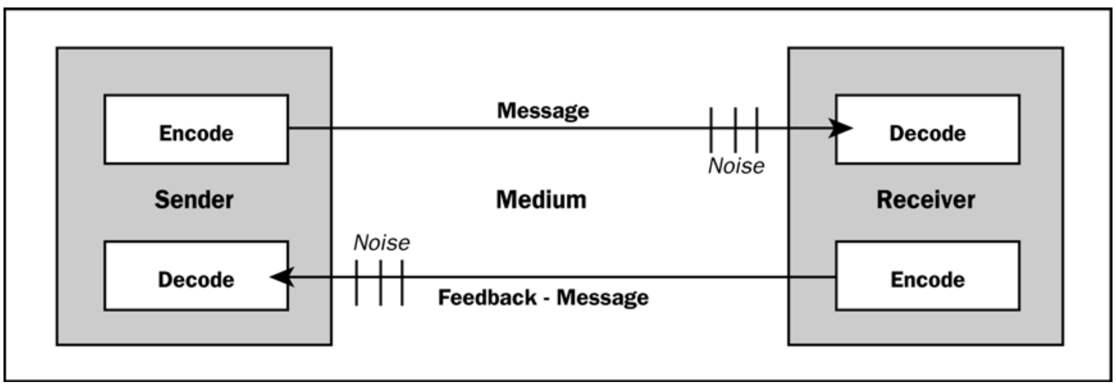


Figure 10-3. Communication – Basic Model

The components in the communications model need to be taken into account when discussing project communications. There are many challenges in using these components to effectively communicate with project stakeholders. Consider a highly technical, multi-national project team. For one team member to successfully communicate a technical concept to another team member in a different country can involve encoding the message in the appropriate language, sending the message using a variety of technologies, and having the receiver decode the message. Any noise introduced along the way compromises the original meaning of the message. A breakdown in communications can negatively impact the project.

10.1 Communications Planning

The Communications Planning process determines the information and communications needs of the stakeholders; for example, who needs what information, when they will need it, how it will be given to them, and by whom. While all projects share the need to communicate project information, the informational needs and methods of distribution vary widely. Identifying the informational needs of the stakeholders and determining a suitable means of meeting those needs is an important factor for project success.

On most projects, the majority of Communications Planning is done as part of the earliest project phases. However, the results of this planning process are reviewed regularly throughout the project and revised as needed to ensure continued applicability.

Communications Planning is often tightly linked with enterprise environmental factors (Section 4.1.1.3) and organizational influences (Section 2.3), since the project's organizational structure will have a major effect on the project's communications requirements.

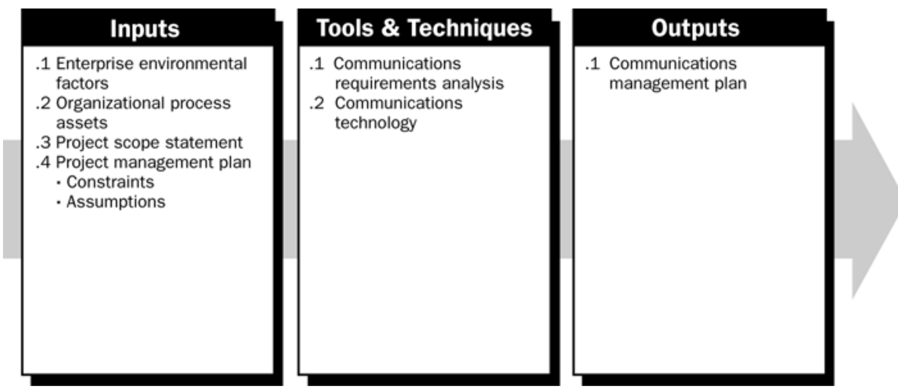


Figure 10-4. Communications Planning: Inputs, Tools & Techniques, and Outputs

10.1.1 Communications Planning: Inputs

.1 Enterprise Environmental Factors

All the factors described in Section 4.1.1.3 are used as inputs for this process.

.2 Organizational Process Assets

While all of the assets described in Section 4.1.1.4 are used as inputs for this process, lessons learned and historical information are of particular importance. Lessons learned and historical information can provide both decisions and results based on previous similar projects concerning communications issues.

.3 Project Scope Statement

The project scope statement (Section 5.2.3.1) provides a documented basis for future project decisions and for confirming a common knowledge of project scope among the stakeholders. Stakeholder analysis is completed as part of the Scope Definition process.

.4 Project Management Plan

The project management plan (Section 4.3) provides background information about the project, including dates and constraints that may be relevant to Communications Planning.

- **Constraints.** Constraints are factors that can limit the project management team's options. Examples of constraints include team members situated in different geographic locations, incompatible communication software versions, or limited communications technical capabilities.
- **Assumptions.** Specific assumptions that affect Communications Planning will depend upon the particular project.

10.1.2 Communications Planning: Tools and Techniques

.1 Communications Requirements Analysis

The analysis of the communications requirements results in the sum of the information needs of the project stakeholders. These requirements are defined by combining the type and format of information needed with an analysis of the value of that information. Project resources are expended only on communicating information that contributes to success, or where a lack of communication can lead to failure. This does not mean that "bad news" should not be shared; rather, the intent is to prevent overwhelming stakeholders with minutiae.

The project manager should consider the number of potential communication channels or paths as an indicator of the complexity of a project's communications.

The total number of communication channels is n(n-1)/2, where n = number of stakeholders. Thus, a project with 10 stakeholders has 45 potential communication channels. A key component of planning the project's communications, therefore, is to determine and limit who will communicate with whom and who will receive what information. Information typically required to determine project communications requirements includes:

- Organization charts
- Project organization and stakeholder responsibility relationships
- Disciplines, departments, and specialties involved in the project
- Logistics of how many persons will be involved with the project and at which locations
- Internal information needs (e.g., communicating across organizations)
- External information needs (e.g., communicating with the media or contractors)
- Stakeholder information.

.2 Communications Technology

The methodologies used to transfer information among project stakeholders can vary significantly. For example, a project management team may include brief conversations all the way through to extended meetings, or simple written documents to material (e.g., schedules and databases) that is accessible online as methods of communication.

Communications technology factors that can affect the project include:

- **The urgency of the need for information.** Is project success dependent upon having frequently updated information available on a moment's notice, or would regularly issued written reports suffice?
- **The availability of technology.** Are the systems already in place appropriate, or do project needs warrant change?
- **The expected project staffing.** Are the proposed communications systems compatible with the experience and expertise of the project participants, or is extensive training and learning required?
- **The length of the project.** Is the available technology likely to change before the project is over?
- **The project environment.** Does the team meet and operate on a face-to-face basis or in a virtual environment?

10

10.1.3 Communications Planning: Outputs

.1 Communications Management Plan

The communications management plan is contained in, or is a subsidiary plan of, the project management plan (Section 4.3). The communications management plan provides:

- Stakeholder communication requirements
- Information to be communicated, including format, content, and level of detail
- Person responsible for communicating the information
- Person or groups who will receive the information
- Methods or technologies used to convey the information, such as memoranda, e-mail, and/or press releases
- Frequency of the communication, such as weekly
- Escalation process-identifying time frames and the management chain (names) for escalation of issues that cannot be resolved at a lower staff level
- Method for updating and refining the communications management plan as the project progresses and develops
- Glossary of common terminology.

The communications management plan can also include guidelines for project status meetings, project team meetings, e-meetings, and e-mail. The communications management plan can be formal or informal, highly detailed or broadly framed, and based on the needs of the project. The communications management plan is contained in, or is a subsidiary plan of, the overall project management plan (Section 4.3). Sample attributes of a communications management plan can include:

- **Communications item.** The information that will be distributed to stakeholders.
- **Purpose.** The reason for the distribution of that information.
- **Frequency.** How often that information will be distributed.
- **Start/end dates.** The time frame for the distribution of the information.
- **Format/medium.** The layout of the information and the method of transmission.
- **Responsibility.** The team member charged with the distribution of information.

Communication Planning often entails creation of additional deliverables that, in turn, require additional time and effort. Thus, the project's work breakdown structure, project schedule, and project budget are updated accordingly.

10.2 Information Distribution

Information Distribution involves making information available to project stakeholders in a timely manner. Information distribution includes implementing the communications management plan, as well as responding to unexpected requests for information.

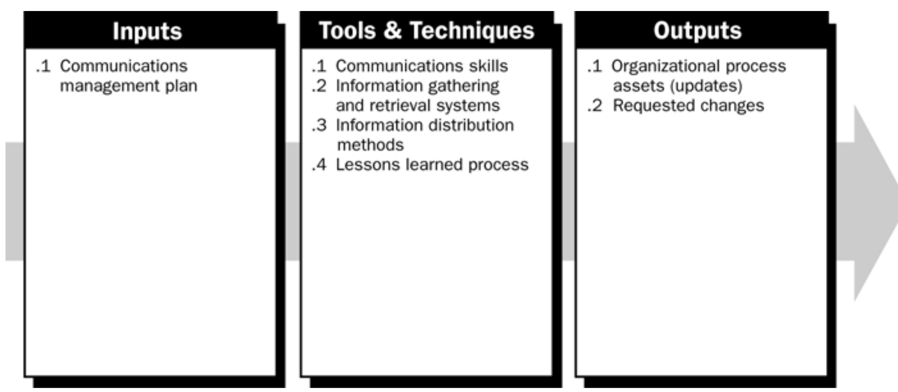


Figure 10-5. Information Distribution: Inputs, Tools & Techniques, and Outputs

10.2.1 Information Distribution: Inputs

.1 Communications Management Plan

Described in Section 10.1.3.1.

10.2.2 Information Distribution: Tools and Techniques

.1 Communications Skills

Communications skills are part of general management skills and are used to exchange information. General management skills related to communications include ensuring that the right persons get the right information at the right time, as defined in the communications management plan. General management skills also include the art of managing stakeholder requirements.

As part of the communications process, the sender is responsible for making the information clear and complete so that the receiver can receive it correctly, and for confirming that it is properly understood. The receiver is responsible for making sure that the information is received in its entirety and understood correctly. Communicating has many dimensions:

- Written and oral, listening, and speaking
- Internal (within the project) and external (customer, the media, the public)
- Formal (reports, briefings) and informal (memos, ad hoc conversations)
- Vertical (up and down the organization) and horizontal (with peers).

.2 Information Gathering and Retrieval Systems

Information can be gathered and retrieved through a variety of media including manual filing systems, electronic databases, project management software, and systems that allow access to technical documentation, such as engineering drawings, design specifications, and test plans.

.3 Information Distribution Methods

Information Distribution is information collection, sharing, and distribution to project stakeholders in a timely manner across the project life cycle. Project information can be distributed using a variety of methods, including:

- Project meetings, hard-copy document distribution, manual filing systems, and shared-access electronic databases
- Electronic communication and conferencing tools, such as e-mail, fax, voice mail, telephone, video and Web conferencing, and Web publishing
- Electronic tools for project management, such as Web interfaces to scheduling and project management software, meeting and virtual office support software, portals, and collaborative work management tools.

.4 Lessons Learned Process

A lessons learned session focuses on identifying project successes and project failures, and includes recommendations to improve future performance on projects. During the project life cycle, the project team and key stakeholders identify lessons learned concerning the technical, managerial, and process aspects of the project. The lessons learned are compiled, formalized, and stored through the project's duration.

The focus of lessons learned meetings can vary. In some cases, the focus is on strong technical or product development processes, while in other cases, the focus is on the processes that aided or hindered performance of the work. Teams can gather information more frequently if they feel that the increased quantity of data merits the additional investment of time and money. Lessons learned provide future project teams with the information that can increase effectiveness and efficiency of project management. In addition, phase-end lessons learned sessions provide a good team-building exercise. Project managers have a professional obligation to conduct lessons learned sessions for all projects with key internal and external stakeholders, particularly if the project yielded less than desirable results. Some specific results from lessons learned include:

- Update of the lessons learned knowledge base
- Input to knowledge management system
- Updated corporate policies, procedures, and processes
- Improved business skills
- Overall product and service improvements
- Updates to the risk management plan.

