5.3.1 Define Scope: Inputs

5.3.1.1 Scope Management Plan

Described in Section 5.1.3.1.The scope management plan is a component of the project management plan that establishes the activities for developing, monitoring, and controlling the project scope.

5.3.1.2 Project Charter

Described in Section 4.1.3.1. The project charter provides the high-level project description and product characteristics. It also contains project approval requirements. If a project charter is not used in the performing organization, then comparable information needs to be acquired or developed, and used as a basis for the detailed project scope statement. Organizations that do not produce a formal project charter will usually perform an informal analysis to identify the content necessary for further scope planning.

5.3.1.3 Requirements Documentation

Described in Section 5.2.3.1. This documentation will be used to select the requirements that will be included in the project.

5.3.1.4 Organizational Process Assets

Described in Section 2.1.4. Organizational process assets can influence how scope is defined. Examples include, but are not limited to:

- Policies, procedures, and templates for a project scope statement;
- Project files from previous projects; and
- Lessons learned from previous phases or projects.

5.3.2 Define Scope: Tools and Techniques

5.3.2.1 Expert Judgment

Expert judgment is often used to analyze the information needed to develop the project scope statement. Such judgment and expertise is applied to any technical detail. Such expertise is provided by any group or individual with specialized knowledge or training, and is available from many sources, including but not limited to:

- Other units within the organization;
- Consultants;
- Stakeholders, including customers or sponsors;
- Professional and technical associations;
- Industry groups; and
- Subject matter experts.

5.3.2.2 Product Analysis

For projects that have a product as a deliverable, as opposed to a service or result, product analysis can be an effective tool. Each application area has one or more generally accepted methods for translating high-level product descriptions into tangible deliverables. Product analysis includes techniques such as product breakdown, systems analysis, requirements analysis, systems engineering, value engineering, and value analysis.

5.3.2.3 Alternatives Generation

Alternatives generation is a technique used to develop as many potential options as possible in order to identify different approaches to execute and perform the work of the project. A variety of general management techniques can be used, such as brainstorming, lateral thinking, analysis of alternatives, etc.

5.3.2.4 Facilitated Workshops

Described in Section 5.2.2.3. The participation of key players with a variety of expectations and/or fields of expertise in these intensive working sessions helps to reach a cross-functional and common understanding of the project objectives and its limits.

5.3.3 Define Scope: Outputs

5.3.3.1 Project Scope Statement

The project scope statement is the description of the project scope, major deliverables, assumptions, and constraints. The project scope statement documents the entire scope, including project and product scope. It describes, in detail, the project's deliverables and the work required to create those deliverables. It also provides a common understanding of the project scope among project stakeholders. It may contain explicit scope exclusions that can assist in managing stakeholder expectations. It enables the project team to perform more detailed planning, guides the project team's work during execution, and provides the baseline for evaluating whether requests for changes or additional work are contained within or outside the project's boundaries.

The degree and level of detail to which the project scope statement defines the work that will be performed and the work that is excluded can help determine how well the project management team can control the overall project scope. The detailed project scope statement, either directly, or by reference to other documents, includes the following:

- **Product scope description.** Progressively elaborates the characteristics of the product, service, or result described in the project charter and requirements documentation.
- **Acceptance criteria.** A set of conditions that is required to be met before deliverables are accepted.
- **Deliverable.** Any unique and verifiable product, result, or capability to perform a service that is required to be produced to complete a process, phase, or project. Deliverables also include ancillary results, such as project management reports and documentation. These deliverables may be described at a summary level or in great detail.
- **Project exclusion.** Generally identifies what is excluded from the project. Explicitly stating what is out of scope for the project helps to manage stakeholders' expectations.
- **Constraints.** A limiting factor that affects the execution of a project or process. Constraints identified with the project scope statement list and describe the specific internal or external restrictions or limitations associated with the project scope that affect the execution of the project, for example, a predefined budget or any imposed dates or schedule milestones that are issued by the customer or performing organization. When a project is performed under an agreement, contractual provisions

will generally be constraints. Information on constraints may be listed in the project scope statement or in a separate log.

- **Assumptions.** A factor in the planning process that is considered to be true, real, or certain, without proof or demonstration. Also describes the potential impact of those factors if they prove to be false. Project teams frequently identify, document, and validate assumptions as part of their planning process. Information on assumptions may be listed in the project scope statement or in a separate log.

Although the project charter and the project scope statement are sometimes perceived as containing a certain degree of redundancy, they are different in the level of detail contained in each. The project charter contains high-level information, while the project scope statement contains a detailed description of the scope elements. These elements are progressively elaborated throughout the project. Table 5-1 describes some of the key elements for each document.

Table 5-1. Elements of the Project Charter and Project Scope Statement

Project Charter	Project Scope Statement
Project purpose or justification	Project scope description (progressively elaborated)
Measurable project objectives and related success criteria	Acceptance criteria
High-level requirements	Project deliverables
High-level project description	Project exclusions
High-level risks	Project constraints
Summary milestone schedule	Project assumptions
Summary budget	
Stakeholder list	
Project approval requirements (what constitutes success, who decides it, who signs off)	
Assigned project manager, responsibility, and authority level	
Name and authority of the sponsor or other person(s) authorizing the project charter	

5.3.3.2 Project Documents Updates

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

- Stakeholder register,
- Requirements documentation, and
- Requirements traceability matrix.

5.4 Create WBS

Create WBS is the process of subdividing project deliverables and project work into smaller, more manageable components. The key benefit of this process is that it provides a structured vision of what has to be delivered. The inputs, tools and techniques, and outputs of this process are depicted in Figure 5-9. Figure 5-10 depicts the data flow diagram of the process.

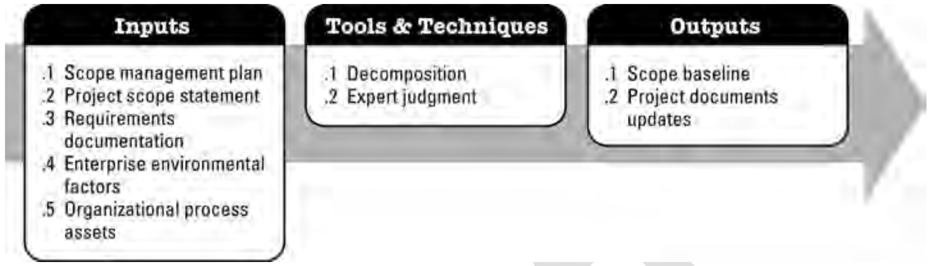

Figure 5-9. Create WBS: Inputs, Tools & Techniques, and Outputs

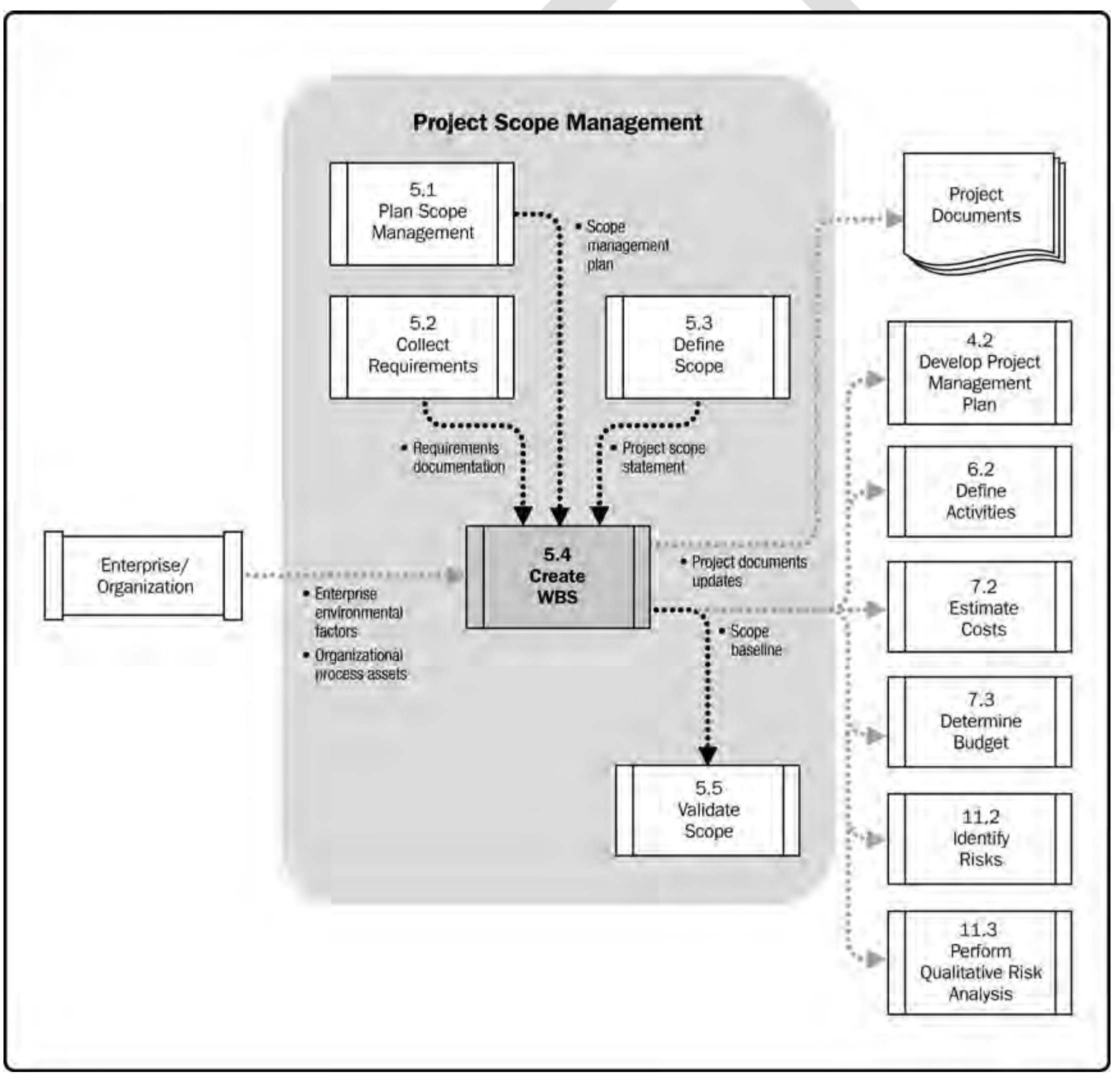

Figure 5-10. Create WBS Data Flow Diagram

The WBS is a hierarchical decomposition of the total scope of work to be carried out by the project team to accomplish the project objectives and create the required deliverables. The WBS organizes and defines the total scope of the project, and represents the work specified in the current approved project scope statement.

The planned work is contained within the lowest level of WBS components, which are called work packages. A work package can be used to group the activities where work is scheduled and estimated, monitored, and controlled. In the context of the WBS, work refers to work products or deliverables that are the result of activity and not to the activity itself.

5.4.1 Create WBS: Inputs

5.4.1.1 Scope Management Plan

Described in Section 5.1.3.1. The scope management plan specifies how to create the WBS from the detailed project scope statement and how the WBS will be maintained and approved.

5.4.1.2 Project Scope Statement

Described in Section 5.3.3.1. The project scope statement describes the work that will be performed and the work that is excluded. It also lists and describes the specific internal or external restrictions or limitations that may affect the execution of the project.

5.4.1.3 Requirements Documentation

Described in Section 5.2.3.1. Detailed requirements documentation is essential for understanding what needs to be produced as the result of the project and what needs to be done to deliver the project and its final products.

5.4.1.4 Enterprise Environmental Factors

Described in Section 2.1.5. Industry- specific WBS standards, relevant to the nature of the project, may serve as external reference sources for creation of the WBS. For example, engineering projects may reference ISO/IEC 15288 on Systems Engineering – System Life Cycle Processes, to create a WBS for a new project.

5.4.1.5 Organizational Process Assets

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

- Policies, procedures, and templates for the WBS;
- Project files from previous projects; and
- Lessons learned from previous projects.

5.4.2 Create WBS: Tools and Techniques

5.4.2.1 Decomposition

Decomposition is a technique used for dividing and subdividing the project scope and project deliverables into smaller, more manageable parts. The work package is the work defined at the lowest level of the WBS for which cost and duration can be estimated and managed. The level of decomposition is often guided by the degree of control needed to effectively manage the project. The level of detail for work packages will vary with the size and complexity of the project. Decomposition of the total project work into work packages generally involves the following activities:

- Identifying and analyzing the deliverables and related work;
- Structuring and organizing the WBS;
- Decomposing the upper WBS levels into lower-level detailed components;
- Developing and assigning identification codes to the WBS components; and
- Verifying that the degree of decomposition of the deliverables is appropriate.

A portion of a WBS with some branches of the WBS decomposed down through the work package level is shown in Figure 5-11.

5.4.2.2 Expert Judgment

Expert judgment is often used to analyze the information needed to decompose the project deliverables down into smaller component parts in order to create an effective WBS. Such judgment and expertise is applied to technical details of the project's scope and used to reconcile differences in opinion on how to best break down the overall scope of the project. This level of expertise is provided by any group or individual with relevant training, knowledge, or experience with similar projects or business areas. Expert judgment can also come in the form of predefined templates that provide guidance on how to effectively break down common deliverables. Such templates may be industry or discipline specific or may come from experience gained in similar projects. The project manager, in collaboration with the project team, then determines the final decomposition of the project scope into the discrete work packages that will be used to effectively manage the work of the project.

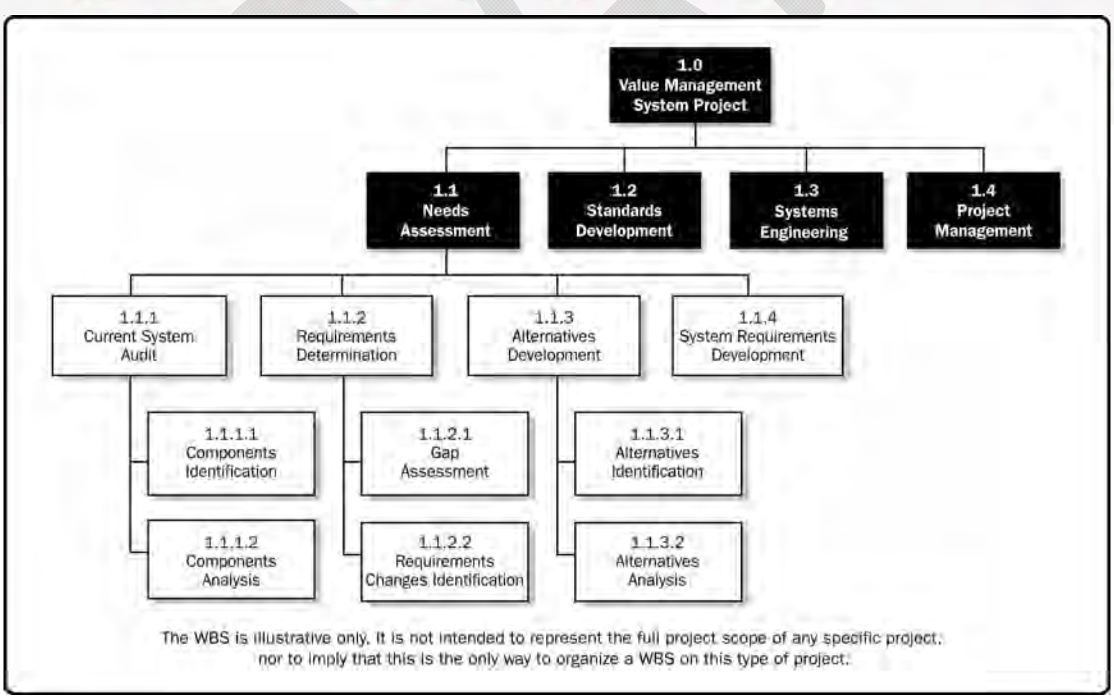

Figure 5-11. Sample WBS Decomposed Down Through Work Packages

A WBS structure may be created through various approaches. Some of the popular methods include the top-down approach, the use of organization-specific guidelines, and the use of WBS templates. A bottom-up approach can be used during the integration of subcomponents. The WBS structure can be represented in a number of forms, such as:

- Using phases of the project life cycle as the second level of decomposition, with the product and project deliverables inserted at the third level, as shown in Figure 5-12;
- Using major deliverables as the second level of decomposition, as shown in Figure 5-13; and
- Incorporating subcomponents which may be developed by organizations outside the project team, such as contracted work. The seller then develops the supporting contract WBS as part of the contracted work.

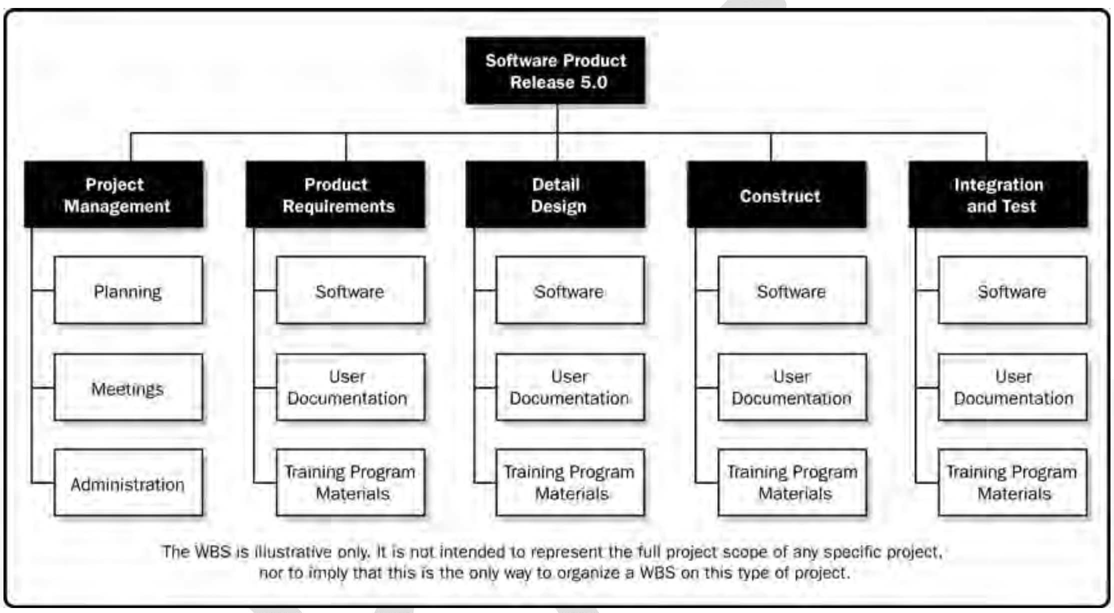

Figure 5-12. Sample WBS Organized by Phase

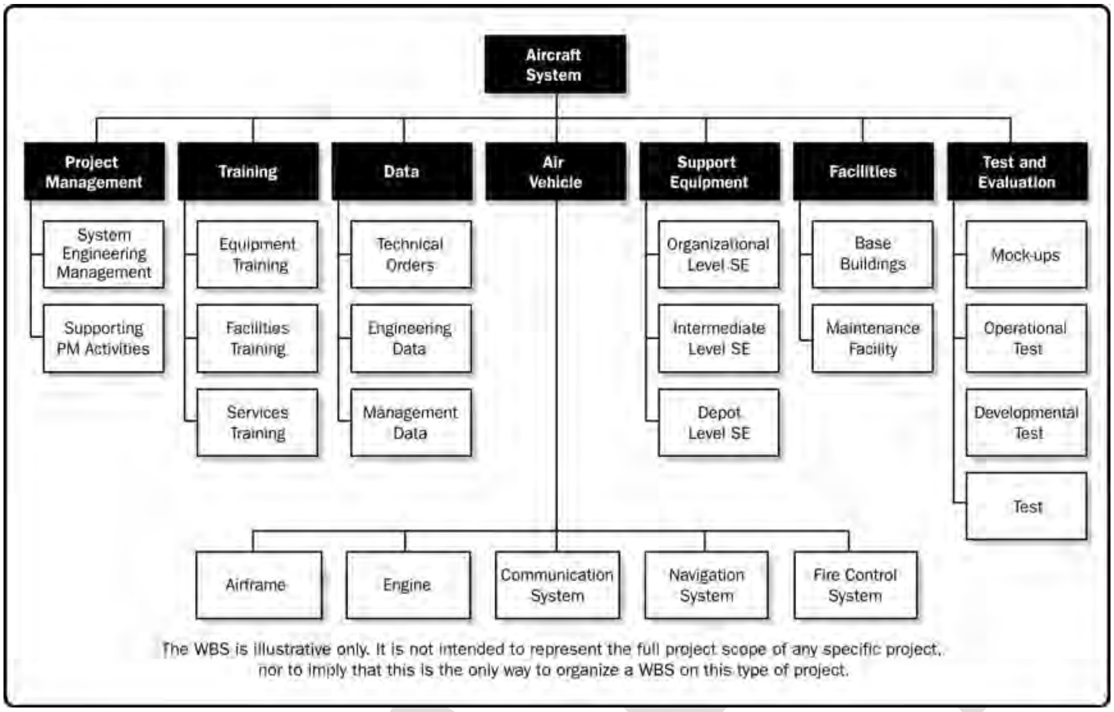

Figure 5-13. Sample WBS with Major Deliverables

Decomposition of the upper-level WBS components requires subdividing the work for each of the deliverables or subcomponents into its most fundamental elements, where the WBS components represent verifiable products, services, or results. The WBS may be structured as an outline, an organizational chart, or other method that identifies a hierarchical breakdown. Verifying the correctness of the decomposition requires determining that the lower-level WBS components are those that are necessary and sufficient for completion of the corresponding higher-level deliverables. Different deliverables can have different levels of decomposition. To arrive at a work package, the work for some deliverables needs to be decomposed only to the next level, while others need additional levels of decomposition. As the work is decomposed to greater levels of detail, the ability to plan, manage, and control the work is enhanced. However, excessive decomposition can lead to nonproductive management effort, inefficient use of resources, decreased efficiency in performing the work, and difficulty aggregating data over different levels of the WBS.

Decomposition may not be possible for a deliverable or subcomponent that will be accomplished far into the future. The project management team usually waits until the deliverable or subcomponent is agreed on, so the details of the WBS can be developed. This technique is sometimes referred to as rolling wave planning.

The WBS represents all product and project work, including the project management work. The total of the work at the lowest levels should roll up to the higher levels so that nothing is left out and no extra work is performed. This is sometimes called the 100 percent rule.

For specific information regarding the WBS, refer to the *Practice Standard for Work Breakdown Structures* – Second Edition. This standard contains industry-specific examples of WBS templates that can be tailored to specific projects in a particular application area.

5.4.3 Create WBS: Outputs

5.4.3.1 Scope Baseline

The scope baseline is the approved version of a scope statement, work breakdown structure (WBS), and its associated WBS dictionary, that can be changed only through formal change control procedures and is used as a basis for comparison. It is a component of the project management plan. Components of the scope baseline include:

- **Project scope statement.** The project scope statement includes the description of the project scope, major deliverables, assumptions, and constraints.
- **WBS.** The WBS is a hierarchical decomposition of the total scope of work to be carried out by the project team to accomplish the project objectives and create the required deliverables. Each descending level of the WBS represents an increasingly detailed definition of the project work. The WBS is finalized by assigning each work package to a control account and establishing a unique identifier for that work package from a code of accounts. These identifiers provide a structure for hierarchical summation of costs, schedule, and resource information. A control account is a management control point where scope, budget, actual cost, and schedule are integrated and compared to the earned value for performance measurement. Control accounts are placed at selected management points in the WBS. Each control account may include one or more work packages, but each of the work packages should be associated with only one control account. A control account may include one or more planning packages. A planning package is a work breakdown structure component below the control account with known work content but without detailed schedule activities.
- **WBS dictionary.** The WBS dictionary is a document that provides detailed deliverable, activity, and scheduling information about each component in the WBS. The WBS dictionary is a document that supports the WBS. Information in the WBS dictionary may include, but is not limited to:
    - Code of account identifier,
    - Description of work,
    - Assumptions and constraints,
    - Responsible organization,
    - Schedule milestones,
    - Associated schedule activities,
    - Resources required,
    - Cost estimates,
    - Quality requirements,
    - Acceptance criteria,
    - Technical references, and
    - Agreement information.

5.4.3.2 Project Documents Updates

Project documents that may be updated include, but are not limited to, requirements documentation, which may need to be updated to include approved changes. If approved change requests result from the Create WBS process, then the requirements documentation may need to be updated to include approved changes.

5.5 Validate Scope

Validate Scope is the process of formalizing acceptance of the completed project deliverables. The key benefit of this process is that it brings objectivity to the acceptance process and increases the chance of final product, service, or result acceptance by validating each deliverable. The inputs, tools and techniques, and outputs of this process are depicted in Figure 5-14. Figure 5-15 depicts the data flow diagram of the process.

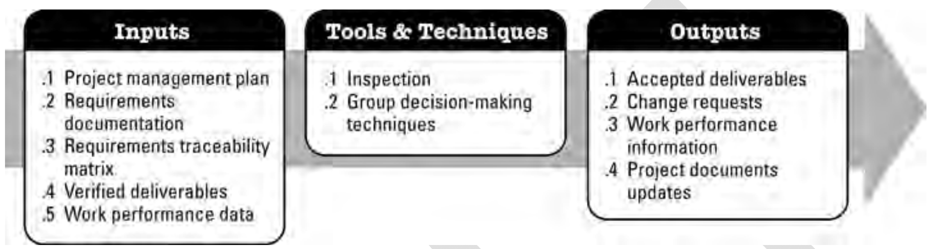

Figure 5-14. Validate Scope: Inputs, Tools & Techniques, and Outputs

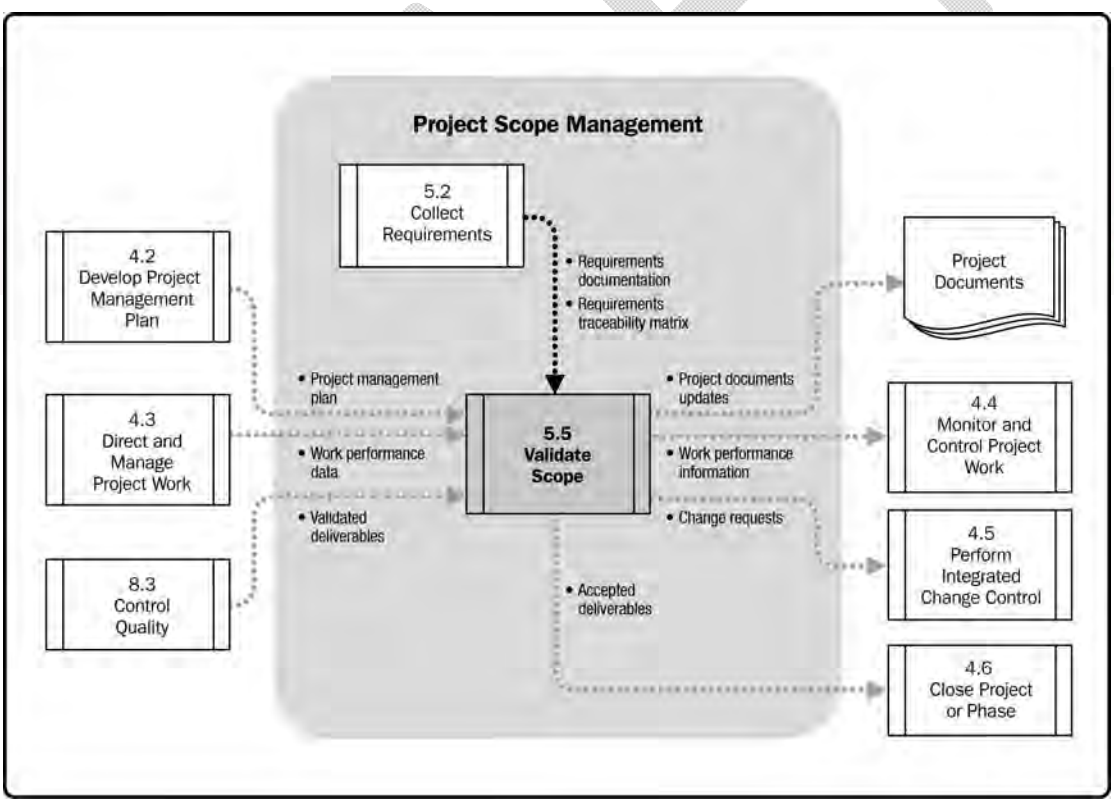

Figure 5-15. Validate Scope Data Flow Diagram

The verified deliverables obtained from the Control Quality process are reviewed with the customer or sponsor to ensure that they are completed satisfactorily and have received formal acceptance of the deliverables by the customer or sponsor. In this process, the outputs obtained as a result of the Planning processes in the Project Scope Management Knowledge Area, such as the requirements documentation or the scope baseline, as well as the work performance data obtained from the Execution processes in other Knowledge Areas, are the basis for performing the validation and for final acceptance.

The Validate Scope process differs from the Control Quality process in that the former is primarily concerned with acceptance of the deliverables, while quality control is primarily concerned with correctness of the deliverables and meeting the quality requirements specified for the deliverables. Control Quality is generally performed before Validate Scope, although the two processes may be performed in parallel.

5.5.1 Validate Scope: Inputs

5.5.1.1 Project Management Plan

Described in Section 4.2.3.1. The project management plan contains the scope management plan and the scope baseline. As described in Section 5.1.3.1., the scope management plan specifies how formal acceptance of the completed project deliverables will be obtained. The scope baseline (Section 5.4.3.1.) includes the approved version of a scope statement, work breakdown structure (WBS), and its associated WBS dictionary, that can be changed only through formal change control procedures and is used as a basis for comparison.

5.5.1.2 Requirements Documentation

Described in Section 5.2.3.1. The requirements documentation lists all the project, product, and other types of requirements for the project and product, along with their acceptance criteria.

5.5.1.3 Requirements Traceability Matrix

Described in Section 5.2.3.2. The requirements traceability matrix links requirements to their origin and tracks them throughout the project life cycle.

5.5.1.4 Verified Deliverables

Described in Section 8.3.3.3. Verified deliverables are project deliverables that are completed and checked for correctness through the Control Quality process.

5.5.1.5 Work Performance Data

Described in Section 4.3.3.2. Work performance data can include the degree of compliance with requirements, number of nonconformities, severity of the nonconformities, or the number of validation cycles performed in a period of time.

5.5.2 Validate Scope: Tools and Techniques

5.5.2.1 Inspection

Inspection includes activities such as measuring, examining, and validating to determine whether work and deliverables meet requirements and product acceptance criteria. Inspections are sometimes called reviews, product reviews, audits, and walkthroughs. In some application areas, these different terms have unique and specific meanings.