10.2.3 Information Distribution: Outputs

.1 Organizational Process Assets (Updates)

- **Lessons learned documentation.** Documentation includes the causes of issues, reasoning behind the corrective action chosen, and other types of lessons learned about Information Distribution. Lessons learned are documented so that they become part of the historical database for both this project and the performing organization.
- **Project records.** Project records can include correspondence, memos, and documents describing the project. This information should, to the extent possible and appropriate, be maintained in an organized fashion. Project team members can also maintain records in a project notebook.
- **Project reports.** Formal and informal project reports detail project status, and include lessons learned, issues logs, project closure reports, and outputs from other Knowledge Areas (Chapters 4–12).

- **Project presentations.** The project team provides information formally or informally to any or all of the project stakeholders. The information is relevant to the needs of the audience, and the method of presentation is appropriate.
- **Feedback from stakeholders.** Information received from stakeholders concerning project operations can be distributed and used to modify or improve future performance of the project.
- **Stakeholder notifications.** Information may be provided to stakeholders about resolved issues, approved changes, and general project status.

.2 Requested Changes

Changes to the Information Distribution process should trigger changes to the project management plan and the communications management plan. Requested changes (additions, modifications, revisions) to the project management plan and its subsidiary plans are reviewed, and the disposition is managed through the Integrated Change Control process (Section 4.6).

10.3 Performance Reporting

The performance reporting process involves the collection of all baseline data, and distribution of performance information to stakeholders. Generally, this performance information includes how resources are being used to achieve project objectives. Performance reporting should generally provide information on scope, schedule, cost, and quality. Many projects also require information on risk and procurement. Reports may be prepared comprehensively or on an exception basis.

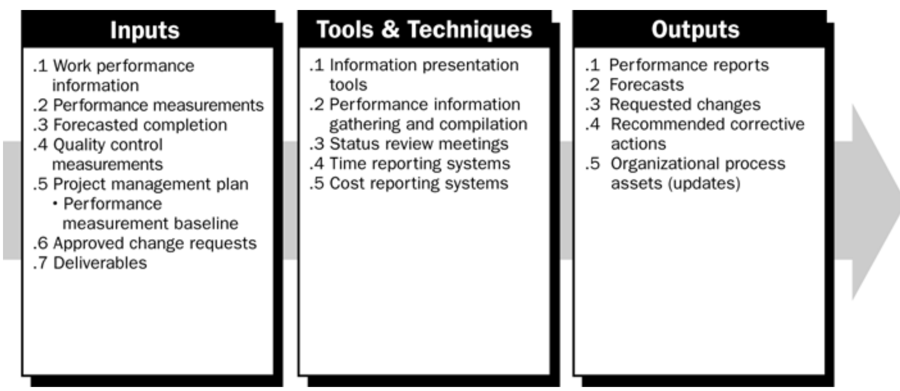


Figure 10-6. Performance Reporting: Inputs, Tools & Techniques, and Outputs

10.3.1 Performance Reporting: Inputs

.1 Work Performance Information

Work performance information on the completion status of the deliverables and what has been accomplished is collected as part of project execution, and is fed into the Performance Reporting process. Collecting the work performance information is discussed in further detail in the Direct and Manage Project Execution process (Section 4.4).

.2 Performance Measurements

Described in Section 6.6.3.3 and Section 7.3.3.3.

.3 Forecasted Completion

Described in Section 7.3.3.4.

.4 Quality Control Measurements

Described in Section 8.3.3.1.

.5 Project Management Plan

The project management plan provides baseline information (Section 4.3).

- **Performance measurement baseline.** An approved plan for the project work against which project execution is compared, and deviations are measured for management control. The performance measurement baseline typically integrates scope, schedule, and cost parameters of a project, but may also include technical and quality parameters.

.6 Approved Change Requests

Approved change requests (Section 4.6.3.1) are requested changes to expand or contract project scope, to modify the estimated cost, or to revise activity duration estimates that have been approved and are ready for implementation by the project team.

.7 Deliverables

Deliverables (Section 4.4.3.1) are any unique and verifiable product, result, or capability to perform a service that must be produced to complete a process, phase, or project. The term is often used more narrowly in reference to an external deliverable that is subject to approval by the project sponsor or customer.

10.3.2 Performance Reporting: Tools and Techniques

.1 Information Presentation Tools

Software packages that include table reporting, spreadsheet analysis, presentations, or graphic capabilities can be used to create presentation-quality images of project performance data.

.2 Performance Information Gathering and Compilation

Information can be gathered and compiled from a variety of media including manual filing systems, electronic databases, project management software, and systems that allow access to technical documentation, such as engineering drawings, design specifications and test plans, to produce forecasts as well as performance, status and progress reports.

.3 Status Review Meetings

Status review meetings are regularly scheduled events to exchange information about the project. On most projects, status review meetings will be held at various frequencies and on different levels. For example, the project management team can meet weekly by itself and monthly with the customer.

.4 Time Reporting Systems

Time reporting systems record and provide time expended for the project.

.5 Cost Reporting Systems

Cost reporting systems record and provide the cost expended for the project.

10.3.3 Performance Reporting: Outputs

.1 Performance Reports

Performance reports organize and summarize the information gathered, and present the results of any analysis as compared to the performance measurement baseline. Reports should provide the status and progress information, and the level of detail required by various stakeholders, as documented in the communications management plan. Common formats for performance reports include bar charts, S-curves, histograms, and tables. Earned value analysis data is often included as part of performance reporting. While S-curves, such as those in Figure 7-7, can display one view of earned value analysis data, Figure 10-7 gives a tabular view of earned value data.

	Planned	Earned	Cost					Performance Index	
WBS Element	Budget	Earned Value	Actual Cost	Cost Variance		Schedule Variance		Cost	Schedule
	($) (PV)	($) (EV)	($) (AC)	($) (EV – AC)	(%) (CV ÷ EV)	($) (EV – PV)	(%) (SV ÷ PV)	CPI (EV ÷ AC)	SPI (EV ÷ PV)
1.0 Pre-Pilot Plan	63,000	58,000	62,500	-4,500	-7.8	-5,000	-7.9	0.93	0.92
2.0 Checklists	64,000	48,000	46,800	1,200	2.5	-16,000	-25.0	1.03	0.75
3.0 Curriculum	23,000	20,000	23,500	-3,500	-17.5	-3,000	-13.0	0.85	0.87
4.0 Mid-Term Evaluation	68,000	68,000	72,500	-4,500	-6.6	0	0.0	0.94	1.00
5.0 Implementation Support	12,000	10,000	10,000	0	0.0	-2,000	-16.7	1.00	0.83
6.0 Manual of Practice	7,000	6,200	6,000	200	3.2	-800	-11.4	1.03	0.89
7.0 Roll-Out Plan	20,000	13,500	18,100	-4,600	-34.1	-6,500	-32.5	.075	0.68
Totals	**257,000**	**223,700**	**239,400**	**-15,700**	**-7.0**	**-33,300**	**-13.0**	**0.93**	**0.87**

Note: All figures are project-to-date
*Other units of measure that may be used in these calculations may include: labor hours, cubic yards of concrete, etc.

Figure 10-7 Tabular Performance Report Sample

.2 Forecasts

Forecasts are updated and reissued based on work performance information provided as the project is executed. This information is about the project's past performance that could impact the project in the future, for example, estimate at completion and estimate to complete.

.3 Requested Changes

Analysis of project performance often generates requested changes (Section 4.4.3.2) to some aspect of the project. These requested changes are processed and dispositioned through the Integrated Change Control process (Section 4.6).

.4 Recommended Corrective Actions

Recommended corrective actions (Section 4.5.3.1) include changes that bring the expected future performance of the project in line with the project management plan.

.5 Organizational Process Assets (Updates)

Lessons learned documentation includes the causes of issues, reasoning behind the corrective action chosen, and other types of lessons learned about performance reporting. Lessons learned are documented so that they become part of the historical database for both this project and the performing organization.

10.4 Manage Stakeholders

Stakeholder management refers to managing communications to satisfy the needs of, and resolve issues with, project stakeholders. Actively managing stakeholders increases the likelihood that the project will not veer off track due to unresolved stakeholder issues, enhances the ability of persons to operate synergistically, and limits disruptions during the project. The project manager is usually responsible for stakeholder management.

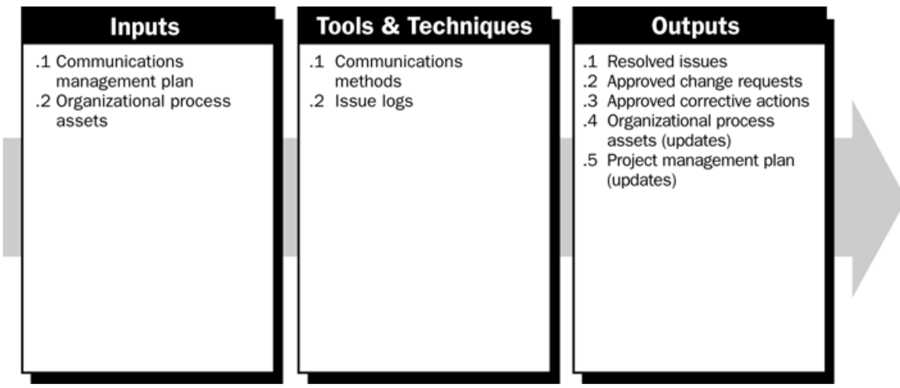


Figure 10-8. Manage Stakeholders: Inputs, Tools & Techniques, and Outputs

10.4.1 Manage Stakeholders: Inputs

.1 Communications Management Plan

Stakeholder requirements and expectations provide an understanding of stakeholder goals, objectives, and level of communication during the project. The needs and expectations are identified, analyzed, and documented in the communications management plan (Section 10.1.3.1), which is a subsidiary of the project management plan.

.2 Organizational Process Assets

As project issues arise, the project manager should address and resolve them with the appropriate project stakeholders.

10.4.2 Manage Stakeholders: Tools and Techniques

.1 Communications Methods

The methods of communications identified for each stakeholder in the communications management plan are utilized during stakeholder management.

Face-to-face meetings are the most effective means for communicating and resolving issues with stakeholders. When face-to-face meetings are not warranted or practical (such as on international projects), telephone calls, electronic mail, and other electronic tools are useful for exchanging information and dialoguing.

.2 Issue Logs

An issue log or action-item log is a tool that can be used to document and monitor the resolution of issues. Issues do not usually rise to the importance of becoming a project or activity, but are usually addressed in order to maintain good, constructive working relationships among various stakeholders, including team members.

An issue is clarified and stated in a way that it can be resolved. An owner is assigned and a target date is usually established for closure. Unresolved issues can be a major source of conflict and project delays.

10.4.3 Manage Stakeholders: Outputs

.1 Resolved Issues

As stakeholder requirements are identified and resolved, the issues log will document concerns that have been addressed and closed. Examples include:

- Customers agree to a follow-on contract, which ends protracted discussion of whether requested changes to project scope are within or outside the scope of the current project
- More staff is added to the project, thus closing the issue that the project is short on required skills
- Negotiations with functional managers in the organization competing for scarce human resources end in a mutually satisfactory solution before causing project delays
- Issues raised by board members about the financial viability of the project have been answered, allowing the project to move forward as planned.

.2 Approved Change Requests

Approved change requests (Section 4.6.3.1) include stakeholder issue status changes in the staffing management plan, which are necessary to reflect changes to how communications with stakeholders will occur.

.3 Approved Corrective Actions

Approved corrective actions (Section 4.6.3.5) include changes that bring the expected future performance of the project in line with the project management plan.

.4 Organizational Process Assets (Updates)

Lessons learned documentation includes the causes of issues, the reasoning behind the corrective action chosen, and other types of lessons learned about stakeholder management. Lessons learned are documented so that they become part of the historical database for both this project and the performing organization.