5.5.2.2 Group Decision-Making Techniques

Described in Section 5.2.2.5. These techniques are used to reach a conclusion when the validation is performed by the project team and other stakeholders.

5.5.3 Validate Scope: Outputs

5.5.3.1 Accepted Deliverables

Deliverables that meet the acceptance criteria are formally signed off and approved by the customer or sponsor. Formal documentation received from the customer or sponsor acknowledging formal stakeholder acceptance of the project's deliverables is forwarded to the Close Project or Phase process (Section 4.6).

5.5.3.2 Change Requests

The completed deliverables that have not been formally accepted are documented, along with the reasons for nonacceptance of those deliverables. Those deliverables may require a change request for defect repair. The change requests are processed for review and disposition through the Perform Integrated Change Control process (Section 4.5).

5.5.3.3 Work Performance Information

Work performance information includes information about project progress, such as which deliverables have started, their progress, which deliverables have finished, or which have been accepted. This information is documented as described in Section 10.3.3.1 and communicated to stakeholders.

5.5.3.4 Project Documents Updates

Project documents that may be updated as a result of the Validate Scope process include any documents that define the product or report status on product completion. Verified project documents may require approvals from the customer or sponsor in the form of signatures or signoffs.

5.6 Control Scope

Control Scope is the process of monitoring the status of the project and product scope and managing changes to the scope baseline. The key benefit of this process is that it allows the scope baseline to be maintained throughout the project. The inputs, tools and techniques, and outputs of this process are depicted in Figure 5-16. Figure 5-17 depicts the data flow diagram of the process.

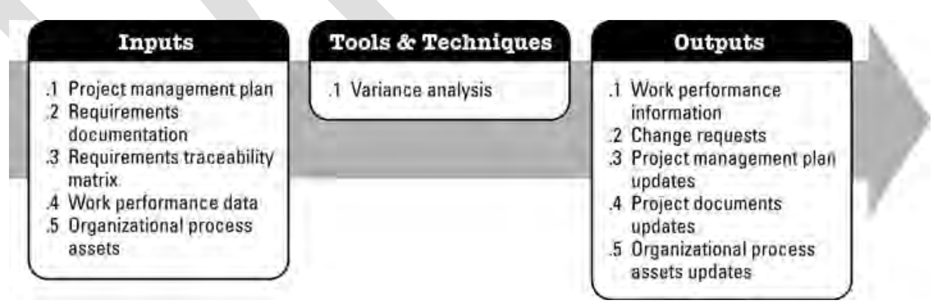

Figure 5-16. Control Scope: Inputs, Tools & Techniques, and Outputs

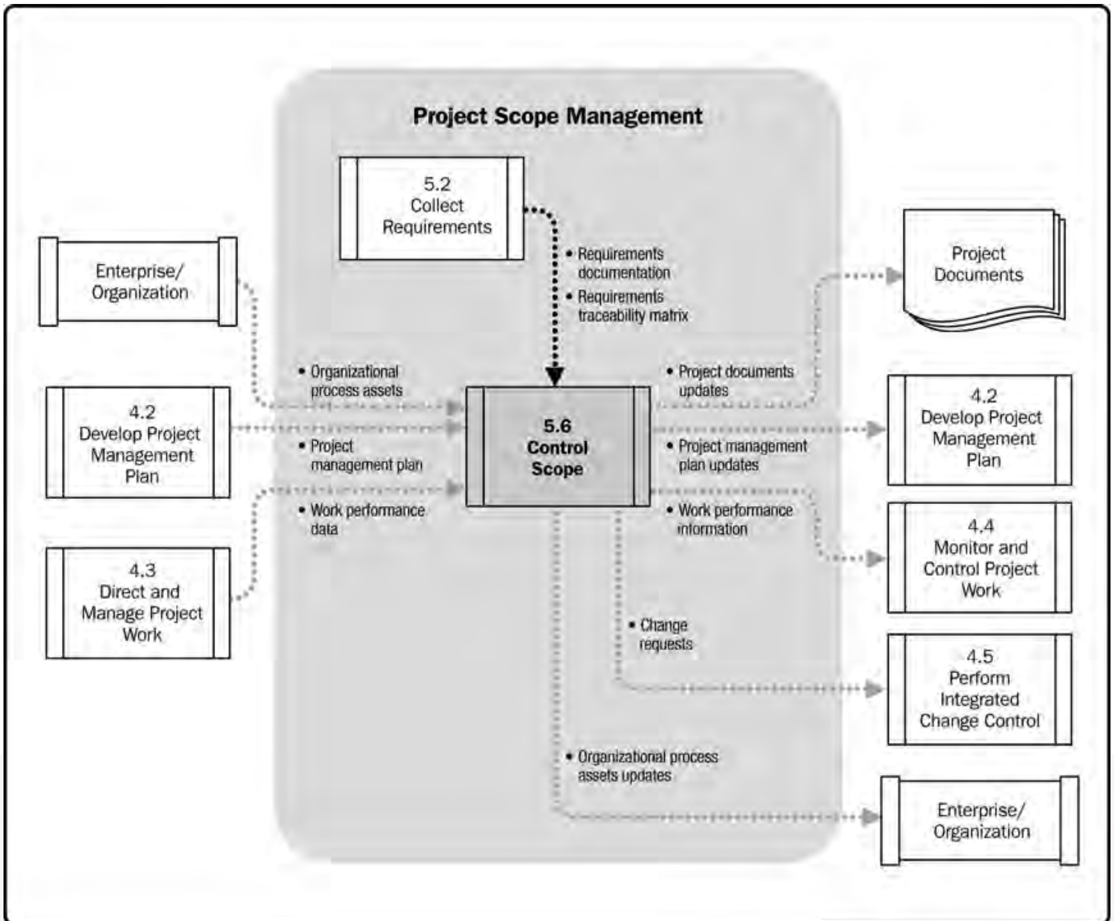

Figure 5-17. Control Scope Data Flow Diagram

Controlling the project scope ensures all requested changes and recommended corrective or preventive actions are processed through the Perform Integrated Change Control process (see Section 4.5). Control Scope is also used to manage the actual changes when they occur and is integrated with the other control processes. The uncontrolled expansion to product or project scope without adjustments to time, cost, and resources is referred to as scope creep. Change is inevitable; therefore some type of change control process is mandatory for every project.

5.6.1 Control Scope: Inputs

5.6.1.1 Project Management Plan

Described in Section 4.2.3.1. The following information from the project management plan is used to control scope:

- **Scope baseline.** The scope baseline is compared to actual results to determine if a change, corrective action, or preventive action is necessary.
- **Scope management plan.** Sections from the scope management plan describe how the project scope will be monitored and controlled.
- **Change management plan.** The change management plan defines the process for managing change on the project.

- **Configuration management plan.** The configuration management plan defines those items that are configurable, those items that require formal change control, and the process for controlling changes to such items.
- **Requirements management plan.** This plan is a component of the project management plan and describes how the project requirements will be analyzed, documented, and managed.

5.6.1.2 Requirements Documentation

Described in Section 5.2.3.1. Requirements should be unambiguous (measurable and testable), traceable, complete, consistent, and acceptable to key stakeholders. Well-documented requirements make it easier to detect any deviation in the scope agreed for the project or product.

5.6.1.3 Requirements Traceability Matrix

Described in Section 5.2.3.2. The requirements traceability matrix helps to detect the impact of any change or deviation from the scope baseline on the project objectives.

5.6.1.4 Work Performance Data

Described in Section 4.3.3.2. Work performance data can include the number of change requests received, the number of requests accepted or the number of deliverables completed, etc.

5.6.1.5 Organizational Process Assets

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

- Existing formal and informal scope, control-related policies, procedures, guidelines; and
- Monitoring and reporting methods and templates to be used.

5.6.2 Control Scope: Tools and Techniques

5.6.2.1 Variance Analysis

Variance analysis is a technique for determining the cause and degree of difference between the baseline and actual performance. Project performance measurements are used to assess the magnitude of variation from the original scope baseline. Important aspects of project scope control include determining the cause and degree of variance relative to the scope baseline (Section 5.4.3.1) and deciding whether corrective or preventive action is required.

5.6.3 Control Scope: Outputs

5.6.3.1 Work Performance Information

Work performance information produced includes correlated and contextualized information on how the project scope is performing compared to the scope baseline. It can include the categories of the changes received, the identified scope variances and their causes, how they impact schedule or cost, and the forecast of the future scope performance. This information provides a foundation for making scope decisions.

5.6.3.2 Change Requests

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

5.6.3.3 Project Management Plan Updates

Project management plan updates may include, but are not limited to:

- **Scope Baseline Updates.** If the approved change requests have an effect on the project scope, then the scope statement, the WBS, and the WBS dictionary are revised and reissued to reflect the approved changes through Perform Integrated Change Control process.
- **Other Baseline Updates.** If the approved change requests have an effect on the project besides the project scope, then the corresponding cost baseline and schedule baselines are revised and reissued to reflect the approved changes.

5.6.3.4 Project Documents Updates

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

- Requirements documentation, and
- Requirements traceability matrix.

5.6.3.5 Organizational Process Assets Updates

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

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

6

PROJECT TIME MANAGEMENT

Project Time Management includes the processes required to manage the timely completion of the project.

Figure 6-1 provides an overview of the Project Time Management processes, which are as follows:

6.1 Plan Schedule Management—The process of establishing the policies, procedures, and documentation for planning, developing, managing, executing, and controlling the project schedule.

6.2 Define Activities—The process of identifying and documenting the specific actions to be performed to produce the project deliverables.

6.3 Sequence Activities—The process of identifying and documenting relationships among the project activities.

6.4 Estimate Activity Resources—The process of estimating the type and quantities of material, human resources, equipment, or supplies required to perform each activity.

6.5 Estimate Activity Durations—The process of estimating the number of work periods needed to complete individual activities with estimated resources.

6.6 Develop Schedule—The process of analyzing activity sequences, durations, resource requirements, and schedule constraints to create the project schedule model.

6.7 Control Schedule—The process of monitoring the status of project activities to update project progress and manage changes to the schedule baseline to achieve the plan.

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

Distinguishing the project schedule presentation (schedule) from the schedule data (Section 6.6.3.3) and calculations that produce the project schedule (Section 6.6.3.2) is practiced by referring to the scheduling tool populated with project data as the schedule model. A schedule model is a representation of the plan for executing the project's activities including durations, dependencies, and other planning information, used to produce project schedules along with other scheduling artifacts. For specific information regarding the schedule model, refer to the *Practice Standard for Scheduling*.

On some projects, especially those of smaller scope, defining activities, sequencing activities, estimating activity resources, estimating activity durations, and developing the schedule model 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 elements because the tools and techniques for each process are different.

The Project Time Management processes and their associated tools and techniques are documented in the schedule management plan. The schedule management plan is a subsidiary plan of, and integrated with, the project management plan through the Develop Project Management Plan process (Section 4.2), The schedule management plan identifies a scheduling method and scheduling tool (Figure 6-2), and sets the format and establishes criteria for developing and controlling the project schedule. The selected scheduling method defines the framework and algorithms used in the scheduling tool to create the schedule model. Some of the better known scheduling methods include critical path method (CPM) and critical chain method (CCM).

Project schedule development uses the outputs from the processes to define activities, sequence activities, estimate activity resources, and estimate activity durations in combination with the scheduling tool to produce the schedule model. The finalized and approved schedule is the baseline that will be used in the Control Schedule process (Section 6.7). As the project activities are being performed, the majority of effort in the Project Time Management Knowledge Area will occur in the Control Schedule process to ensure completion of project work in a timely manner. Figure 6-2 provides a scheduling overview that shows how the scheduling method, scheduling tool, and outputs from the Project Time Management processes interact to create a project schedule.

Figure 6-1. Project Time Management Overview

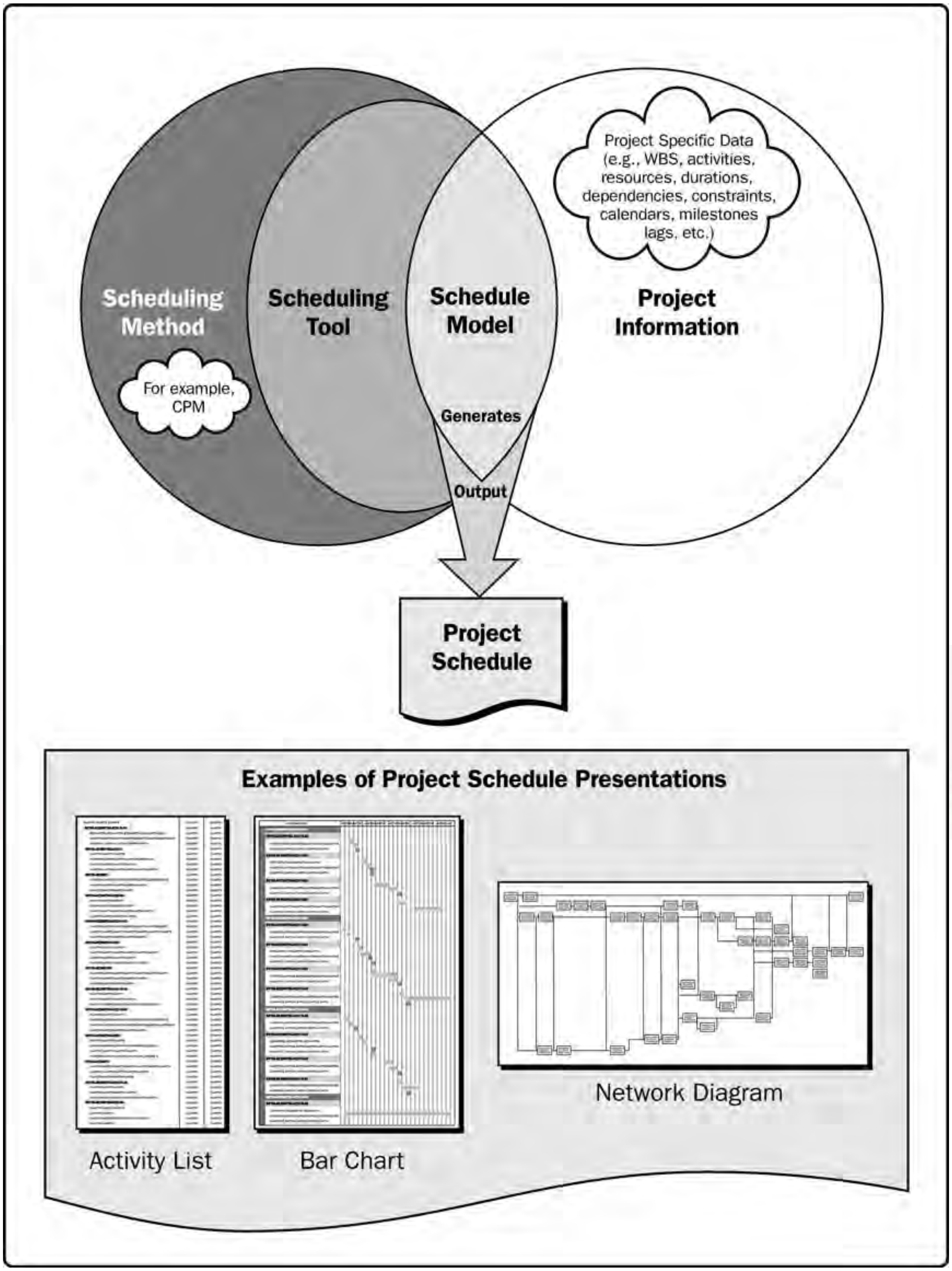

Figure 6-2. Scheduling Overview

6.1 Plan Schedule Management

Plan Schedule Management is the process of establishing the policies, procedures, and documentation for planning, developing, managing, executing, and controlling the project schedule. The key benefit of this process is that it provides guidance and direction on how the project schedule will be managed throughout the project. The inputs, tools and techniques, and outputs of this process are depicted in Figure 6-3. Figure 6-4 depicts the data flow diagram of the process.