.5 Project Management Plan (Updates)

The project management plan is updated to reflect the changes made to the communications plan.

CHAPTER 11

Project Risk Management

Project Risk Management includes the processes concerned with conducting risk management planning, identification, analysis, responses, and monitoring and control on a project; most of these processes are updated throughout the project. The objectives of Project Risk Management are to increase the probability and impact of positive events, and decrease the probability and impact of events adverse to the project. Figure 11-1 provides an overview of the Project Risk Management processes, and Figure 11-2 provides a process flow diagram of those processes and their inputs, outputs, and other related Knowledge Area processes. The Project Risk Management processes include the following:

11.1 **Risk Management Planning** – deciding how to approach, plan, and execute the risk management activities for a project.

11.2 **Risk Identification** – determining which risks might affect the project and documenting their characteristics.

11.3 **Qualitative Risk Analysis** – prioritizing risks for subsequent further analysis or action by assessing and combining their probability of occurrence and impact.

11.4 **Quantitative Risk Analysis** – numerically analyzing the effect on overall project objectives of identified risks.

11.5 **Risk Response Planning** – developing options and actions to enhance opportunities, and to reduce threats to project objectives.

11.6 **Risk Monitoring and Control** – tracking identified risks, monitoring residual risks, identifying new risks, executing risk response plans, and evaluating their effectiveness throughout the project life cycle.

These processes interact with each other and with the processes in the other Knowledge Areas as well. Each process can involve effort from one or more persons or groups of persons based on the needs of the project. Each process occurs at least once in every project and occurs in one or more project phases, if the project is divided into phases. Although the processes are presented here as discrete elements with well-defined interfaces, in practice they may overlap and interact in ways not detailed here. Process interactions are discussed in detail in Chapter 3.

Project risk is an uncertain event or condition that, if it occurs, has a positive or a negative effect on at least one project objective, such as time, cost, scope, or quality (i.e., where the project time objective is to deliver in accordance with the agreed-upon schedule; where the project cost objective is to deliver within the agreed-upon cost; etc.). A risk may have one or more causes and, if it occurs, one or more impacts. For example, a cause may be requiring an environmental permit to do work, or having limited personnel assigned to design the project. The risk event is that the permitting agency may take longer than planned to issue a permit, or the design personnel available and assigned may not be adequate for the activity. If either of these uncertain events occurs, there may be an impact on the project cost, schedule, or performance. Risk conditions could include aspects of the project's or organization's environment that may contribute to project risk, such as poor project management practices, lack of integrated management systems, concurrent multiple projects, or dependency on external participants who cannot be controlled.

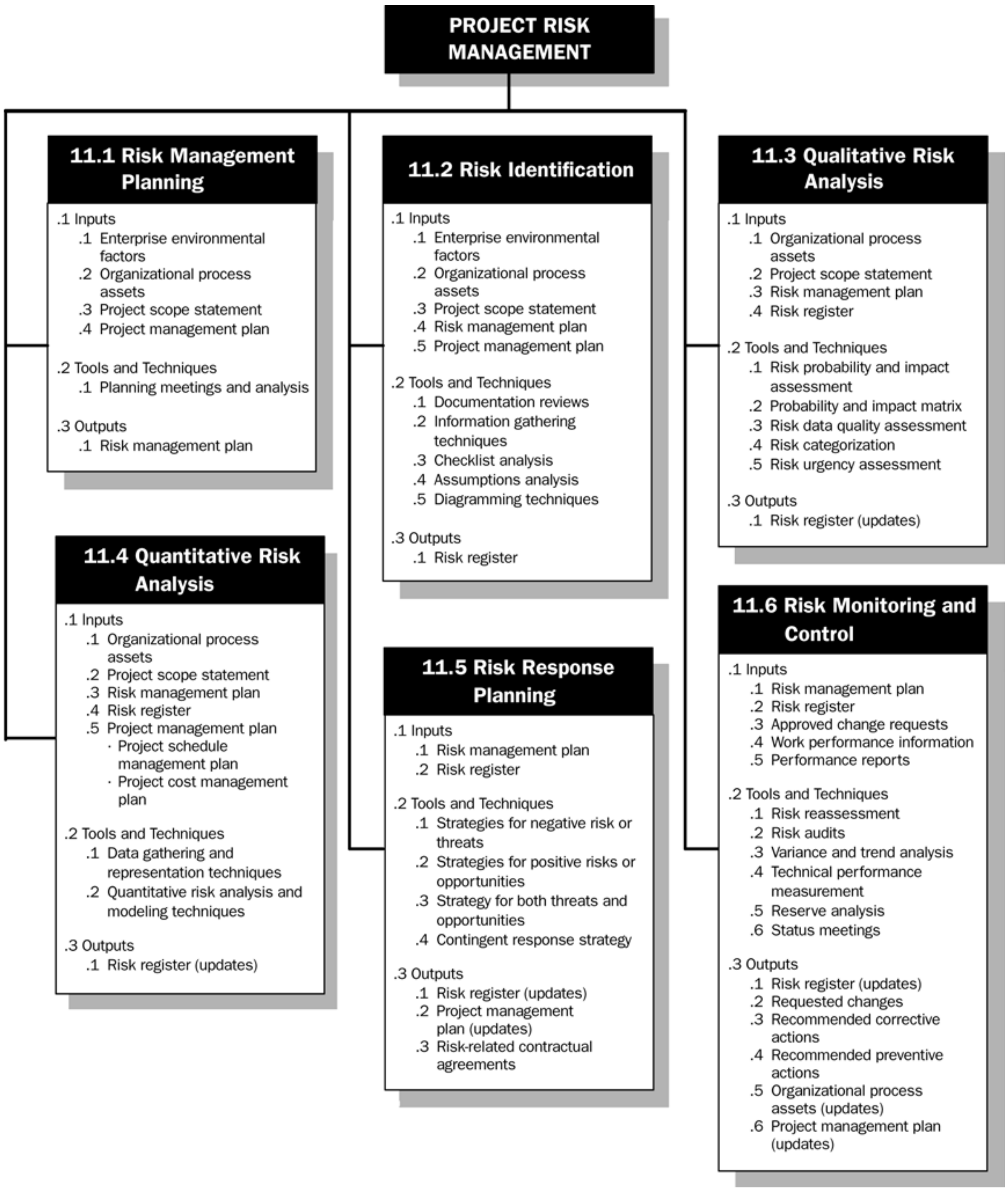


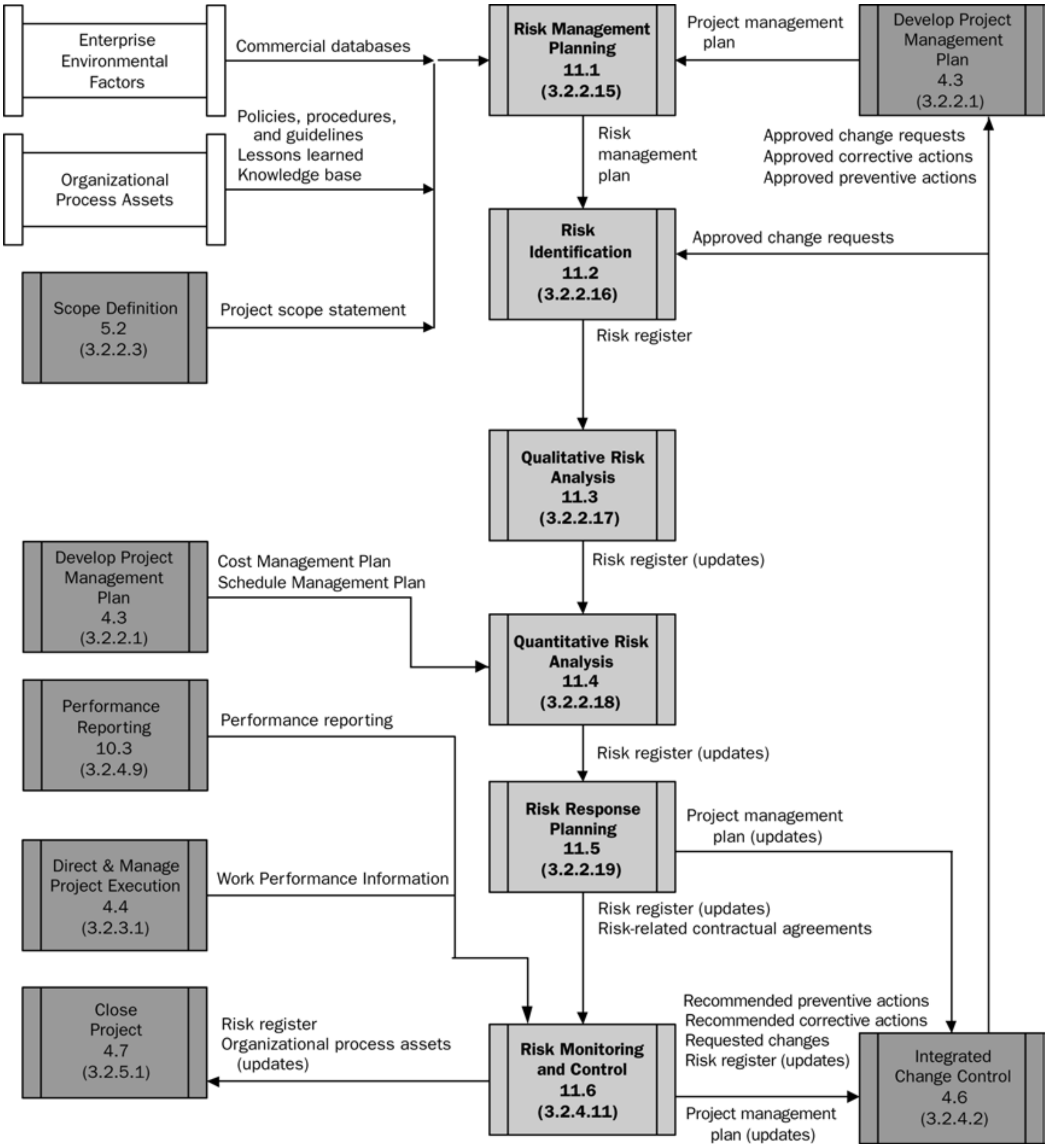
Figure 11-1. Project Risk Management Overview

Project risk has its origins in the uncertainty that is present in all projects. Known risks are those that have been identified and analyzed, and it may be possible to plan for those risks using the processes described in this chapter. Unknown risks cannot be managed proactively, and a prudent response by the project team can be to allocate general contingency against such risks, as well as against any known risks for which it may not be cost-effective or possible to develop a proactive response.

Organizations perceive risk as it relates to threats to project success, or to opportunities to enhance chances of project success. Risks that are threats to the project may be accepted if the risk is in balance with the reward that may be gained by taking the risk. For example, adopting a fast track schedule (Section 6.5.2.3) that may be overrun is a risk taken to achieve an earlier completion date. Risks that are opportunities, such as work acceleration that may be gained by assigning additional staff, may be pursued to benefit the project's objectives.

Persons and, by extension, organizations have attitudes toward risk that affect both the accuracy of the perception of risk and the way they respond. Attitudes about risk should be made explicit wherever possible. A consistent approach to risk that meets the organization's requirements should be developed for each project, and communication about risk and its handling should be open and honest. Risk responses reflect an organization's perceived balance between risk-taking and risk-avoidance.

To be successful, the organization should be committed to addressing the management of risk proactively and consistently throughout the project.



Note: Not all process interactions and data flow among the processes are shown.

Figure 11-2. Project Risk Management Process Flow Diagram

11

11.1 Risk Management Planning

Careful and explicit planning enhances the possibility of success of the five other risk management processes. Risk Management Planning is the process of deciding how to approach and conduct the risk management activities for a project. Planning of risk management processes is important to ensure that the level, type, and visibility of risk management are commensurate with both the risk and importance of the project to the organization, to provide sufficient resources and time for risk management activities, and to establish an agreed-upon basis for evaluating risks. The Risk Management Planning process should be completed early during project planning, since it is crucial to successfully performing the other processes described in this chapter.