Figure 6-3. Plan Schedule Management: Inputs, Tools & Techniques, and Outputs

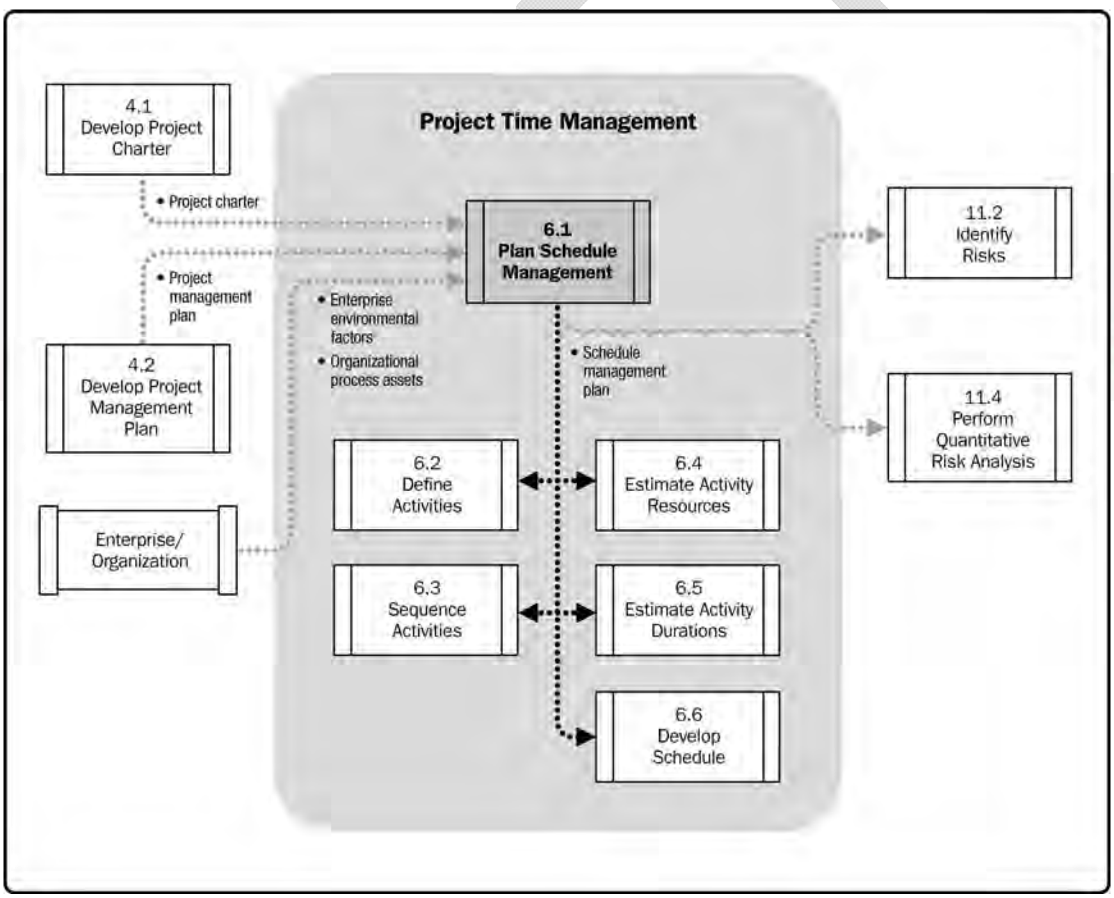

Figure 6-4. Plan Schedule Management Data Flow Diagram

The schedule management plan is a component of the project management plan. The schedule management plan may be formal or informal, highly detailed or broadly framed, based upon the needs of the project, and includes appropriate control thresholds. The schedule management plan defines how schedule contingencies will be reported and assessed. The schedule management plan may be updated to reflect a change in the way the schedule is managed. The schedule management plan is a major input into the Develop Project Management Plan process, as referenced in Section 6.1.3.1.

6.1.1 Plan Schedule Management: Inputs

6.1.1.1 Project Management Plan

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

- **Scope baseline.** The scope baseline includes the project scope statement and the work breakdown structure (WBS) details used for defining activities, duration estimation, and schedule management; and
- **Other information.** Other scheduling related cost, risk, and communications decisions from the project management plan are used to develop the schedule.

6.1.1.2 Project Charter

Described in Section 4.1.3.1. The project charter defines the summary milestone schedule and project approval requirements that will influence the management of the project schedule.

6.1.1.3 Enterprise Environmental Factors

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

- Organizational culture and structure can all influence schedule management;
- Resource availability and skills that may influence schedule planning;
- Project management software provides the scheduling tool and alternative possibilities for managing the schedule;
- Published commercial information, such as resource productivity information, is often available from commercial databases that track; and
- Organizational work authorization systems.

6.1.1.4 Organizational Process Assets

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

- Monitoring and reporting tools to be used;
- Historical information;
- Schedule control tools;
- Existing formal and informal schedule control related policies, procedures, and guidelines;
- Templates;
- Project closure guidelines;
- Change control procedures; and
- Risk control procedures including risk categories, probability definition and impact, and probability and impact matrix.

6.1.2 Plan Schedule Management: Tools and Techniques

6.1.2.1 Expert Judgment

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

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

6.1.2.2 Analytical Techniques

The Plan Schedule Management process may involve choosing strategic options to estimate and schedule the project such as: scheduling methodology, scheduling tools and techniques, estimating approaches, formats, and project management software. The schedule management plan may also detail ways to fast track or crash (Section 6.6.2.7) the project schedule such as undertaking work in parallel. These decisions, like other schedule decisions affecting the project, may affect project risks.

Organizational policies and procedures may influence which scheduling techniques are employed in these decisions. Techniques may include, but are not limited to, rolling wave planning (Section 6.2.2.2), leads and lags (Section 6.3.2.3), alternatives analysis (Section 6.4.2.2), and methods for reviewing schedule performance (Section 6.7.2.1).

6.1.2.3 Meetings

Project teams may hold planning meetings to develop the schedule management plan. Participants at these meetings may include the project manager, the project sponsor, selected project team members, selected stakeholders, anyone with responsibility for schedule planning or execution, and others as needed.

6.1.3 Plan Schedule Management: Outputs

6.1.3.1 Schedule Management Plan

A component of the project management plan that establishes the criteria and the activities for developing, monitoring, and controlling the schedule. The schedule management plan may be formal or informal, highly detailed or broadly framed, based upon the needs of the project, and includes appropriate control thresholds.

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

- **Project schedule model development.** The scheduling methodology and the scheduling tool to be used in the development of the project schedule model are specified.
- **Level of accuracy**. The acceptable range used in determining realistic activity duration estimates is specified and may include an amount for contingencies.
- **Units of measure.** Each unit used in measurements (such as staff hours, staff days, or weeks for time measures, or meters, liters, tons, kilometers, or cubic yards for quantity measures) is defined for each of the resources.

- **Organizational procedures links.** The WBS (Section 5.4) provides the framework for the schedule management plan, allowing for consistency with the estimates and resulting schedules.
- **Project schedule model maintenance.** The process used to update the status and record progress of the project in the schedule model during the execution of the project is defined.
- **Control thresholds.** Variance thresholds for monitoring schedule performance may be specified to indicate an agreed-upon amount of variation to be allowed before some action needs to be taken. Thresholds are typically expressed as percentage deviations from the parameters established in the baseline plan.
- **Rules of performance measurement.** Earned value management (EVM) rules or other physical measurement rules of performance measurement are set. For example, the schedule management plan may specify:
    - Rules for establishing percent complete,
    - Control accounts at which management of progress and schedule will be measured,
    - Earned value measurement techniques (e.g., baselines, fixed-formula, percent complete, etc.) to be employed (for more specific information, refer to the *Practice Standard for Earned Value Management*),
    - Schedule performance measurements such as schedule variance (SV) and schedule performance index (SPI) used to assess the magnitude of variation to the original schedule baseline.
- **Reporting formats.** The formats and frequency for the various schedule reports are defined.
- **Process descriptions.** Descriptions of each of the schedule management processes are documented.

6.2 Define Activities

Define Activities is the process of identifying and documenting the specific actions to be performed to produce the project deliverables. The key benefit of this process is to break down work packages into activities that provide a basis for estimating, scheduling, executing, monitoring, and controlling the project work. The inputs, tools and techniques, and outputs of this process are depicted in Figure 6-5. Figure 6-6 depicts the data flow diagram of the process.

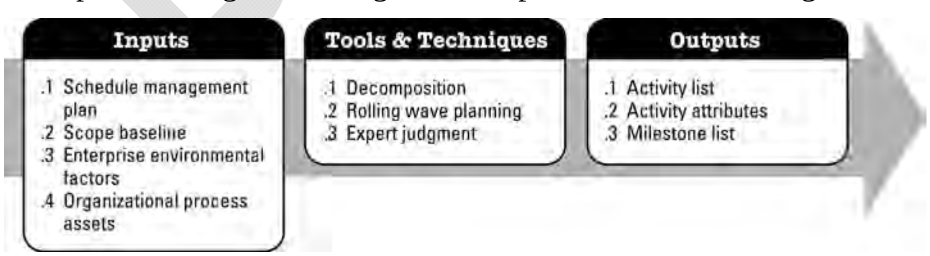

Figure 6-5. Define Activities: Inputs, Tools & Techniques, and Outputs

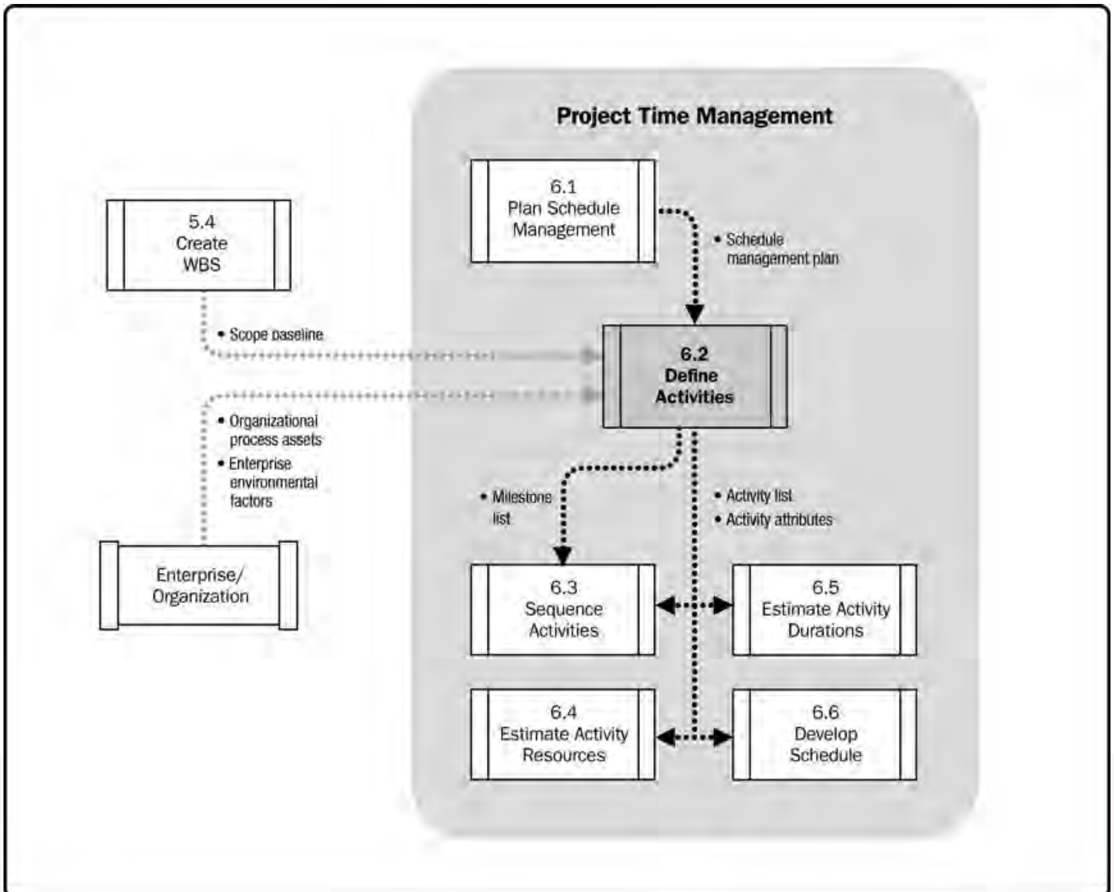

Figure 6-6. Define Activities Data Flow Diagram

Implicit in this process are defining and planning the schedule activities such that the project objectives will be met. The Create WBS process identifies the deliverables at the lowest level in the WBS—the work package. Work packages are typically decomposed into smaller components called activities that represent the work effort required to complete the work package.

6.2.1 Define Activities: Inputs

6.2.1.1 Schedule Management Plan

Described in Section 6.1.3.1. A key input from the schedule management plan is the prescribed level of detail necessary to manage the work.

6.2.1.2 Scope Baseline

Described in Section 5.4.3.1. The project WBS, deliverables, constraints, and assumptions documented in the scope baseline are considered explicitly while defining activities.

6.2.1.3 Enterprise Environmental Factors

Described in Section 2.1.5. Enterprise environmental factors that influence the Define Activities process include, but are not limited to:

- Organizational cultures and structure,
- Published commercial information from commercial databases, and

- Project management information system (PMIS).

6.2.1.4 Organizational Process Assets

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

- Lessons learned knowledge base containing historical information regarding activity lists used by previous similar projects,
- Standardized processes,
- Templates that contain a standard activity list or a portion of an activity list from a previous project, and
- Existing formal and informal activity planning-related policies, procedures, and guidelines, such as the scheduling methodology, that are considered in developing the activity definitions.

6.2.2 Define Activities: Tools and Techniques

6.2.2.1 Decomposition

Decomposition is a technique used for dividing and subdividing the project scope and project deliverables into smaller, more manageable parts. Activities represent the effort needed to complete a work package. The Define Activities process defines the final outputs as activities rather than deliverables, as done in the Create WBS process (Section 5.4).

The activity list, WBS, and WBS dictionary can be developed either sequentially or concurrently, with the WBS and WBS dictionary as the basis for development of the final activity list. Each work package within the WBS is decomposed into the activities required to produce the work package deliverables. Involving team members in the decomposition can lead to better and more accurate results.

6.2.2.2 Rolling Wave Planning

Rolling wave planning is an iterative planning technique in which the work to be accomplished in the near term is planned in detail, while the work in the future is planned at a higher level. It is a form of progressive elaboration. Therefore, work can exist at various levels of detail depending on where it is in the project life cycle. During early strategic planning, when information is less defined, work packages may be decomposed to the known level of detail. As more is known about the upcoming events in the near term, work packages can be decomposed into activities.

6.2.2.3 Expert Judgment

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

6.2.3 Define Activities: Outputs

6.2.3.1 Activity List

The activity list is a comprehensive list that includes all schedule activities required on the project. The activity list also includes the activity identifier and a scope of work description for each activity in sufficient detail to ensure that project team members understand what work is required to be completed. Each activity should have a unique title that describes its place in the schedule, even if that activity title is displayed outside the context of the project schedule.

6.2.3.2 Activity Attributes

Activities, distinct from milestones, have durations, during which the work of that activity is performed, and may have resources and costs associated with that work. Activity attributes extend the description of the activity by identifying the multiple components associated with each activity. The components for each activity evolve over time. During the initial stages of the project, they include the activity identifier (ID), WBS ID, and activity label or name, and when completed, may include activity codes, activity description, predecessor activities, successor activities, logical relationships, leads and lags (Section 6.3.2.3), resource requirements, imposed dates, constraints, and assumptions. Activity attributes can be used to identify the person responsible for executing the work, geographic area, or place where the work has to be performed, the project calendar the activity is assigned to, and activity type such as level of effort (often abbreviated as LOE), discrete effort, and apportioned effort. Activity attributes are used for 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.

6.2.3.3 Milestone List

A milestone is a significant point or event in a project. A milestone list is a list identifying all project milestones and indicates whether the milestone is mandatory, such as those required by contract, or optional, such as those based upon historical information. Milestones are similar to regular schedule activities, with the same structure and attributes, but they have zero duration because milestones represent a moment in time.

6.3 Sequence Activities

Sequence Activities is the process of identifying and documenting relationships among the project activities. The key benefit of this process is that it defines the logical sequence of work to obtain the greatest efficiency given all project constraints. The inputs, tools and techniques, and outputs of this process are depicted in Figure 6-7. Figure 6-8 depicts the data flow diagram of the process.

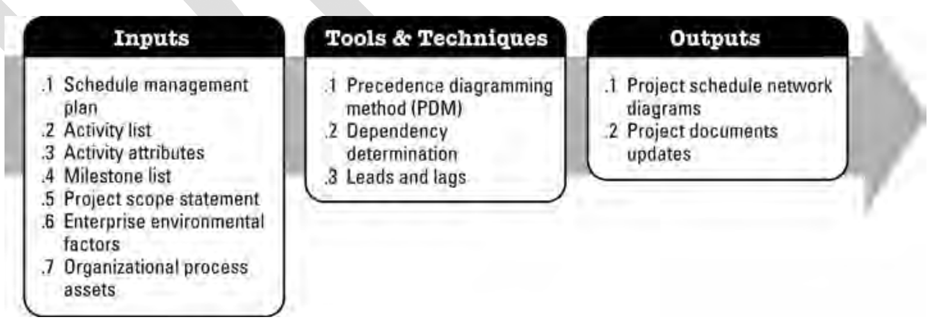

Figure 6-7. Sequence Activities: Inputs, Tools & Techniques, and Outputs

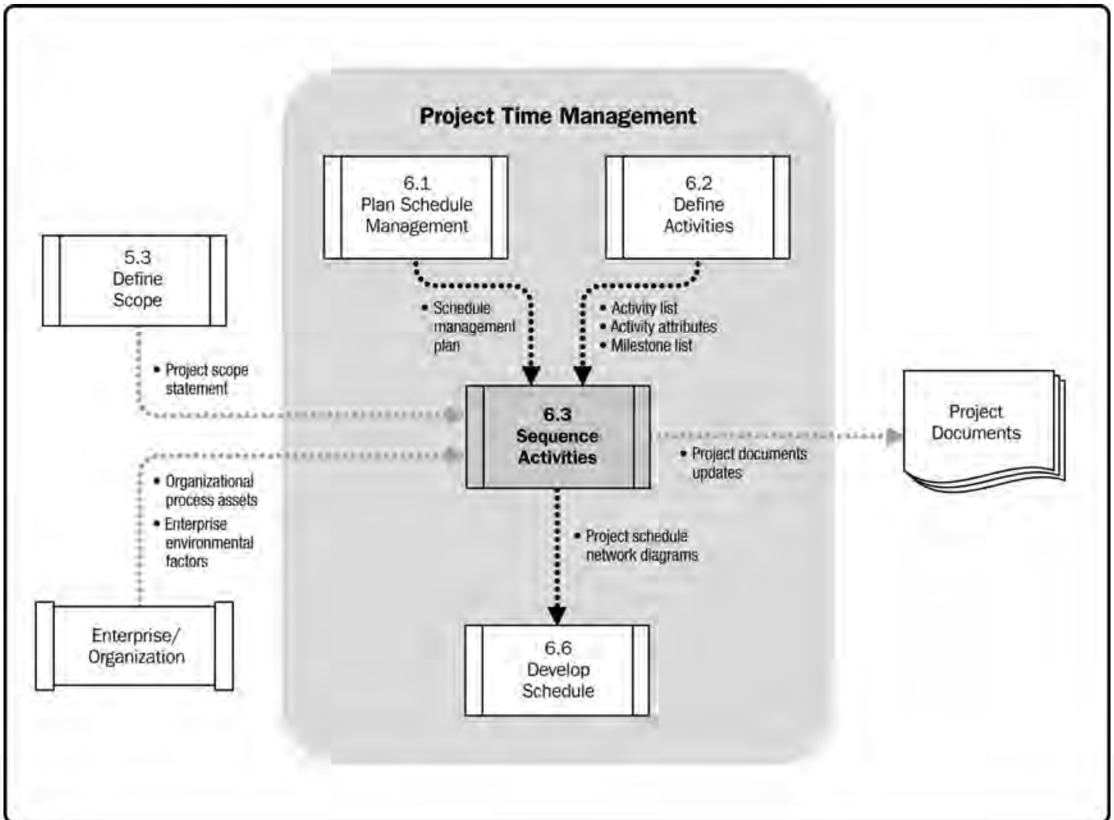

Figure 6-8. Sequence Activities Data Flow Diagram

Every activity and milestone except the first and last should be connected to at least one predecessor with a finish-to-start or start-to-start logical relationship and at least one successor with a finish-to-start or finish-to-finish logical relationship. Logical relationships should be designed to create a realistic project schedule. It may be necessary to use lead or lag time between activities to support a realistic and achievable project schedule. Sequencing can be performed by using project management software or by using manual or automated techniques.

6.3.1 Sequence Activities: Inputs

6.3.1.1 Schedule Management Plan

Described in Section 6.1.3.1. The schedule management plan identifies the scheduling method and tool to be used for the project, which will guide how the activities may be sequenced.

6.3.1.2 Activity List

Described in Section 6.2.3.1. The activity list contains all schedule activities required on the project, which are to be sequenced. Dependencies and other constraints for these activities can influence the sequencing of the activities.

6.3.1.3 Activity Attributes

Described in Section 6.2.3.2. Activity attributes may describe a necessary sequence of events or defined predecessor or successor relationships.

6.3.1.4 Milestone List

Described in Section 6.2.3.3. The milestone list may have scheduled dates for specific milestones, which may influence the way activities are sequenced.

6.3.1.5 Project Scope Statement

Described in Section 5.3.3.1. The project scope statement contains the product scope description, which includes product characteristics that may affect activity sequencing, such as the physical layout of a plant to be constructed or subsystem interfaces on a software project. Other information from the project scope statement including project deliverables, project constraints, and project assumptions may also affect activity sequencing. While these effects are often apparent in the activity list, the product scope description is generally reviewed to ensure accuracy.

6.3.1.6 Enterprise Environmental Factors

Described in Section 2.1.5. Enterprise environmental factors that influence the Sequence Activities process include, but are not limited to:

- Government or industry standards,
- Project management information system (PMIS),
- Scheduling tool,
- Company work authorization systems.

6.3.1.7 Organizational Process Assets

Described in Section 2.1.4. The organizational process assets that can influence the Sequence Activities process include, but are not limited to: project files from the corporate knowledge base used for scheduling methodology, existing formal and informal activity planning-related policies, procedures, and guidelines, such as the scheduling methodology, that are considered in developing logical relationships, and templates that can be used to expedite the preparation of networks of project activities. Related activity attributes information in templates can also contain additional descriptive information useful in sequencing activities.

6.3.2 Sequence Activities: Tools and Techniques

6.3.2.1 Precedence Diagramming Method

The precedence diagramming method (PDM) is a technique used for constructing a schedule model in which activities are represented by nodes and are graphically linked by one or more logical relationships to show the sequence in which the activities are to be performed. Activity-on-node (AON) is one method of representing a precedence diagram. This is the method used by most project management software packages.

PDM includes four types of dependencies or logical relationships. A predecessor activity is an activity that logically comes before a dependent activity in a schedule. A successor activity is a dependent activity that logically comes after another activity in a schedule. These relationships are defined below and are illustrated in Figure 6-9:

- **Finish-to-start (FS).** A logical relationship in which a successor activity cannot start until a predecessor activity has finished. Example: The awards ceremony (successor) cannot start until the race (predecessor) has finished.

- **Finish-to-finish (FF).** A logical relationship in which a successor activity cannot finish until a predecessor activity has finished. Example: Writing a document (predecessor) is required to finish before editing the document (successor) can finish.
- **Start-to-start (SS).** A logical relationship in which a successor activity cannot start until a predecessor activity has started. Example: Level concrete (successor) cannot begin until pour foundation (predecessor) begins.
- **Start-to-finish (SF).** A logical relationship in which a successor activity cannot finish until a predecessor activity has started. Example: The first security guard shift (successor) cannot finish until the second security guard shift (predecessor) starts.

In PDM, finish-to-start is the most commonly used type of precedence relationship. The start-to-finish relationship is very rarely used but is included to present a complete list of the PDM relationship types.

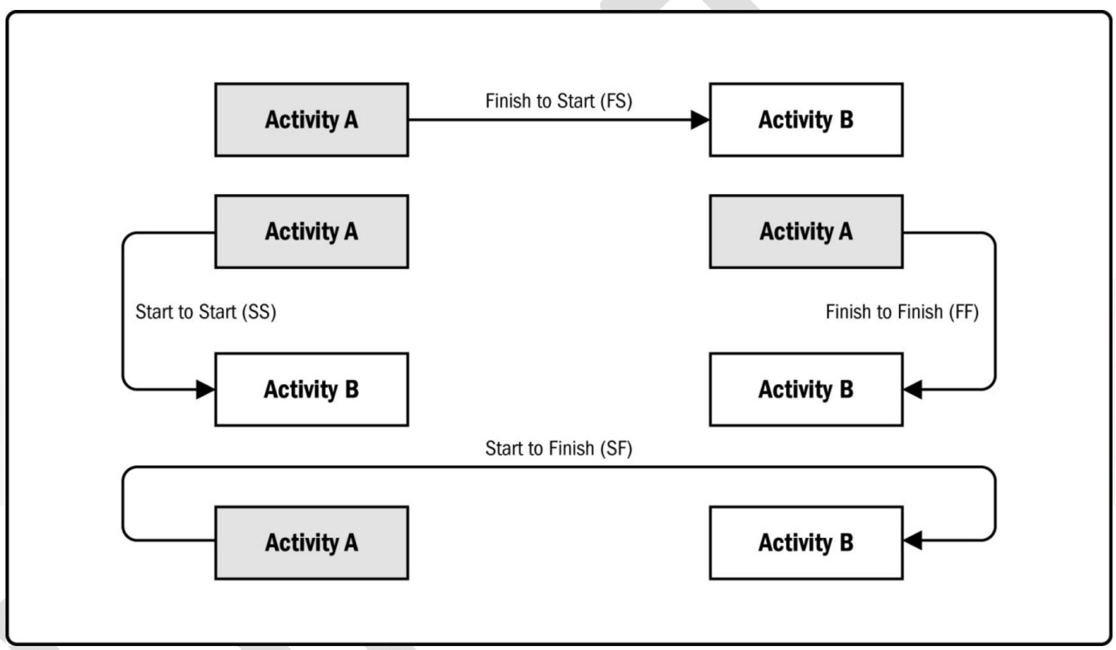

Figure 6-9. Precedence Diagramming Method (PDM) Relationship Types

6.3.2.2 Dependency Determination

Dependencies may be characterized by the following attributes: mandatory or discretionary, internal or external, as described below. Dependency has four attributes, but two can be applicable at the same time in following ways: mandatory external dependencies, mandatory internal dependencies, discretionary external dependencies, or discretionary internal dependencies.

- **Mandatory dependencies.** Mandatory dependencies are those that are legally or contractually required or inherent in the nature of the work. 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 has to be built before it can be tested. Mandatory dependencies are also sometimes referred to as hard logic or hard dependencies. Technical dependencies may not be mandatory. The project team determines which dependencies are mandatory during the process of sequencing the activities. Mandatory dependencies should not be confused with assigning schedule constraints in the scheduling tool.

- **Discretionary dependencies.** Discretionary dependencies are sometimes referred to as preferred logic, preferential logic, or soft logic. Discretionary dependencies are 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 may be other acceptable sequences. Discretionary dependencies should be fully documented since they can create arbitrary total float values and can limit later scheduling options. When fast tracking techniques are employed, these discretionary dependencies should be reviewed and considered for modification or removal. The project team determines which dependencies are discretionary during the process of sequencing the activities.
- **External dependencies.** External dependencies involve a relationship between project activities and non-project activities. These dependencies are usually outside the project team's control. For example, the testing activity in a software project may be dependent on the 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. The project management team determines which dependencies are external during the process of sequencing the activities.
- **Internal dependencies.** Internal dependencies involve a precedence relationship between project activities and are generally inside the project team's control. For example, if the team cannot test a machine until they assemble it, this is an internal mandatory dependency. The project management team determines which dependencies are internal during the process of sequencing the activities.

6.3.2.3 Leads and Lags

A lead is the amount of time whereby a successor activity can be advanced with respect to a predecessor activity. For example, on a project to construct a new office building, the landscaping could be scheduled to start two weeks prior to the scheduled punch list completion. This would be shown as a finish-to-start with a two-week lead as shown in Figure 6-10. Lead is often represented as a negative value for lag in scheduling software.

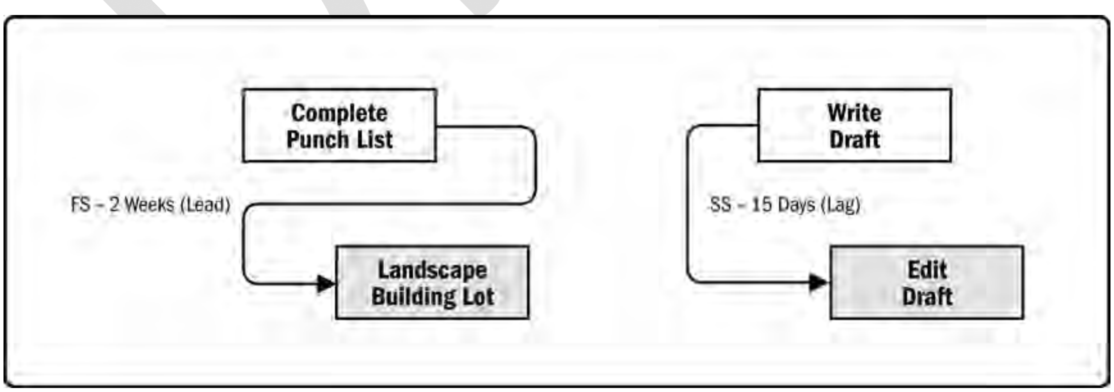

Figure 6-10. Examples of Lead and Lag

A lag is the amount of time whereby a successor activity will be delayed with respect to a predecessor activity. For example, a technical writing team may begin editing the draft of a large document 15 days after they begin writing it. This can be shown as a start-to-start relationship with a 15-day lag as shown in Figure 6-10. Lag can also be represented in project schedule network diagrams as shown in Figure 6-11 in the relationship between activities H and I, as indicated by the nomenclature SS+10 (start-to-start plus 10 days lag) even though offset is not shown relative to a timescale.