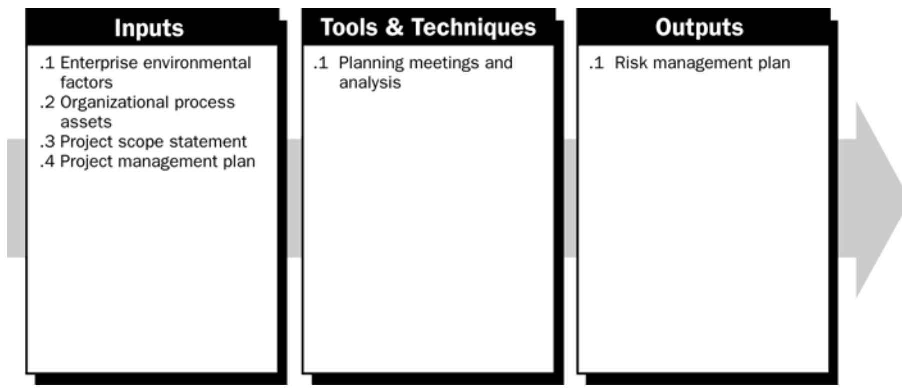


Figure 11-3. Risk Management Planning: Inputs, Tools & Techniques, and Outputs

11.1.1 Risk Management Planning: Inputs

.1 Enterprise Environmental Factors

The attitudes toward risk and the risk tolerance of organizations and people involved in the project will influence the project management plan (Section 4.3). Risk attitudes and tolerances may be expressed in policy statements or revealed in actions (Section 4.1.1.3).

.2 Organizational Process Assets

Organizations may have predefined approaches to risk management such as risk categories, common definition of concepts and terms, standard templates, roles and responsibilities, and authority levels for decision-making.

.3 Project Scope Statement

Described in Section 5.2.3.1.

.4 Project Management Plan

Described in Section 4.3.

11.1.2 Risk Management Planning: Tools and Techniques

.1 Planning Meetings and Analysis

Project teams hold planning meetings to develop the risk management plan. Attendees at these meetings may include the project manager, selected project team members and stakeholders, anyone in the organization with responsibility to manage the risk planning and execution activities, and others, as needed.

Basic plans for conducting the risk management activities are defined in these meetings. Risk cost elements and schedule activities will be developed for inclusion in the project budget and schedule, respectively. Risk responsibilities will be assigned. General organizational templates for risk categories and definitions of terms such as levels of risk, probability by type of risk, impact by type of objectives, and the probability and impact matrix will be tailored to the specific project. The outputs of these activities will be summarized in the risk management plan.

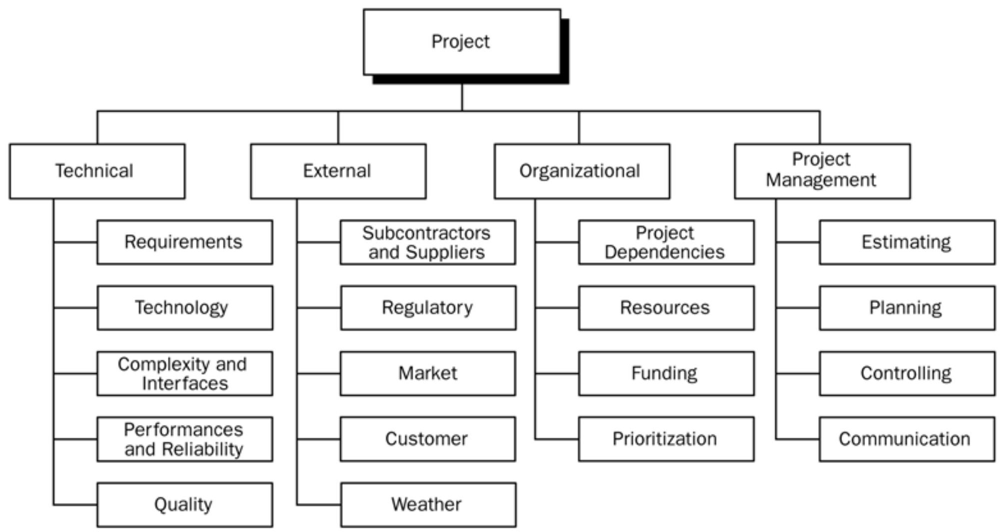
11.1.3 Risk Management Planning: Outputs

.1 Risk Management Plan

The risk management plan describes how risk management will be structured and performed on the project. It becomes a subset of the project management plan (Section 4.3). The risk management plan includes the following:

- **Methodology.** Defines the approaches, tools, and data sources that may be used to perform risk management on the project.
- **Roles and responsibilities.** Defines the lead, support, and risk management team membership for each type of activity in the risk management plan, assigns people to these roles, and clarifies their responsibilities.
- **Budgeting.** Assigns resources and estimates costs needed for risk management for inclusion in the project cost baseline (Section 7.2.3.1).
- **Timing.** Defines when and how often the risk management process will be performed throughout the project life cycle, and establishes risk management activities to be included in the project schedule (Section 6.5.3.1).
- **Risk categories.** Provides a structure that ensures a comprehensive process of systematically identifying risk to a consistent level of detail and contributes to the effectiveness and quality of Risk Identification. An organization can use a previously prepared categorization of typical risks. A risk breakdown structure (RBS) (Figure 11-4) is one approach to providing such a structure, but it can also be addressed by simply listing the various aspects of the project. The risk categories may be revisited during the Risk Identification process. A good practice is to review the risk categories during the Risk Management Planning process prior to their use in the Risk Identification process. Risk categories based on prior projects may need to be tailored, adjusted, or extended to new situations before those categories can be used on the current project.

- **Definitions of risk probability and impact.** The quality and credibility of the Qualitative Risk Analysis process requires that different levels of the risks' probabilities and impacts be defined. General definitions of probability levels and impact levels are tailored to the individual project during the Risk Management Planning process for use in the Qualitative Risk Analysis process (Section 11.3).



The Risk Breakdown Structure (RBS) lists the categories and sub-categories within which risks may arise for a typical project. Different RBSs will be appropriate for different types of projects and different types of organizations. One benefit of this approach is to remind participants in a risk identification exercise of the many sources from which project risk may arise.

Figure 11-4. Example of a Risk Breakdown Structure (RBS)

A relative scale representing probability values from "very unlikely" to "almost certainty" could be used. Alternatively, assigned numerical probabilities on a general scale (e.g., 0.1, 0.3, 0.5, 0.7, 0.9) can be used. Another approach to calibrating probability involves developing descriptions of the state of the project that relate to the risk under consideration (e.g., the degree of maturity of the project design).

NAVIGATION LINKS

ABBREVIATION LIST

The impact scale reflects the significance of impact, either negative for threats or positive for opportunities, on each project objective if a risk occurs. Impact scales are specific to the objective potentially impacted, the type and size of the project, the organization's strategies and financial state, and the organization's sensitivity to particular impacts. Relative scales for impact are simply rank-ordered descriptors such as "very low," "low," "moderate," "high," and "very high," reflecting increasingly extreme impacts as defined by the organization. Alternatively, numeric scales assign values to these impacts. These values may be linear (e.g., 0.1, 0.3, 0.5, 0.7, 0.9) or nonlinear (e.g., 0.05, 0.1, 0.2, 0.4, 0.8). Nonlinear scales may represent the organization's desire to avoid high-impact threats or exploit high-impact opportunities, even if they have relatively low probability. In using nonlinear scales, it is important to understand what is meant by the numbers and their relationship to each other, how they were derived, and the effect they may have on the different objectives of the project.

Figure 11-5 is an example of negative impacts of definitions that might be used in evaluating risk impacts related to four project objectives. That figure illustrates both relative and numeric (in this case, nonlinear) approaches. The figure is not intended to imply that the relative and numeric terms are equivalent, but to show the two alternatives in one figure rather than two.

- **Probability and impact matrix.** Risks are prioritized according to their potential implications for meeting the project's objectives. The typical approach to prioritizing risks is to use a look-up table or a Probability and Impact Matrix (Figure 11-8 and Section 11.3.2.2). The specific combinations of probability and impact that lead to a risk being rated as "high," "moderate," or "low" importance—with the corresponding importance for planning responses to the risk (Section 11.5)—are usually set by the organization. They are reviewed and can be tailored to the specific project during the Risk Management Planning process.

Defined Conditions for Impact Scales of a Risk on Major Project Objectives
(Examples are shown for negative impacts only)

Project Objective	Relative or numerical scales are shown				
	Very low /.05	Low /.10	Moderate /.20	High /.40	Very high /.80
Cost	Insignificant cost increase	<10% cost increase	10-20% cost increase	20-40% cost increase	>40% cost Iincrease
Time	Insignificant time increase	<5% time increase	5-10% time increase	10-20% time iIncrease	>20% time increase
Scope	Scope decrease barely noticeable	Minor areas of scope affected	Major areas of scope affected	Scope reduction unacceptable to sponsor	Project end item is effectively useless
Quality	Quality degradation barely noticeable	Only very demanding applications are affected	Quality reduction requires sponsor approval	Quality reduction unacceptable to sponsor	Project end item is effectively useless

This table presents examples of risk impact definitions for four different project objectives. They should be tailored in the Risk Management Planning process to the individual project and to the organization's risk thresholds. Impact definitions can be developed for opportunities in a similar way.

Figure 11-5. Definition of Impact Scales for Four Project Objectives

- **Revised stakeholders' tolerances.** Stakeholders' tolerances may be revised in the Risk Management Planning process, as they apply to the specific project.
- **Reporting formats.** Describes the content and format of the risk register (Sections 11.2, 11.3, 11.4, and 11.5) as well as any other risk reports required. Defines how the outcomes of the risk management processes will be documented, analyzed, and communicated.
- **Tracking.** Documents how all facets of risk activities will be recorded for the benefit of the current project, future needs, and lessons learned. Documents whether and how risk management processes will be audited.

11.2 Risk Identification

Risk Identification determines which risks might affect the project and documents their characteristics. Participants in risk identification activities can include the following, where appropriate: project manager, project team members, risk management team (if assigned), subject matter experts from outside the project team, customers, end users, other project managers, stakeholders, and risk management experts. While these personnel are often key participants for risk identification, all project personnel should be encouraged to identify risks.

Risk Identification is an iterative process because new risks may become known as the project progresses through its life cycle (Section 2.1). The frequency of iteration and who participates in each cycle will vary from case to case. The project team should be involved in the process so that they can develop and maintain a sense of ownership of, and responsibility for, the risks and associated risk response actions. Stakeholders outside the project team may provide additional objective information. The Risk Identification process usually leads to the Qualitative Risk Analysis process (Section 11.3). Alternatively, it can lead directly to the Quantitative Risk Analysis process (Section 11.4) when conducted by an experienced risk manager. On some occasions, simply the identification of a risk may suggest its response, and these should be recorded for further analysis and implementation in the Risk Response Planning process (Section 11.5).

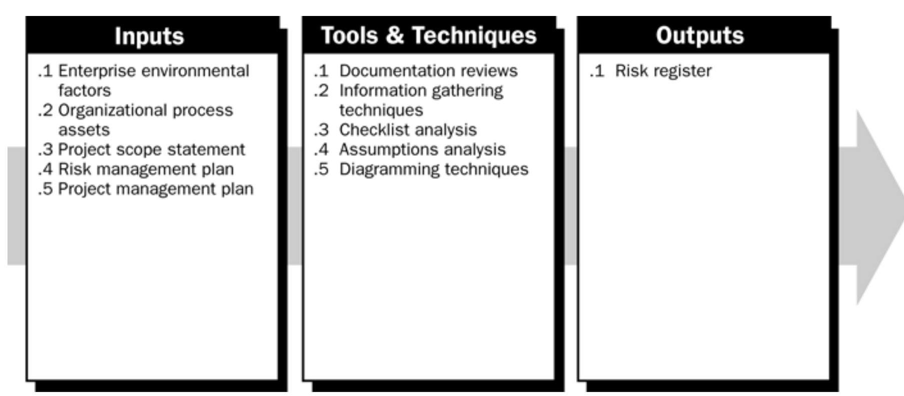


Figure 11-6. Risk Identification: Inputs, Tools & Techniques, and Outputs

11.2.1 Risk Identification: Inputs

.1 Enterprise Environmental Factors

Published information, including commercial databases, academic studies, benchmarking, or other industry studies, may also be useful in identifying risks (Section 4.1.1.3).

.2 Organizational Process Assets

Information on prior projects may be available from previous project files, including actual data and lessons learned (Section 4.1.1.4).

.3 Project Scope Statement

Project assumptions are found in the project scope statement (Section 5.2.3.1). Uncertainty in project assumptions should be evaluated as potential causes of project risk.

.4 Risk Management Plan

Key inputs from the risk management plan to the Risk Identification process are the assignments of roles and responsibilities, provision for risk management activities in the budget and schedule, and categories of risk (Section 11.1.3.1), which are sometimes expressed in an RBS (Figure 11-4).

.5 Project Management Plan

The Risk Identification process also requires an understanding of the schedule, cost, and quality management plans found in the project management plan (Section 4.3). Outputs of other Knowledge Area processes should be reviewed to identify possible risks across the entire project.

11.2.2 Risk Identification: Tools and Techniques

.1 Documentation Reviews

A structured review may be performed of project documentation, including plans, assumptions, prior project files, and other information. The quality of the plans, as well as consistency between those plans and with the project requirements and assumptions, can be indicators of risk in the project.

.2 Information Gathering Techniques

Examples of information gathering techniques used in identifying risk can include:

- **Brainstorming.** The goal of brainstorming is to obtain a comprehensive list of project risks. The project team usually performs brainstorming, often with a multidisciplinary set of experts not on the team. Ideas about project risk are generated under the leadership of a facilitator. Categories of risk (Section 11.1), such as a risk breakdown structure, can be used as a framework. Risks are then identified and categorized by type of risk and their definitions are sharpened.

- **Delphi technique.** The Delphi technique is a way to reach a consensus of experts. Project risk experts participate in this technique anonymously. A facilitator uses a questionnaire to solicit ideas about the important project risks. The responses are summarized and are then recirculated to the experts for further comment. Consensus may be reached in a few rounds of this process. The Delphi technique helps reduce bias in the data and keeps any one person from having undue influence on the outcome.
- **Interviewing.** Interviewing experienced project participants, stakeholders, and subject matter experts can identify risks. Interviews are one of the main sources of risk identification data gathering.
- **Root cause identification.** This is an inquiry into the essential causes of a project's risks. It sharpens the definition of the risk and allows grouping risks by causes. Effective risk responses can be developed if the root cause of the risk is addressed.
- **Strengths, weaknesses, opportunities, and threats (SWOT) analysis.** This technique ensures examination of the project from each of the SWOT perspectives, to increase the breadth of considered risks.

.3 Checklist Analysis

Risk identification checklists can be developed based on historical information and knowledge that has been accumulated from previous similar projects and from other sources of information. The lowest level of the RBS can also be used as a risk checklist. While a checklist can be quick and simple, it is impossible to build an exhaustive one. Care should be taken to explore items that do not appear on the checklist. The checklist should be reviewed during project closure to improve it for use on future projects.

.4 Assumptions Analysis

Every project is conceived and developed based on a set of hypotheses, scenarios, or assumptions. Assumptions analysis is a tool that explores the validity of assumptions as they apply to the project. It identifies risks to the project from inaccuracy, inconsistency, or incompleteness of assumptions.

.5 Diagramming Techniques

Risk diagramming techniques may include:

- **Cause-and-effect diagrams** (Section 8.3.2.1). These are also known as Ishikawa or fishbone diagrams, and are useful for identifying causes of risks.
- **System or process flow charts.** These show how various elements of a system interrelate, and the mechanism of causation (Section 8.3.2.3).
- **Influence diagrams.** These are graphical representations of situations showing causal influences, time ordering of events, and other relationships among variables and outcomes.

11.2.3 Risk Identification: Outputs

The outputs from Risk Identification are typically contained in a document that can be called a risk register.

.1 Risk Register

The primary outputs from Risk Identification are the initial entries into the risk register, which becomes a component of the project management plan (Section 4.3). The risk register ultimately contains the outcomes of the other risk management processes as they are conducted. The preparation of the risk register begins in the Risk Identification process with the following information, and then becomes available to other project management and Project Risk Management processes.

- **List of identified risks.** The identified risks, including their root causes and uncertain project assumptions, are described. Risks can cover nearly any topic, but a few examples include the following: A few large items with long lead times are on critical path. There could be a risk that industrial relations disputes at the ports will delay the delivery and, subsequently, delay completion of the construction phase. Another example is a project management plan that assumes a staff size of ten, but there are only six resources available. The lack of resources could impact the time required to complete the work and the activities would be late.
- **List of potential responses.** Potential responses to a risk may be identified during the Risk Identification process. These responses, if identified, may be useful as inputs to the Risk Response Planning process (Section 11.5).
- **Root causes of risk.** These are the fundamental conditions or events that may give rise to the identified risk.
- **Updated risk categories.** The process of identifying risks can lead to new risk categories being added to the list of risk categories. The RBS developed in the Risk Management Planning process may have to be enhanced or amended, based on the outcomes of the Risk Identification process.

11

11.3 Qualitative Risk Analysis

Qualitative Risk Analysis includes methods for prioritizing the identified risks for further action, such as Quantitative Risk Analysis (Section 11.4) or Risk Response Planning (Section 11.5). Organizations can improve the project's performance effectively by focusing on high-priority risks. Qualitative Risk Analysis assesses the priority of identified risks using their probability of occurring, the corresponding impact on project objectives if the risks do occur, as well as other factors such as the time frame and risk tolerance of the project constraints of cost, schedule, scope, and quality.

Definitions of the levels of probability and impact, and expert interviewing, can help to correct biases that are often present in the data used in this process. The time criticality of risk-related actions may magnify the importance of a risk. An evaluation of the quality of the available information on project risks also helps understand the assessment of the risk's importance to the project.

Qualitative Risk Analysis is usually a rapid and cost-effective means of establishing priorities for Risk Response Planning, and lays the foundation for Quantitative Risk Analysis, if this is required. Qualitative Risk Analysis should be revisited during the project's life cycle to stay current with changes in the project risks. Qualitative Risk Analysis requires outputs of the Risk Management Planning (Section 11.1) and Risk Identification (Section 11.2) processes. This process can lead into Quantitative Risk Analysis (Section 11.4) or directly into Risk Response Planning (Section 11.5).

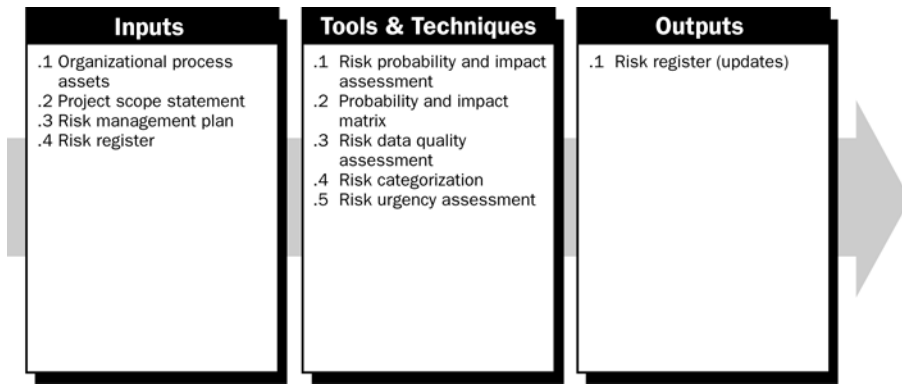


Figure 11-7. Qualitative Risk Analysis: Inputs, Tools & Techniques, and Outputs

11.3.1 Qualitative Risk Analysis: Inputs

.1 Organizational Process Assets

Data about risks on past projects and the lessons learned knowledge base can be used in the Qualitative Risk Analysis process.

.2 Project Scope Statement

Projects of a common or recurrent type tend to have more well-understood risks. Projects using state-of-the-art or first-of-its-kind technology, and highly complex projects, tend to have more uncertainty. This can be evaluated by examining the project scope statement (Section 5.2.3.1).

.3 Risk Management Plan

Key elements of the risk management plan for Qualitative Risk Analysis include roles and responsibilities for conducting risk management, budgets, and schedule activities for risk management, risk categories, definition of probability and impact, the probability and impact matrix, and revised stakeholders' risk tolerances (also enterprise environmental factors in Section 4.1.1.3). These inputs are usually tailored to the project during the Risk Management Planning process. If they are not available, they can be developed during the Qualitative Risk Analysis process.

.4 Risk Register

A key item from the risk register for Qualitative Risk Analysis is the list of identified risks (Section 11.2.3.1).

11.3.2 Qualitative Risk Analysis: Tools and Techniques

.1 Risk Probability and Impact Assessment

Risk probability assessment investigates the likelihood that each specific risk will occur. Risk impact assessment investigates the potential effect on a project objective such as time, cost, scope, or quality, including both negative effects for threats and positive effects for opportunities.

Probability and impact are assessed for each identified risk. Risks can be assessed in interviews or meetings with participants selected for their familiarity with the risk categories on the agenda. Project team members and, perhaps, knowledgeable persons from outside the project, are included. Expert judgment is required, since there may be little information on risks from the organization's database of past projects. An experienced facilitator may lead the discussion, since the participants may have little experience with risk assessment.

The level of probability for each risk and its impact on each objective is evaluated during the interview or meeting. Explanatory detail, including assumptions justifying the levels assigned, is also recorded. Risk probabilities and impacts are rated according to the definitions given in the risk management plan (Section 11.1.3.1). Sometimes, risks with obviously low ratings of probability and impact will not be rated, but will be included on a watchlist for future monitoring.

.2 Probability and Impact Matrix

Risks can be prioritized for further quantitative analysis (Section 11.4) and response (Section 11.5), based on their risk rating. Ratings are assigned to risks based on their assessed probability and impact (Section 11.3.2.2). Evaluation of each risk's importance and, hence, priority for attention is typically conducted using a look-up table or a probability and impact matrix (Figure 11-8). Such a matrix specifies combinations of probability and impact that lead to rating the risks as low, moderate, or high priority. Descriptive terms or numeric values can be used, depending on organizational preference.

The organization should determine which combinations of probability and impact result in a classification of high risk ("red condition"), moderate risk ("yellow condition"), and low risk ("green condition"). In a black-and-white matrix, these conditions can be denoted by different shades of gray. Specifically, in Figure 11-8, the dark gray area (with the largest numbers) represents high risk; the medium gray area (with the smallest numbers) represents low risk; and the light gray area (with in-between numbers) represents moderate risk. Usually, these risk-rating rules are specified by the organization in advance of the project, and included in organizational process assets (Section 4.1.1.4). Risk rating rules can be tailored in the Risk Management Planning process (Section 11.1) to the specific project.

A probability and impact matrix, such as the one shown in Figure 11-8, is often used.

Probability and Impact Matrix

Probability	Threats					Opportunities				
0.90	0.05	0.09	0.18	0.36	0.72	0.72	0.36	0.18	0.09	0.05
0.70	0.04	0.07	0.14	0.28	0.56	0.56	0.28	0.14	0.07	0.04
0.50	0.03	0.05	0.10	0.20	0.40	0.40	0.20	0.10	0.05	0.03
0.30	0.02	0.03	0.06	0.12	0.24	0.24	0.12	0.06	0.03	0.02
0.10	0.01	0.01	0.02	0.04	0.08	0.08	0.04	0.02	0.01	0.01
	0.05	0.10	0.20	0.40	0.80	0.80	0.40	0.20	0.10	0.05

Impact (ratio scale) on an objective (e.g., cost, time, scope or quality)

Each risk is rated on its probability of occurring and impact on an objective if it does occur. The organization's thresholds for low, moderate or high risks are shown in the matrix and determine whether the risk is scored as high, moderate or low for that objective.