The project management team determines the dependencies that may require a lead or a lag to accurately define the logical relationship. The use of leads and lags should not replace schedule logic. Activities and their related assumptions should be documented.

6.3.3 Sequence Activities: Outputs

6.3.3.1 Project Schedule Network Diagrams

A project schedule network diagram is a graphical representation of the logical relationships, also referred to as dependencies, among the project schedule activities. Figure 6-11 illustrates a project schedule network diagram. A project schedule network diagram is produced manually or by using project management software. It can include full project details, or have one or more summary activities. A summary narrative can accompany the diagram and describe the basic approach used to sequence the activities. Any unusual activity sequences within the network should be fully described within the narrative.

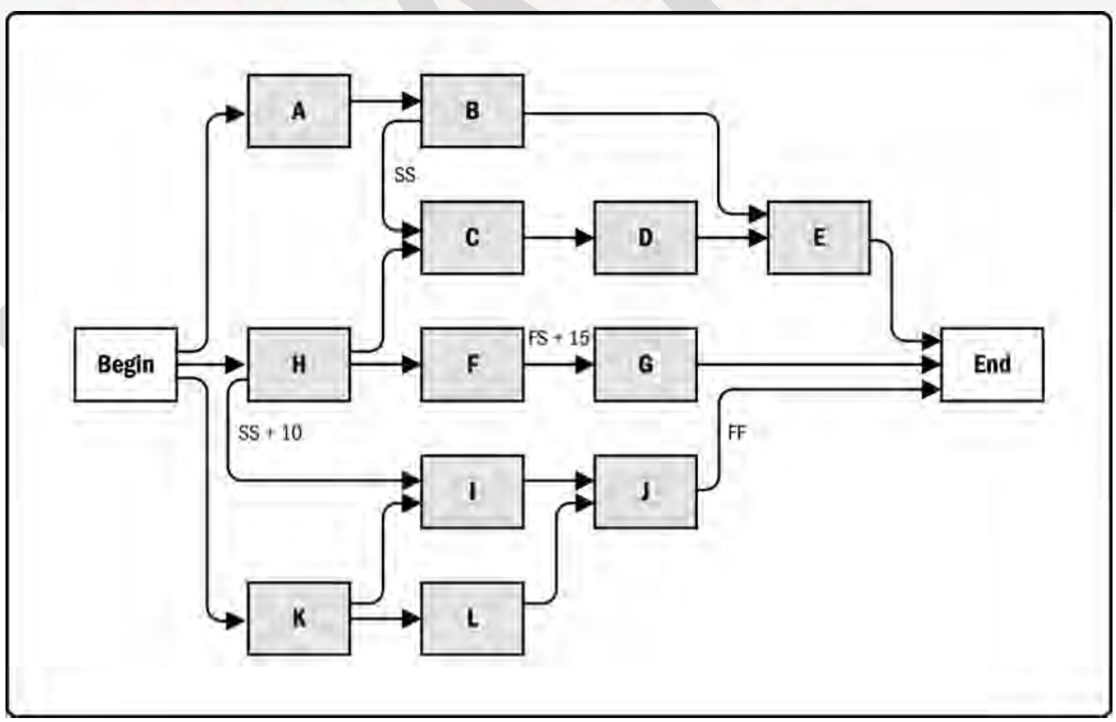

Figure 6-11. Project Schedule Network Diagram

6.3.3.2 Project Documents Updates

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

- Activity lists,

- Activity attributes,
- Milestone list, and
- Risk register.

6.4 Estimate Activity Resources

Estimate Activity Resources is the process of estimating the type and quantities of material, human resources, equipment, or supplies required to perform each activity. The key benefit of this process is that it identifies the type, quantity, and characteristics of resources required to complete the activity which allows more accurate cost and duration estimates. The inputs, tools and techniques, and outputs of this process are depicted in Figure 6-12. Figure 6-13 depicts the data flow diagram of the process.

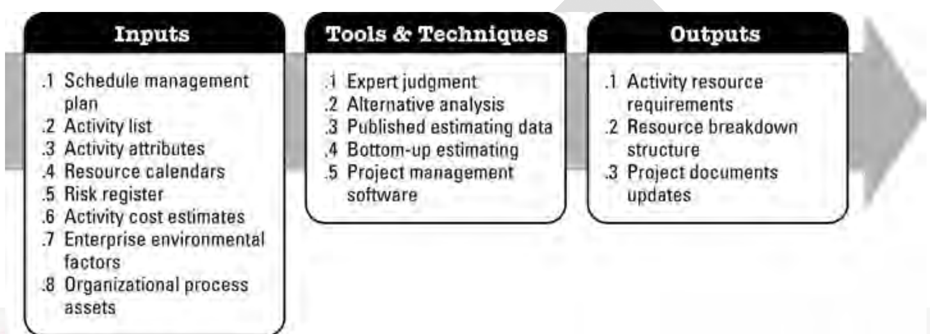

Figure 6-12. Estimate Activity Resources: Inputs, Tools & Techniques, and Outputs

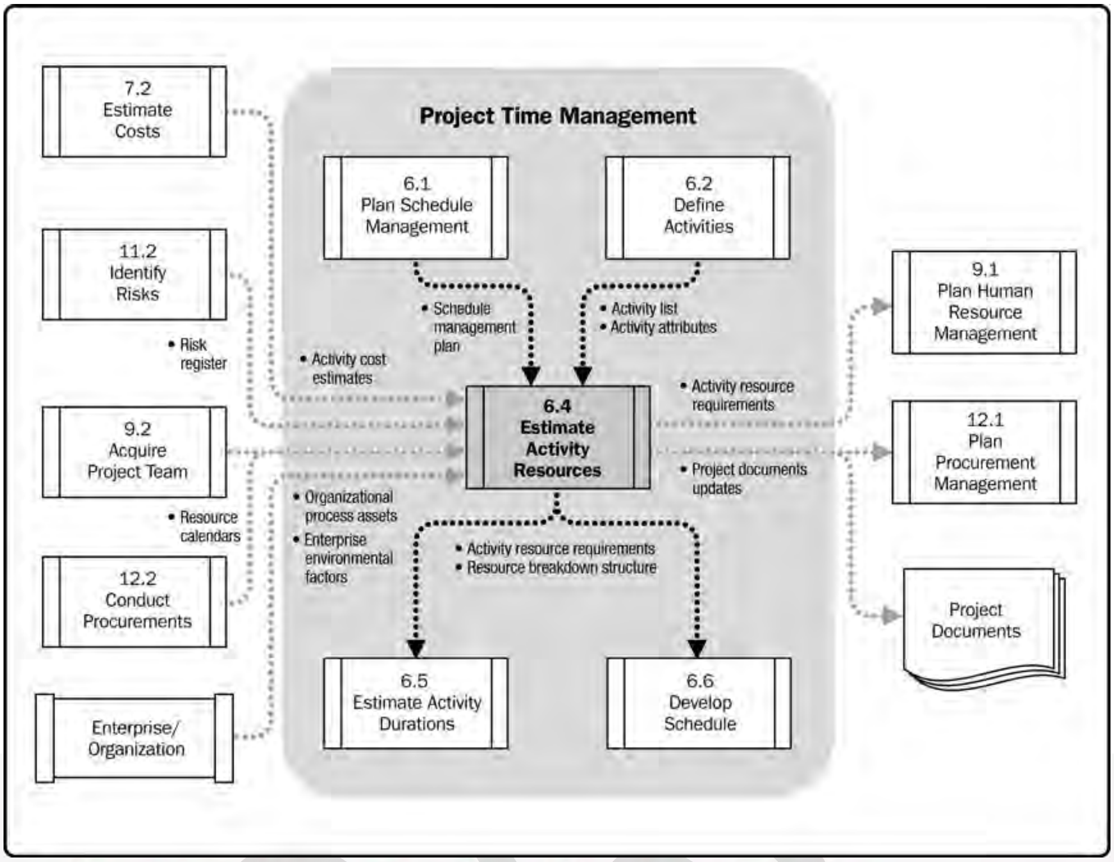

Figure 6-13. Estimate Activity Resources Data Flow Diagram

The Estimate Activity Resources process is closely coordinated with the Estimate Costs process (Section 7.2). 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 may 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.

6.4.1 Estimate Activity Resources: Inputs

6.4.1.1 Schedule Management Plan

Described in Section 6.1.3.1. The schedule management plan identifies the level of accuracy and the units of measure for the resources to be estimated.

6.4.1.2 Activity List

Described in Section 6.2.3.1. The activity list identifies the activities which will need resources.

6.4.1.3 Activity Attributes

Described in Section 6.2.3.2. The activity attributes provide the primary data input for use in estimating those resources required for each activity in the activity list.

6.4.1.4 Resource Calendars

Described in Sections 9.2.3.2 and 12.2.3.3. A resource calendar is a calendar that identifies the working days and shifts on which each specific resource is available. Information on which resources (such as human resources, equipment, and material) are potentially available during a planned activity period, is used for estimating resource utilization. Resource calendars specify when and how long identified project resources will be available during the project. This information may be at the activity or project level. This knowledge includes consideration of attributes such as resource experience and/or skill level, as well as various geographical locations from which the resources originate and when they may be available.

The composite resource calendar includes the availability, capabilities, and skills of human resources (Section 9.2.3.2). For example, during the early phases of an engineering design project, the pool of resources may include junior and senior engineers in large numbers. During later phases of the same project, however, the pool may be limited to those individuals who are knowledgeable about the project as a result of having worked on the earlier phases of the project.

6.4.1.5 Risk Register

Described in Section 11.2.3.1. Risk events may impact resource selection and availability. Updates to the risk register are included with project documents updates described in Section 11.5.3.2, from Plan Risk Responses.

6.4.1.6 Activity Cost Estimates

Described in Section 7.2.3.1. The cost of resources may impact resource selection.

6.4.1.7 Enterprise Environmental Factors

Described in Section 2.1.5. The enterprise environmental factors that can influence the Estimate Activity Resources process include, but are not limited to, resource location, availability, and skills.

6.4.1.8 Organizational Process Assets

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

- Policies and procedures regarding staffing,
- Policies and procedures relating to rental and purchase of supplies and equipment, and
- Historical information regarding types of resources used for similar work on previous projects.

6.4.2 Estimate Activity Resources: Tools and Techniques

6.4.2.1 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.

6.4.2.2 Alternative 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-rent-or-buy decisions regarding the resource (Section 12.1.3.5).

6.4.2.3 Published Estimating Data

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

6.4.2.4 Bottom-Up Estimating

Bottom-up estimating is a method of estimating project duration or cost by aggregating the estimates of the lower-level components of the WBS. When an activity cannot be estimated with a reasonable degree of confidence, the work within the activity is decomposed into more detail. The resource needs are estimated. These estimates are then aggregated into a total quantity for each of the activity's resources. 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 and documented in the estimated requirements of the activity.

6.4.2.5 Project Management Software

Project management software, such as a scheduling software tool, has the capability to help plan, organize, and manage resource pools and develop resource estimates. Depending on the sophistication of the software, resource breakdown structures, resource availability, resource rates, and various resource calendars can be defined to assist in optimizing resource utilization.

6.4.3 Estimate Activity Resources: Outputs

6.4.3.1 Activity Resource Requirements

Activity resource requirements identify the types and quantities of resources required for each activity in a work package. These requirements then can be aggregated to determine the estimated resources for each work package and each work period. 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 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 quantities are used.

6.4.3.2 Resource Breakdown Structure

The resource breakdown structure is a hierarchical representation of resources by category and type. Examples of resource categories include labor, material, equipment, and supplies. Resource types may include the skill level, grade level, or other information as appropriate to the project. The resource breakdown structure is useful for organizing and reporting project schedule data with resource utilization information.

6.4.3.3 Project Documents Updates

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

- Activity list,
- Activity attributes, and
- Resource calendars.

6.5 Estimate Activity Durations

Estimate Activity Durations is the process of estimating the number of work periods needed to complete individual activities with estimated resources. The key benefit of this process is that it provides the amount of time each activity will take to complete, which is a major input into the Develop Schedule process. The inputs, tools and techniques, and outputs of this process are depicted in Figure 6-14. Figure 6-15 depicts the data flow diagram of the process.

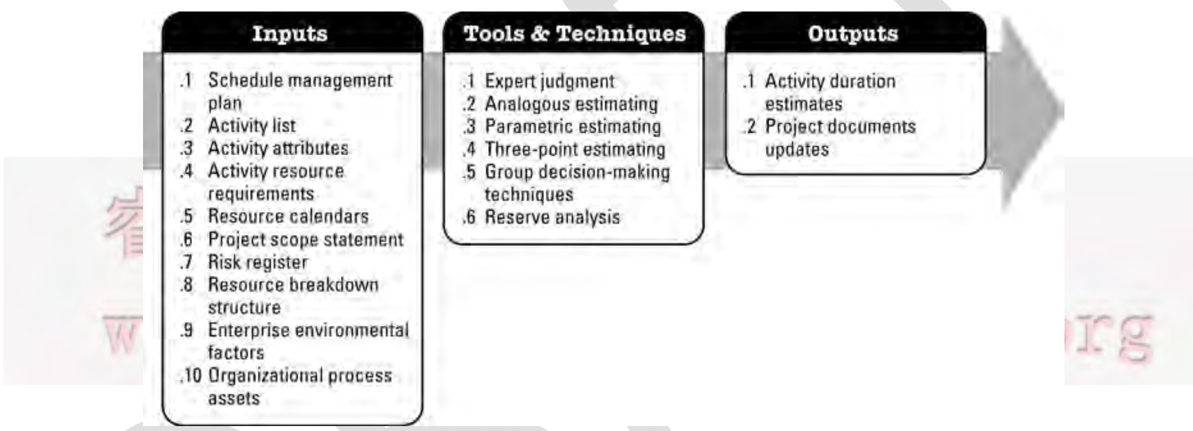

Figure 6-14. Estimate Activity Durations: Inputs, Tools & Techniques, and Outputs