Figure 11-8. Probability and Impact Matrix

As illustrated in Figure 11-8, an organization can rate a risk separately for each objective (e.g., cost, time, and scope). In addition, it can develop ways to determine one overall rating for each risk. Finally, opportunities and threats can be handled in the same matrix using definitions of the different levels of impact that are appropriate for each.

The risk score helps guide risk responses. For example, risks that have a negative impact on objectives if they occur (threats), and that are in the high-risk (dark gray) zone of the matrix, may require priority action and aggressive response strategies. Threats in the low-risk (medium gray) zone may not require proactive management action beyond being placed on a watchlist or adding a contingency reserve.

Similarly for opportunities, those in the high-risk (dark gray) zone that can be obtained most easily and offer the greatest benefit should, therefore, be targeted first. Opportunities in the low-risk (medium gray) zone should be monitored.

.3 Risk Data Quality Assessment

A qualitative risk analysis requires accurate and unbiased data if it is to be credible. Analysis of the quality of risk data is a technique to evaluate the degree to which the data about risks is useful for risk management. It involves examining the degree to which the risk is understood and the accuracy, quality, reliability, and integrity of the data about the risk.

The use of low-quality risk data may lead to a qualitative risk analysis of little use to the project. If data quality is unacceptable, it may be necessary to gather better data. Often, collection of information about risks is difficult, and consumes time and resources beyond that originally planned.

.4 **Risk Categorization**

Risks to the project can be categorized by sources of risk (e.g., using the RBS), the area of the project affected (e.g., using the WBS), or other useful category (e.g., project phase) to determine areas of the project most exposed to the effects of uncertainty. Grouping risks by common root causes can lead to developing effective risk responses.

.5 **Risk Urgency Assessment**

Risks requiring near-term responses may be considered more urgent to address. Indicators of priority can include time to effect a risk response, symptoms and warning signs, and the risk rating.

11.3.3 Qualitative Risk Analysis: Outputs

.1 **Risk Register (Updates)**

The risk register is initiated during the Risk Identification process. The risk register is updated with information from Qualitative Risk Analysis and the updated risk register is included in the project management plan. The risk register updates from Qualitative Risk Analysis include:

- **Relative ranking or priority list of project risks.** The probability and impact matrix can be used to classify risks according to their individual significance. The project manager can then use the prioritized list to focus attention on those items of high significance to the project, where responses can lead to better project outcomes. Risks may be listed by priority separately for cost, time, scope, and quality, since organizations may value one objective over another. A description of the basis for the assessed probability and impact should be included for risks assessed as important to the project.
- **Risks grouped by categories.** Risk categorization can reveal common root causes of risk or project areas requiring particular attention. Discovering concentrations of risk may improve the effectiveness of risk responses.
- **List of risks requiring response in the near-term.** Those risks that require an urgent response and those that can be handled at a later date may be put into different groups.
- **List of risks for additional analysis and response.** Some risks might warrant more analysis, including Quantitative Risk Analysis, as well as response action.
- **Watchlists of low priority risks.** Risks that are not assessed as important in the Qualitative Risk Analysis process can be placed on a watchlist for continued monitoring.
- **Trends in qualitative risk analysis results.** As the analysis is repeated, a trend for particular risks may become apparent, and can make risk response or further analysis more or less urgent/important.

11.4 Quantitative Risk Analysis

Quantitative Risk Analysis is performed on risks that have been prioritized by the Qualitative Risk Analysis process as potentially and substantially impacting the project's competing demands. The Quantitative Risk Analysis process analyzes the effect of those risk events and assigns a numerical rating to those risks. It also presents a quantitative approach to making decisions in the presence of uncertainty. This process uses techniques such as Monte Carlo simulation and decision tree analysis to:

- Quantify the possible outcomes for the project and their probabilities
- Assess the probability of achieving specific project objectives
- Identify risks requiring the most attention by quantifying their relative contribution to overall project risk
- Identify realistic and achievable cost, schedule, or scope targets, given the project risks
- Determine the best project management decision when some conditions or outcomes are uncertain.

Quantitative Risk Analysis generally follows the Qualitative Risk Analysis process, although experienced risk managers sometimes perform it directly after Risk Identification. In some cases, Quantitative Risk Analysis may not be required to develop effective risk responses. Availability of time and budget, and the need for qualitative or quantitative statements about risk and impacts, will determine which method(s) to use on any particular project. Quantitative Risk Analysis should be repeated after Risk Response Planning, as well as part of Risk Monitoring and Control, to determine if the overall project risk has been satisfactorily decreased. Trends can indicate the need for more or less risk management action. It is an input to the Risk Response Planning process.

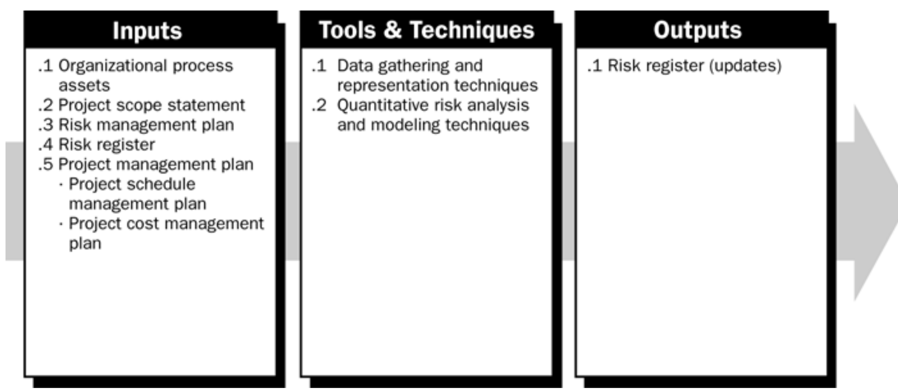


Figure 11-9. Quantitative Risk Analysis: Inputs, Tools & Techniques, and Outputs

11.4.1 Quantitative Risk Analysis: Inputs

.1 **Organizational Process Assets**

Information on prior, similar completed projects, studies of similar projects by risk specialists, and risk databases that may be available from industry or proprietary sources.

.2 **Project Scope Statement**

Described in Section 5.2.3.1.

.3 **Risk Management Plan**

Key elements of the risk management plan for Quantitative Risk Analysis include roles and responsibilities for conducting risk management, budgets, and schedule activities for risk management, risk categories, the RBS, and revised stakeholders' risk tolerances.

.4 **Risk Register**

Key items from the risk register for Quantitative Risk Analysis include the list of identified risks, the relative ranking or priority list of project risks, and the risks grouped by categories.

.5 **Project Management Plan**

The project management plan includes:

- **Project schedule management plan.** The project schedule management plan sets the format and establishes criteria for developing and controlling the project schedule (described in the Chapter 6 introductory material).
- **Project cost management plan.** The project cost management plan sets the format and establishes criteria for planning, structuring, estimating, budgeting, and controlling project costs (described in the Chapter 7 introductory material).

11

11.4.2 Quantitative Risk Analysis: Tools and Techniques

.1 **Data Gathering and Representation Techniques**

- **Interviewing.** Interviewing techniques are used to quantify the probability and impact of risks on project objectives. The information needed depends upon the type of probability distributions that will be used. For instance, information would be gathered on the optimistic (low), pessimistic (high), and most likely scenarios for some commonly used distributions, and the mean and standard deviation for others. Examples of three-point estimates for a cost estimate are shown in Figure 11-10. Documenting the rationale of the risk ranges is an important component of the risk interview, because it can provide information on reliability and credibility of the analysis.

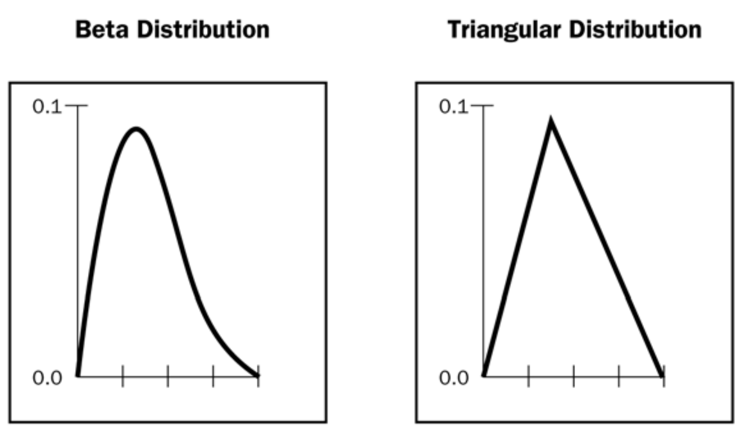
Range of Project Cost Estimates

WBS Element	Low	Most Likely	High
Design	4	6	10
Build	16	20	35
Test	11	15	23
Total Project		41	

The risk interview determines the three-point estimates for each WBS element for triangular or other asymmetrical distributions. In this example, the likelihood of completing the project at or below the traditional estimate of $41 is relatively small as shown in the simulation results (Figure 11-13).

Figure 11-10. Range of Project Cost Estimates Collected During the Risk Interview

- **Probability distributions.** Continuous probability distributions represent the uncertainty in values, such as durations of schedule activities and costs of project components. Discrete distributions can be used to represent uncertain events, such as the outcome of a test or a possible scenario in a decision tree. Two examples of widely used continuous distributions are shown in Figure 11-11. These asymmetrical distributions depict shapes that are compatible with the data typically developed during the project risk analysis. Uniform distributions can be used if there is no obvious value that is more likely than any other between specified high and low bounds, such as in the early concept stage of design.



Beta and triangular distributions are frequently used in quantitative risk analysis. The data shown here is one example of a family of such distributions determined by two "shape parameters". Other commonly used distributions include the uniform, normal and lognormal. In these charts the horizontal (X) axes represent possible values of time or cost and the vertical (Y) axes represent relative likelihood.

Figure 11-11. Examples of Commonly Used Probability Distributions

- **Expert judgment.** Subject matter experts internal or external to the organization, such as engineering or statistical experts, validate data and techniques.

.2 Quantitative Risk Analysis and Modeling Techniques

Commonly used techniques in Quantitative Risk Analysis include:

- **Sensitivity analysis.** Sensitivity analysis helps to determine which risks have the most potential impact on the project. It examines the extent to which the uncertainty of each project element affects the objective being examined when all other uncertain elements are held at their baseline values. One typical display of sensitivity analysis is the tornado diagram, which is useful for comparing relative importance of variables that have a high degree of uncertainty to those that are more stable.
- **Expected monetary value analysis.** Expected monetary value (EMV) analysis is a statistical concept that calculates the average outcome when the future includes scenarios that may or may not happen (i.e., analysis under uncertainty). The EMV of opportunities will generally be expressed as positive values, while those of risks will be negative. EMV is calculated by multiplying the value of each possible outcome by its probability of occurrence, and adding them together. A common use of this type of analysis is in decision tree analysis (Figure 11-12). Modeling and simulation are recommended for use in cost and schedule risk analysis, because they are more powerful and less subject to misuse than EMV analysis.
- **Decision tree analysis.** Decision tree analysis is usually structured using a decision tree diagram (Figure 11-12) that describes a situation under consideration, and the implications of each of the available choices and possible scenarios. It incorporates the cost of each available choice, the probabilities of each possible scenario, and the rewards of each alternative logical path. Solving the decision tree provides the EMV (or other measure of interest to the organization) for each alternative, when all the rewards and subsequent decisions are quantified.

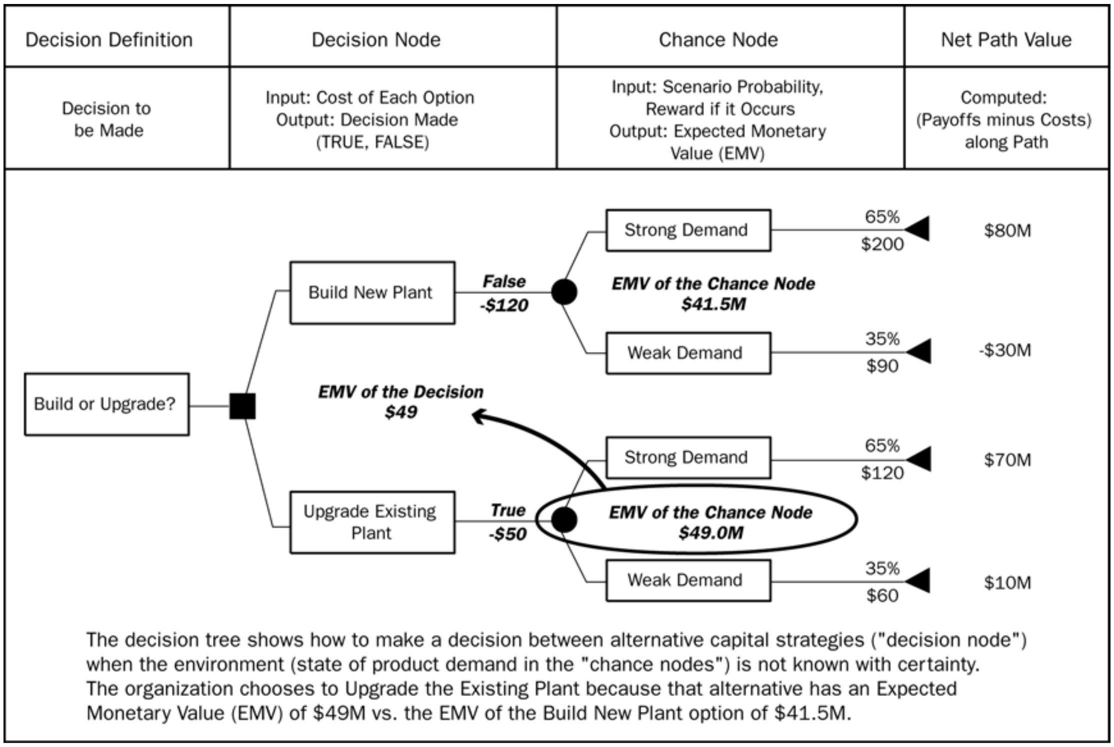
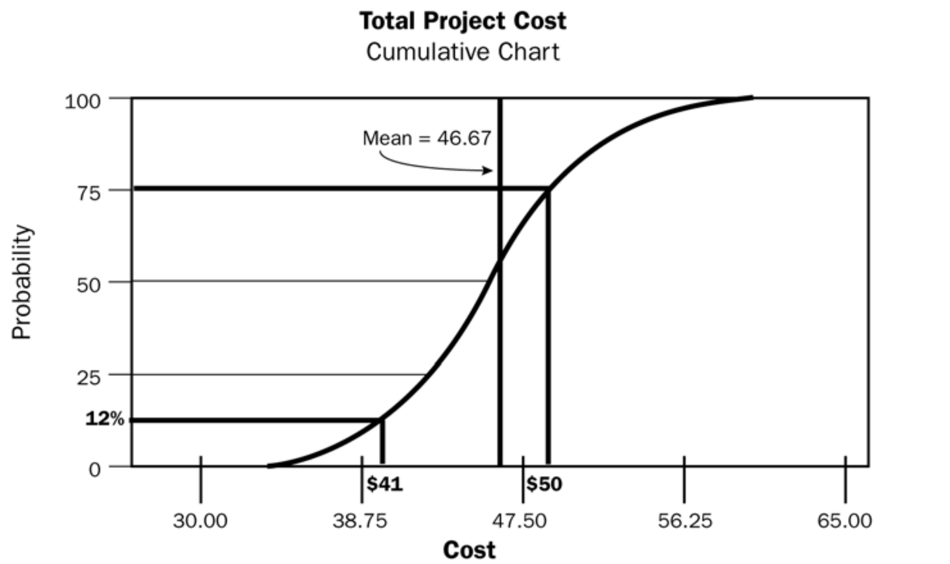


Figure 11-12. Decision Tree Diagram

- **Modeling and simulation.** A project simulation uses a model that translates the uncertainties specified at a detailed level of the project into their potential impact on project objectives. Simulations are typically performed using the Monte Carlo technique. In a simulation, the project model is computed many times (iterated), with the input values randomized from a probability distribution function (e.g., cost of project elements or duration of schedule activities) chosen for each iteration from the probability distributions of each variable. A probability distribution (e.g., total cost or completion date) is calculated.

For a cost risk analysis, a simulation can use the traditional project WBS (Section 5.3.3.2) or a cost breakdown structure as its model. For a schedule risk analysis, the precedence diagramming method (PDM) schedule is used (Section 6.2.2.1). A cost risk simulation is shown in Figure 11-13.



This cumulative likelihood distribution reflects the risk of overrunning the sum of the most likely cost estimate, assuming the data ranges contained in Figure 11-10 and triangular distributions. It shows that the project is only 12 percent likely to meet the $41 estimate. If a conservative organization wants a 75% likelihood of success, a budget of $50 (a contingency of nearly 22 %) is required.

Figure 11-13 Cost Risk Simulation Results

11.4.3 Quantitative Risk Analysis: Outputs

.1 Risk Register (Updates)

The risk register is initiated in the Risk Identification process (Section 11.2) and updated in Qualitative Risk Analysis (Section 11.3). It is further updated in Quantitative Risk Analysis. The risk register is a component of the project management plan. Updates include the following main components:

- **Probabilistic analysis of the project.** Estimates are made of potential project schedule and cost outcomes, listing the possible completion dates and costs with their associated confidence levels. This output, typically expressed as a cumulative distribution, is used with stakeholder risk tolerances to permit quantification of the cost and time contingency reserves. Such contingency reserves are needed to bring the risk of overrunning stated project objectives to a level acceptable to the organization. For instance, in Figure 11-13, the cost contingency to the 75th percentile is $9, or about 22% versus the $41 sum of the most likely estimates.
- **Probability of achieving cost and time objectives.** With the risks facing the project, the probability of achieving project objectives under the current plan can be estimated using quantitative risk analysis results. For instance, in Figure 11-13, the likelihood of achieving the cost estimate of $41 (from Figure 11-10) is about 12%.

- **Prioritized list of quantified risks.** This list of risks includes those that pose the greatest threat or present the greatest opportunity to the project. These include the risks that require the greatest cost contingency and those that are most likely to influence the critical path.
- **Trends in quantitative risk analysis results.** As the analysis is repeated, a trend may become apparent that leads to conclusions affecting risk responses.

11.5 Risk Response Planning

Risk Response Planning is the process of developing options, and determining actions to enhance opportunities and reduce threats to the project's objectives. It follows the Qualitative Risk Analysis and Quantitative Risk Analysis processes. It includes the identification and assignment of one or more persons (the "risk response owner") to take responsibility for each agreed-to and funded risk response. Risk Response Planning addresses the risks by their priority, inserting resources and activities into the budget, schedule, and project management plan, as needed.

Planned risk responses must be appropriate to the significance of the risk, cost effective in meeting the challenge, timely, realistic within the project context, agreed upon by all parties involved, and owned by a responsible person. Selecting the best risk response from several options is often required.

The Risk Response Planning section presents commonly used approaches to planning responses to the risks. Risks include threats and opportunities that can affect project success, and responses are discussed for each.

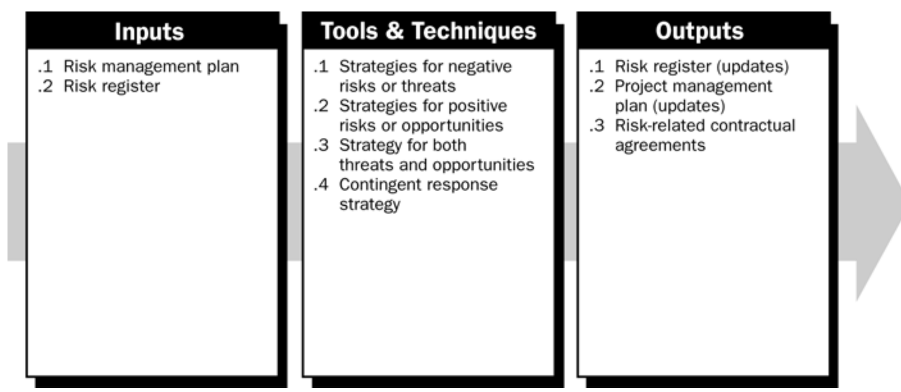


Figure 11-14. Risk Response Planning: Inputs, Tools & Techniques, and Outputs

11.5.1 Risk Response Planning: Inputs

.1 Risk Management Plan

Important components of the risk management plan include roles and responsibilities, risk analysis definitions, risk thresholds for low, moderate, and high risks, and the time and budget required to conduct Project Risk Management.

Outputs from the Risk Management Planning process that are important inputs to Risk Response Planning can include probabilistic analysis of the project, probability of achieving the cost and time objectives, prioritized list of quantified risks, and trends in quantitative risk analysis results.

.2 Risk Register

The risk register is first developed in the Risk Identification process, and is updated during the Qualitative and Quantitative Risk Analysis processes. The Risk Response Planning process may have to refer back to identified risks, root causes of risks, lists of potential responses, risk owners, symptoms, and warning signs in developing risk responses.

Important inputs to Risk Response Planning include the relative rating or priority list of project risks, a list of risks requiring response in the near term, a list of risks for additional analysis and response, trends in qualitative risk analysis results, root causes, risks grouped by categories, and a watchlist of low priority risks. The risk register is further updated during the Quantitative Risk Analysis process.

11.5.2 Risk Response Planning: Tools and Techniques

Several risk response strategies are available. The strategy or mix of strategies most likely to be effective should be selected for each risk. Risk analysis tools, such as decision tree analysis, can be used to choose the most appropriate responses. Then, specific actions are developed to implement that strategy. Primary and backup strategies may be selected. A fallback plan can be developed for implementation if the selected strategy turns out not to be fully effective, or if an accepted risk occurs. Often, a contingency reserve is allocated for time or cost. Finally, contingency plans can be developed, along with identification of the conditions that trigger their execution.

.1 Strategies for Negative Risks or Threats

Three strategies typically deal with threats or risks that may have negative impacts on project objectives if they occur. These strategies are to avoid, transfer, or mitigate:

- **Avoid.** Risk avoidance involves changing the project management plan to eliminate the threat posed by an adverse risk, to isolate the project objectives from the risk's impact, or to relax the objective that is in jeopardy, such as extending the schedule or reducing scope. Some risks that arise early in the project can be avoided by clarifying requirements, obtaining information, improving communication, or acquiring expertise.

- **Transfer.** Risk transference requires shifting the negative impact of a threat, along with ownership of the response, to a third party. Transferring the risk simply gives another party responsibility for its management; it does not eliminate it. Transferring liability for risk is most effective in dealing with financial risk exposure. Risk transference nearly always involves payment of a risk premium to the party taking on the risk. Transference tools can be quite diverse and include, but are not limited to, the use of insurance, performance bonds, warranties, guarantees, etc. Contracts may be used to transfer liability for specified risks to another party. In many cases, use of a cost-type contract may transfer the cost risk to the buyer, while a fixed-price contract may transfer risk to the seller, if the project's design is stable.
- **Mitigate.** Risk mitigation implies a reduction in the probability and/or impact of an adverse risk event to an acceptable threshold. Taking early action to reduce the probability and/or impact of a risk occurring on the project is often more effective than trying to repair the damage after the risk has occurred. Adopting less complex processes, conducting more tests, or choosing a more stable supplier are examples of mitigation actions. Mitigation may require prototype development to reduce the risk of scaling up from a bench-scale model of a process or product. Where it is not possible to reduce probability, a mitigation response might address the risk impact by targeting linkages that determine the severity. For example, designing redundancy into a subsystem may reduce the impact from a failure of the original component.