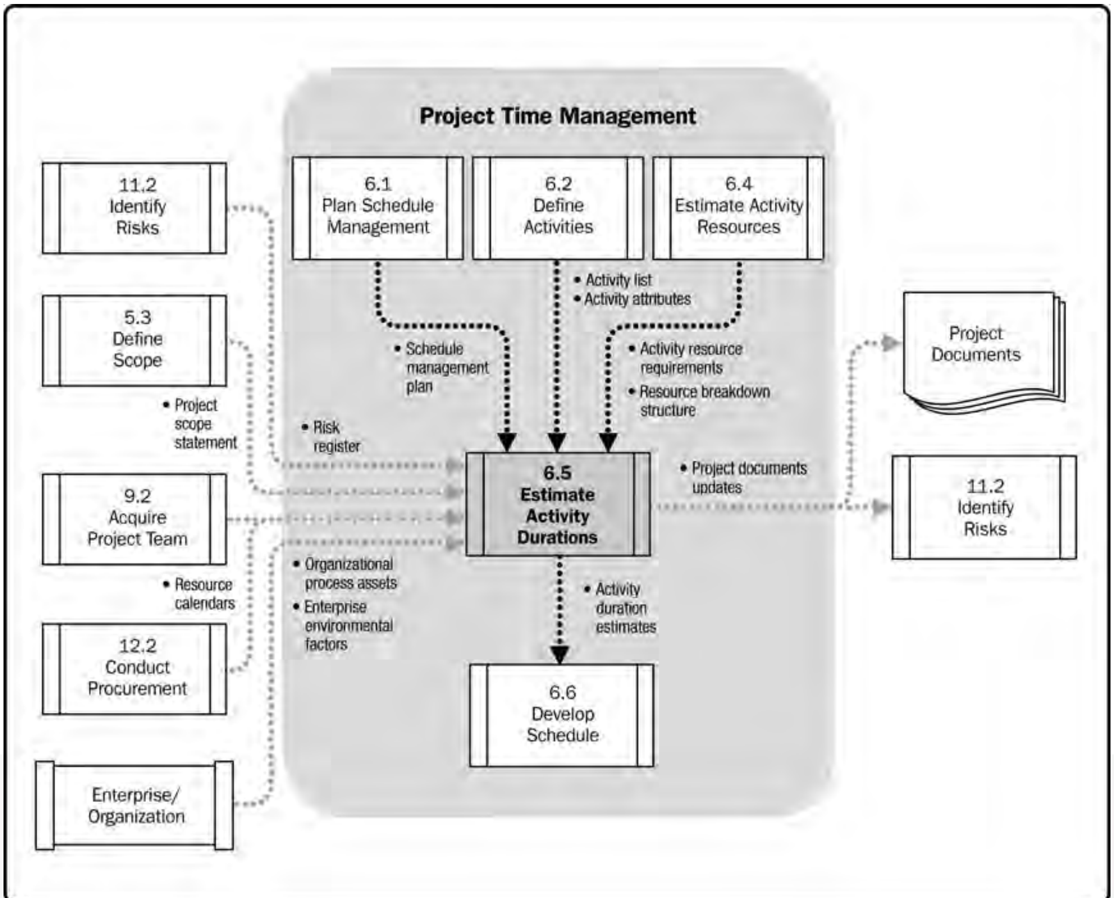

Figure 6-15. Estimate Activity Durations Data Flow Diagram

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

The Estimate Activity Durations process requires an estimation of the amount of work effort required to complete the activity and the amount of available resources estimated to complete the activity. These estimates are used to approximate the number of work periods (activity duration) needed to complete the activity using the appropriate project and resource calendars. All data and assumptions that support duration estimating are documented for each estimate of activity duration.

6.5.1 Estimate Activity Durations: Inputs

6.5.1.1 Schedule Management Plan

Described in Section 6.1.3.1. The schedule management plan defines the method used and the level of accuracy along with other criteria required to estimate activity durations including the project update cycle.

6.5.1.2 Activity List

Described in Section 6.2.3.1. The activity list identifies the activities that will need duration estimates.

6.5.1.3 Activity Attributes

Described in Section 6.2.3.2. The activity attributes provide the primary data input for use in estimating durations required for each activity in the activity list.

6.5.1.4 Activity Resource Requirements

Described in Section 6.4.3.1. The estimated activity resource requirements will have an effect on the duration of the activity, since the level to which the resources assigned to the activity meet the requirements will significantly influence the duration of most activities. For example, if additional or lower-skilled resources are assigned to an activity, there may be reduced efficiency or productivity due to increased communication, training, and coordination needs leading to a longer duration estimate.

6.5.1.5 Resource Calendars

Described in Section 6.4.1.4. The resource calendars influence the duration of schedule activities due to the availability of specific resources, type of resources, and resources with specific attributes. For example, when staff members are assigned to an activity on a full-time basis, in general, a skilled staff member can be expected to complete a given activity in less time than a relatively less-skilled staff member.

6.5.1.6 Project Scope Statement

Described in Section 5.3.3.1. The assumptions and constraints from the project scope statement are considered when estimating the activity durations. Examples of assumptions include, but are not limited to:

- Existing conditions,
- Availability of information, and
- Length of the reporting periods.

Examples of constraints include, but are not limited to:

- Available skilled resources, and
- Contract terms and requirements.

6.5.1.7 Risk Register

Described in Section 11.2.3.1. The risk register provides the list of risks, along with the results of risk analysis and risk response planning. Updates to the risk register are included with project document updates described in Section 11.5.3.2.

6.5.1.8 Resource Breakdown Structure

Described in Section 6.4.3.2. The resource breakdown structure provides a hierarchical structure of the identified resources by resource category and resource type.

6.5.1.9 Enterprise Environmental Factors

Described in Section 2.1.5. The enterprise environmental factors that can influence the Estimate Activity Durations process include, but are not limited to:

- Duration estimating databases and other reference data,
- Productivity metrics,
- Published commercial information, and
- Location of team members.

6.5.1.10 Organizational Process Assets

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

- Historical duration information,
- Project calendars,
- Scheduling methodology, and
- Lessons learned.

6.5.2 Estimate Activity Durations: Tools and Techniques

6.5.2.1 Expert Judgment

Expert judgment, guided by historical information, can provide duration estimate information or recommended maximum activity durations from prior similar projects. Expert judgment can also be used to determine whether to combine methods of estimating and how to reconcile differences between them.

6.5.2.2 Analogous Estimating

Analogous estimating is a technique for estimating the duration or cost of an activity or a project using historical data from a similar activity or project. Analogous estimating uses parameters from a previous, similar project, such as duration, budget, size, weight, and complexity, as the basis for estimating the same parameter or measure for a future project. When estimating durations, this technique relies on the actual duration of previous, similar projects as the basis for estimating the duration of the current project. It is a gross value estimating approach, sometimes adjusted for known differences in project complexity. Analogous duration estimating is frequently used to estimate project duration when there is a limited amount of detailed information about the project.

Analogous estimating is generally less costly and less time consuming than other techniques, but it is also less accurate. Analogous duration estimates can be applied to a total project or to segments of a project and may be used in conjunction with other estimating methods. Analogous 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.

6.5.2.3 Parametric Estimating

Parametric estimating is an estimating technique in which an algorithm is used to calculate cost or duration based on historical data and project parameters. Parametric estimating uses a statistical relationship between historical data and other variables (e.g., square footage in construction) to calculate an estimate for activity parameters, such as cost, budget, and duration.

Activity durations can be quantitatively determined by multiplying the quantity of work to be performed by labor hours per unit of work. For example, activity duration on a design project is estimated by the number of drawings multiplied by the number of labor hours per drawing, or on a cable installation, the meters of cable multiplied by the number of labor hours per meter. For example, if the assigned resource is capable of installing 25 meters of cable per hour, the duration required to install 1,000 meters is 40 hours. (1,000 meters divided by 25 meters per hour).

This technique can produce higher levels of accuracy depending upon the sophistication and underlying data built into the model. Parametric time estimates can be applied to a total project or to segments of a project, in conjunction with other estimating methods.

6.5.2.4 Three-Point Estimating

The accuracy of single-point activity duration estimates may be improved by considering estimation uncertainty and risk. This concept originated with the program evaluation and review technique (PERT). PERT uses three estimates to define an approximate range for an activity's duration:

- **Most likely** (*tM*)**.** This estimate is based on the duration of the activity, given the resources likely to be assigned, their productivity, realistic expectations of availability for the activity, dependencies on other participants, and interruptions.
- **Optimistic** (*tO*). The activity duration based on analysis of the best-case scenario for the activity.
- **Pessimistic** (*tP*). The activity duration based on analysis of the worst-case scenario for the activity.

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

- **Triangular Distribution.** $tE = (tO + tM + tP) / 3$
- **Beta Distribution** (from the traditional PERT technique). $tE = (tO + 4tM + tP) / 6$

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

6.5.2.5 Group Decision-Making Techniques

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

6.5.2.6 Reserve Analysis

Duration estimates may include contingency reserves, sometimes referred to as time reserves or buffers, into the project schedule to account for schedule uncertainty. Contingency reserves are the estimated duration within the schedule baseline, which is allocated for identified risks that are accepted and for which contingent or mitigation responses are developed. Contingency reserves are associated with the "known-unknowns," which may be estimated to account for this unknown amount of rework. The contingency reserve may be a percentage of the estimated activity duration, a fixed number of work periods, or may be developed by using quantitative analysis methods such as Monte Carlo simulation (Section 11.4.2.2). Contingency reserves may be separated from the individual activities and aggregated into buffers as shown in Figure 6-19.

As more precise information about the project becomes available, the contingency reserve may be used, reduced, or eliminated. Contingency should be clearly identified in schedule documentation.

Estimates may also be produced for the amount of management reserve of time for the project. Management reserves are a specified amount of the project duration withheld for management control purposes and are reserved for unforeseen work that is within scope of the project. Management reserves are intended to address the "unknown-unknowns" that can affect a project. Management reserve is not included in the schedule baseline, but it is part of the overall project duration requirements. Depending on contract terms, use of management reserves may require a change to the schedule baseline.

6.5.3 Estimate Activity Durations: Outputs

6.5.3.1 Activity Duration Estimates

Activity duration estimates are quantitative assessments of the likely number of time periods that are required to complete an activity. Duration estimates do not include any lags as described in Section 6.3.2.3. Activity duration estimates may include some indication of the range of possible results. For example:

- 2 weeks ± 2 days, which indicates that the activity will take at least eight days and not more than twelve (assuming a five-day workweek); and
- 15 % probability of exceeding three weeks, which indicates a high probability—85 %—that the activity will take three weeks or less.

6.5.3.2 Project Documents Updates

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

- Activity attributes; and
- Assumptions made in developing the activity duration estimate, such as skill levels and availability, as well as a basis of estimates for durations.

6.6 Develop Schedule

Develop Schedule is the process of analyzing activity sequences, durations, resource requirements, and schedule constraints to create the project schedule model. The key benefit of this process is that by entering schedule activities, durations, resources, resource availabilities, and logical relationships into the scheduling tool, it generates a schedule model with planned dates for completing project activities. The inputs, tools and techniques, and outputs of this process are depicted in Figure 6-16. Figure 6-17 depicts the data flow diagram of the process.

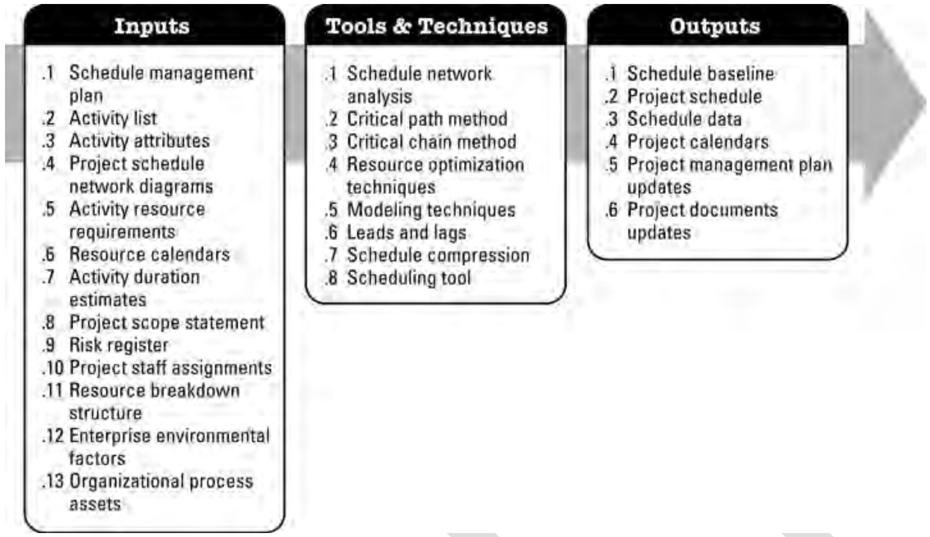

Figure 6-16 Develop Schedule: Inputs, Tools & Techniques, and Outputs

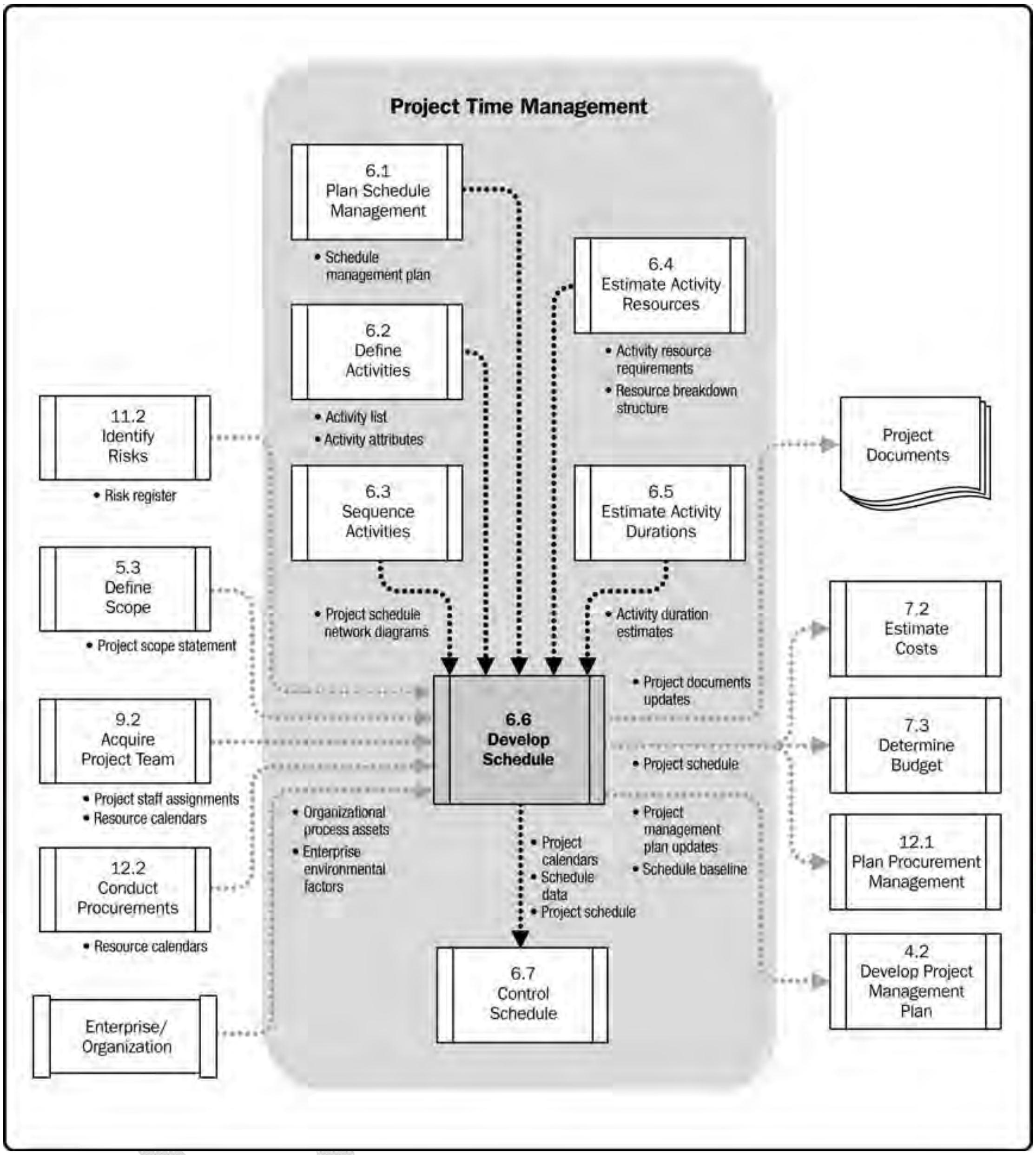

Figure 6-17. Develop Schedule Data Flow Diagram

Developing an acceptable project schedule is often an iterative process. The schedule model is used to determine the planned start and finish dates for project activities and milestones based on the accuracy of the inputs. Schedule development can require the review and revision of duration estimates and resource estimates to create the project schedule model to establish an approved project schedule that can serve as a baseline to track progress. Once the activity start and finish dates have been determined, it is common to have project staff assigned to the activities review their assigned activities and confirm that the start and finish dates present no conflict with resource calendars or assigned activities in other projects or tasks and thus are still valid. As work progresses, revising and maintaining the project schedule model to sustain a realistic schedule continues throughout the duration of the project, as described in Section 6.7.