.2 Strategies for Positive Risks or Opportunities

Three responses are suggested to deal with risks with potentially positive impacts on project objectives. These strategies are to exploit, share, or enhance.

- **Exploit.** This strategy may be selected for risks with positive impacts where the organization wishes to ensure that the opportunity is realized. This strategy seeks to eliminate the uncertainty associated with a particular upside risk by making the opportunity definitely happen. Directly exploiting responses include assigning more talented resources to the project to reduce the time to completion, or to provide better quality than originally planned.
- **Share.** Sharing a positive risk involves allocating ownership to a third party who is best able to capture the opportunity for the benefit of the project. Examples of sharing actions include forming risk-sharing partnerships, teams, special-purpose companies, or joint ventures, which can be established with the express purpose of managing opportunities.
- **Enhance.** This strategy modifies the "size" of an opportunity by increasing probability and/or positive impacts, and by identifying and maximizing key drivers of these positive-impact risks. Seeking to facilitate or strengthen the cause of the opportunity, and proactively targeting and reinforcing its trigger conditions, might increase probability. Impact drivers can also be targeted, seeking to increase the project's susceptibility to the opportunity.

.3 **Strategy for Both Threats and Opportunities**

Acceptance: A strategy that is adopted because it is seldom possible to eliminate all risk from a project. This strategy indicates that the project team has decided not to change the project management plan to deal with a risk, or is unable to identify any other suitable response strategy. It may be adopted for either threats or opportunities. This strategy can be either passive or active. Passive acceptance requires no action, leaving the project team to deal with the threats or opportunities as they occur. The most common active acceptance strategy is to establish a contingency reserve, including amounts of time, money, or resources to handle known—or even sometimes potential, unknown—threats or opportunities.

.4 **Contingent Response Strategy**

Some responses are designed for use only if certain events occur. For some risks, it is appropriate for the project team to make a response plan that will only be executed under certain predefined conditions, if it is believed that there will be sufficient warning to implement the plan. Events that trigger the contingency response, such as missing intermediate milestones or gaining higher priority with a supplier, should be defined and tracked.

11.5.3 Risk Response Planning: Outputs

.1 **Risk Register (Updates)**

The risk register is developed in Risk Identification, and is updated during Qualitative Risk Analysis and Quantitative Risk Analysis. In the Risk Response Planning process, appropriate responses are chosen, agreed-upon, and included in the risk register. The risk register should be written to a level of detail that corresponds with the priority ranking and the planned response. Often, the high and moderate risks are addressed in detail. Risks judged to be of low priority are included in a "watchlist" for periodic monitoring. Components of the risk register at this point can include:

- Identified risks, their descriptions, area(s) of the project (e.g., WBS element) affected, their causes (e.g., RBS element), and how they may affect project objectives
- Risk owners and assigned responsibilities
- Outputs from the Qualitative and Quantitative Risk Analysis processes, including prioritized lists of project risks and probabilistic analysis of the project
- Agreed-upon response strategies
- Specific actions to implement the chosen response strategy
- Symptoms and warning signs of risks' occurrence
- Budget and schedule activities required to implement the chosen responses
- Contingency reserves of time and cost designed to provide for stakeholders' risk tolerances

- Contingency plans and triggers that call for their execution
- Fallback plans for use as a reaction to a risk that has occurred, and the primary response proves to be inadequate
- Residual risks that are expected to remain after planned responses have been taken, as well as those that have been deliberately accepted
- Secondary risks that arise as a direct outcome of implementing a risk response
- Contingency reserves that are calculated based on the quantitative analysis of the project and the organization's risk thresholds.

.2 Project Management Plan (Updates)

The project management plan is updated as response activities are added after review and disposition through the Integrated Change Control process (Section 4.6). Integrated change control is applied in the Direct and Manage Project Execution process (Section 4.4) to ensure that agreed-upon actions are implemented and monitored as part of the ongoing project. Risk response strategies, once agreed to, must be fed back into the appropriate processes in other Knowledge Areas, including the project's budget and schedule.

.3 Risk-Related Contractual Agreements

Contractual agreements, such as agreements for insurance, services, and other items as appropriate, can be prepared to specify each party's responsibility for specific risks, should they occur.

11.6 Risk Monitoring and Control

Planned risk responses (Section 11.5) that are included in the project management plan are executed during the life cycle of the project, but the project work should be continuously monitored for new and changing risks.

Risk Monitoring and Control (Section 4.4) is the process of identifying, analyzing, and planning for newly arising risks, keeping track of the identified risks and those on the watchlist, reanalyzing existing risks, monitoring trigger conditions for contingency plans, monitoring residual risks, and reviewing the execution of risk responses while evaluating their effectiveness. The Risk Monitoring and Control process applies techniques, such as variance and trend analysis, which require the use of performance data generated during project execution. Risk Monitoring and Control, as well as the other risk management processes, is an ongoing process for the life of the project. Other purposes of Risk Monitoring and Control are to determine if:

- Project assumptions are still valid
- Risk, as assessed, has changed from its prior state, with analysis of trends
- Proper risk management policies and procedures are being followed
- Contingency reserves of cost or schedule should be modified in line with the risks of the project.

Risk Monitoring and Control can involve choosing alternative strategies, executing a contingency or fallback plan, taking corrective action, and modifying the project management plan. The risk response owner reports periodically to the project manager on the effectiveness of the plan, any unanticipated effects, and any mid-course correction needed to handle the risk appropriately. Risk Monitoring and Control also includes updating the organizational process assets (Section 4.1.1.4), including project lessons-learned databases and risk management templates for the benefit of future projects.

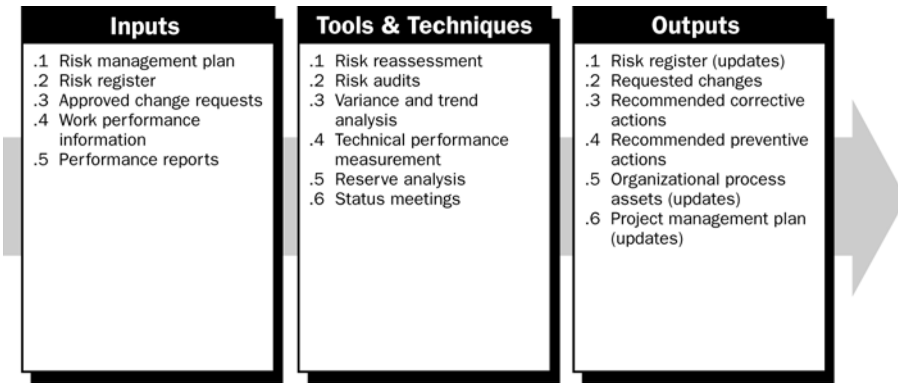


Figure 11-15. Risk Monitoring and Control: Inputs, Tools & Techniques, and Outputs

11

11.6.1 Risk Monitoring and Control: Inputs

.1 Risk Management Plan

This plan has key inputs that include the assignment of people, including the risk owners, time, and other resources to project risk management.

.2 Risk Register

The risk register has key inputs that include identified risks and risk owners, agreed-upon risk responses, specific implementation actions, symptoms and warning signs of risk, residual and secondary risks, a watchlist of low priority risks, and the time and cost contingency reserves.

.3 Approved Change Requests

Approved change requests (Section 4.6.3.1) can include modifications such as work methods, contract terms, scope, and schedule. Approved changes can generate risks or changes in identified risks, and those changes need to be analyzed for any effects upon the risk register, risk response plan, or risk management plan. All changes should be formally documented. Any verbally discussed, but undocumented, changes should not be processed or implemented.

.4 Work Performance Information

Work performance information (Section 4.4.3.7), including project deliverables' status, corrective actions, and performance reports, are important inputs to Risk Monitoring and Control.

.5 Performance Reports

Performance reports (Section 10.3.3.1) provide information on project work performance, such as an analysis that may influence the risk management processes.

11.6.2 Risk Monitoring and Control: Tools and Techniques

.1 Risk Reassessment

Risk Monitoring and Control often requires identification of new risks and reassessment of risks, using the processes of this chapter as appropriate. Project risk reassessments should be regularly scheduled. Project Risk Management should be an agenda item at project team status meetings. The amount and detail of repetition that is appropriate depends on how the project progresses relative to its objectives. For instance, if a risk emerges that was not anticipated in the risk register or included on the watchlist, or if its impact on objectives is different from what was expected, the planned response may not be adequate. It will then be necessary to perform additional response planning to control the risk.

.2 Risk Audits

Risk audits examine and document the effectiveness of risk responses in dealing with identified risks and their root causes, as well as the effectiveness of the risk management process.

.3 Variance and Trend Analysis

Trends in the project's execution should be reviewed using performance data. Earned value analysis (Section 7.3.2.4) and other methods of project variance and trend analysis may be used for monitoring overall project performance. Outcomes from these analyses may forecast potential deviation of the project at completion from cost and schedule targets. Deviation from the baseline plan may indicate the potential impact of threats or opportunities.

.4 Technical Performance Measurement

Technical performance measurement compares technical accomplishments during project execution to the project management plan's schedule of technical achievement. Deviation, such as demonstrating more or less functionality than planned at a milestone, can help to forecast the degree of success in achieving the project's scope.

.5 Reserve Analysis

Throughout execution of the project, some risks may occur, with positive or negative impacts on budget or schedule contingency reserves (Section 11.5.2.4). Reserve analysis compares the amount of the contingency reserves remaining to the amount of risk remaining at any time in the project, in order to determine if the remaining reserve is adequate.

.6 Status Meetings

Project risk management can be an agenda item at periodic status meetings. That item may take no time or a long time, depending on the risks that have been identified, their priority, and difficulty of response. Risk management becomes easier the more often it is practiced, and frequent discussions about risk make talking about risks, particularly threats, easier and more accurate.

11.6.3 Risk Monitoring and Control: Outputs

.1 Risk Register (Updates)

An updated risk register contains:

- Outcomes of risk reassessments, risk audits, and periodic risk reviews. These outcomes may include updates to probability, impact, priority, response plans, ownership, and other elements of the risk register. Outcomes can also include closing risks that are no longer applicable.
- The actual outcomes of the project's risks, and of risk responses that can help project managers plan for risk throughout the organization, as well as on future projects. This completes the record of risk management on the project, is an input to the Close Project process (Section 4.7), and becomes part of the project closure documents.

.2 Requested Changes

Implementing contingency plans or workarounds frequently results in a requirement to change the project management plan to respond to risks. Requested changes are prepared and submitted to the Integrated Change Control process (Section 4.6) as an output of the Risk Monitoring and Control process. Approved change requests are issued and become inputs to the Direct and Manage Project Execution process (Section 4.4) and to the Risk Monitoring and Control process.

.3 Recommended Corrective Actions

Recommended corrective actions include contingency plans and workaround plans. The latter are responses that were not initially planned, but are required to deal with emerging risks that were previously unidentified or accepted passively. Workarounds should be properly documented and included in both the Direct and Manage Project Execution (Section 4.4) and Monitor and Control Project Work (Section 4.5) processes. Recommended corrective actions are inputs to the Integrated Change Control process (Section 4.6).

.4 Recommended Preventive Actions

Recommended preventive actions are used to bring the project into compliance with the project management plan.

.5 Organizational Process Assets (Updates)

The six Project Risk Management processes produce information that can be used for future projects, and should be captured in the organizational process assets (Section 4.1.1.4). The templates for the risk management plan, including the probability and impact matrix, and risk register, can be updated at project closure. Risks can be documented and the RBS updated. Lessons learned from the project risk management activities can contribute to the lessons learned knowledge database of the organization. Data on the actual costs and durations of project activities can be added to the organization's databases. The final versions of the risk register and the risk management plan templates, checklists, and RBSs are included.

.6 Project Management Plan (Updates)

If the approved change requests have an effect on the risk management processes, then the corresponding component documents of the project management plan are revised and reissued to reflect the approved changes.