For more specific information regarding scheduling, refer to the *Practice Standard for Scheduling*.

6.6.1 Develop Schedule: Inputs

6.6.1.1 Schedule Management Plan

Described in Section 6.1.3.1. The schedule management plan identifies the scheduling method and tool used to create the schedule, and how the schedule is to be calculated.

6.6.1.2 Activity List

Described in Section 6.2.3.1. The activity list identifies the activities that will be included in the schedule model.

6.6.1.3 Activity Attributes

Described in Section 6.2.3.2. The activity attributes provide the details used to build the schedule model.

6.6.1.4 Project Schedule Network Diagrams

Described in Section 6.3.3.1. The project schedule network diagrams contain the logical relationships of predecessors and successors that will be used to calculate the schedule.

6.6.1.5 Activity Resource Requirements

Described in Section 6.4.3.1. The activity resource requirements identify the types and quantities of resources required for each activity used to create the schedule model.

6.6.1.6 Resource Calendars

Described in Sections 9.2.3.2 and 12.2.3.3. The resource calendars contain information on the availability of resources during the project.

6.6.1.7 Activity Duration Estimates

Described in Section 6.5.3.1. The activity duration estimates contain the quantitative assessments of the likely number of work periods that will be required to complete an activity that will be used to calculate the schedule.

6.6.1.8 Project Scope Statement

Described in Section 5.3.3.1. The project scope statement contains assumptions and constraints that can impact the development of the project schedule.

6.6.1.9 Risk Register

Described in Section 11.2.3.1. The risk register provides the details of all identified risks and their characteristics that affect the schedule model.

6.6.1.10 Project Staff Assignments

Described in Section 9.2.3.1. The project staff assignments specify which resources are assigned to each activity.

6.6.1.11 Resource Breakdown Structure

Described in Section 6.4.3.2. The resource breakdown structure provides the details by which resource analysis and organizational reporting can be done.

6.6.1.12 Enterprise Environmental Factors

Described in Section 2.1.5. The enterprise environmental factors include, but are not limited to:

- Standards,
- Communication channels, and
- Scheduling tool to be used in developing the schedule model.

6.6.1.13 Organizational Process Assets

Described in Section 2.1.4. The organizational process assets that can influence the Develop Schedule process include, but are not limited to: scheduling methodology and project calendar(s).

6.6.2 Develop Schedule: Tools and Techniques

6.6.2.1 Schedule Network Analysis

Schedule network analysis is a technique that generates the project schedule model. It employs various analytical techniques, such as critical path method, critical chain method, what-if analysis, and resource optimization techniques to calculate the early and late start and finish dates for the uncompleted portions of project activities. 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.

6.6.2.2 Critical Path Method

The critical path method, which is a method used to estimate the minimum project duration and determine the amount of scheduling flexibility on the logical network paths within the schedule model. This schedule network analysis technique calculates the early start, early finish, late start, and late finish dates for all activities without regard for any resource limitations by performing a forward and backward pass analysis through the schedule network, as shown in Figure 6-18. In this example the longest path includes activities A, C, and D, and, hence, the sequence of A-C-D is the critical path. The critical path is the sequence of activities that represents the longest path through a project, which determines the shortest possible project duration. The resulting early and late start and finish dates are not necessarily the project schedule, rather they indicate the time periods within which the activity could be executed, using the parameters entered in the schedule model for activity durations, logical relationships, leads, lags, and other known constraints. The critical path method is used to calculate the amount of scheduling flexibility on the logical network paths within the schedule model.

On any network path, the schedule flexibility is measured by the amount of time that a schedule activity can be delayed or extended from its early start date without delaying the project finish date or violating a schedule constraint, and is termed "total float." A CPM critical path is normally characterized by zero total float on the critical path. As implemented with PDM sequencing, critical paths may have positive, zero, or negative total float depending on constraints applied. Any activity on the critical path is called a critical path activity. Positive total float is caused when the backward pass is calculated from a schedule constraint that is later than the early finish date that has been calculated during forward pass calculation. Negative total float is caused when a constraint on the late dates is violated by duration and logic. Schedule networks may have multiple near-critical paths. Many software packages allow the user to define the parameters used to determine the critical path(s). Adjustments to activity durations (if more resources or less scope can be arranged), logical relationships (if the relationships were discretionary to begin with), 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 has been calculated, then the free float—the amount of time that a schedule activity can be delayed without delaying the early start date of any successor or violating a schedule constraint—can also be determined. For example the free float for Activity B, in Figure 6-18, is 5 days.

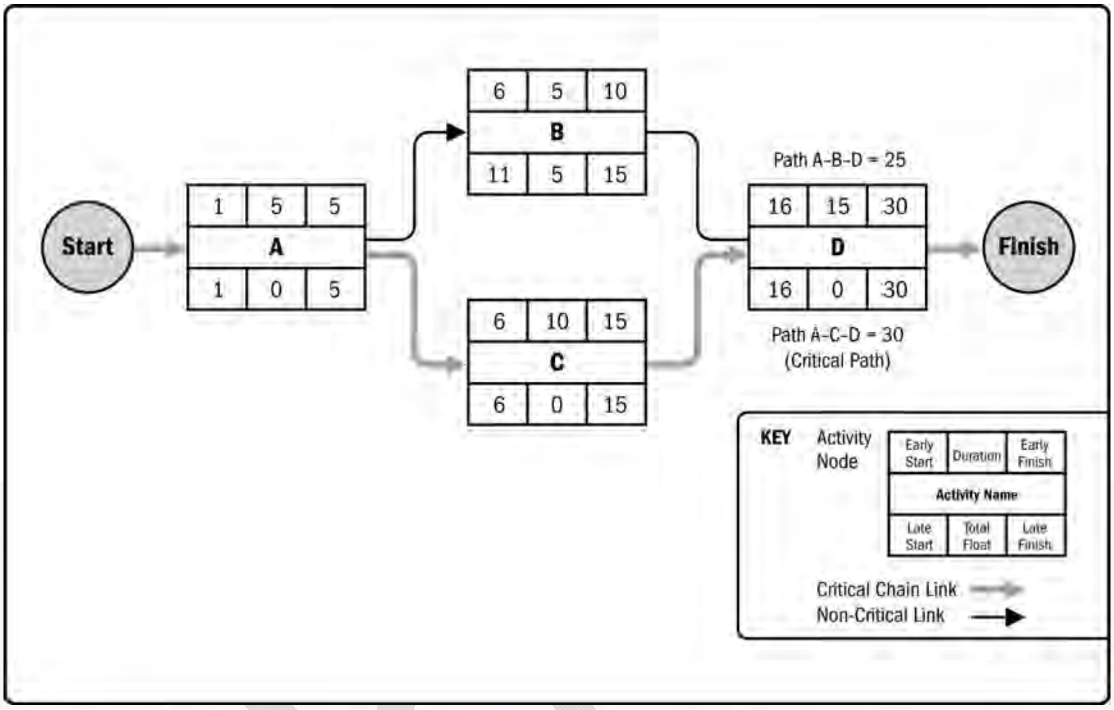

Figure 6-18. Example of Critical Path Method

6.6.2.3 Critical Chain Method

The critical chain method (CCM) is a schedule method that allows the project team to place buffers on any project schedule path to account for limited resources and project uncertainties. It is developed from the critical path method approach and considers the effects of resource allocation, resource optimization, resource leveling, and activity duration uncertainty on the critical path determined using the critical path method. To do so, the critical chain method introduces the concept of buffers and buffer management. The critical chain method uses activities with durations that do not include safety margins, logical relationships, and resource availability with statistically determined buffers composed of the aggregated safety margins of activities at specified points on the project schedule path to account for limited resources and project uncertainties. The resource-constrained critical path is known as the critical chain.

The critical chain method adds duration buffers that are non-work schedule activities to manage uncertainty. One buffer, placed at the end of the critical chain, as shown in Figure 6-19, is known as the project buffer and protects the target finish date from slippage along the critical chain. Additional buffers, known as feeding buffers, are placed at each point where a chain of dependent activities that are not on the critical chain feeds into the critical chain. Feeding buffers thus protect the critical chain from slippage along the feeding chains. The size of each buffer should account for the uncertainty in the duration of the chain of dependent activities leading up to that buffer. Once the buffer schedule activities are determined, the planned activities are scheduled to their latest possible planned start and finish dates. Consequently, instead of managing the total float of network paths, the critical chain method focuses on managing the remaining buffer durations against the remaining durations of chains of activities.

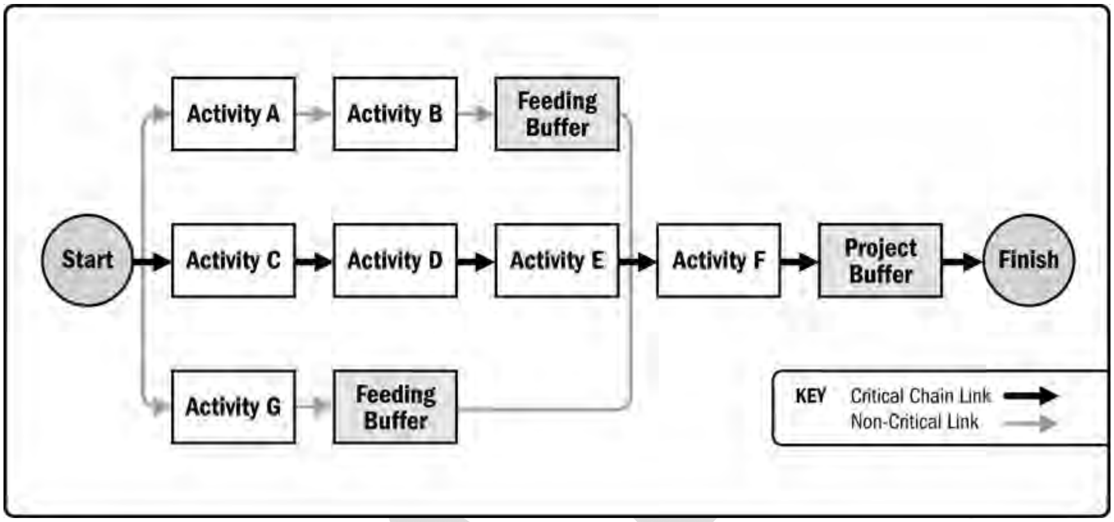

Figure 6-19. Example of Critical Chain Method

6.6.2.4 Resource Optimization Techniques

Examples of resource optimization techniques that can be used to adjust the schedule model due to demand and supply of resources include, but are not limited to:

- **Resource leveling.** A technique in which start and finish dates are adjusted based on resource constraints with the goal of balancing demand for resources with the available supply. Resource leveling can be used when shared or critically required resources are only available at certain times, or in limited quantities, or over-allocated, such as when a resource has been assigned to two or more activities during the same time period, as shown in Figure 6-20, or to keep resource usage at a constant level. Resource leveling can often cause the original critical path to change, usually to increase.

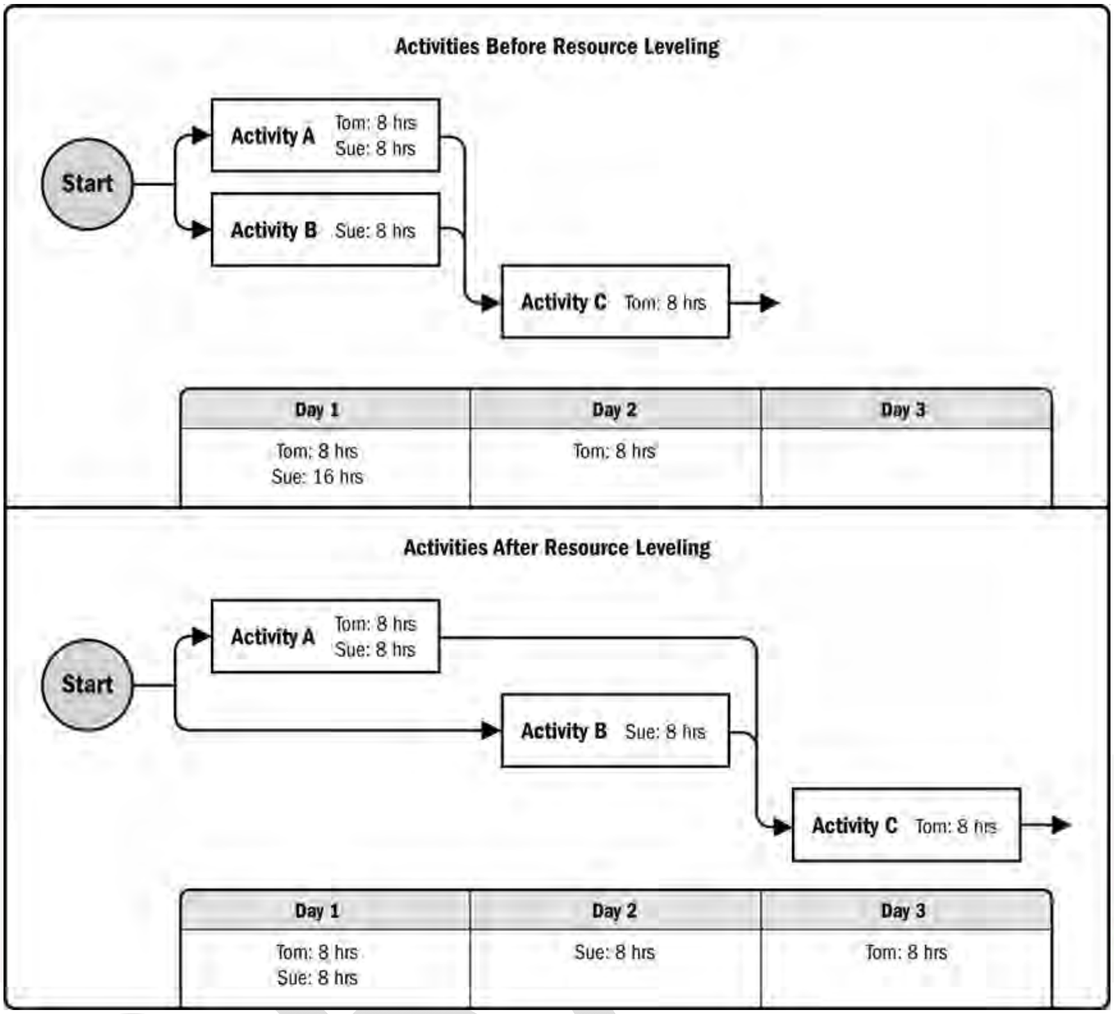

Figure 6-20. Resource Leveling

- **Resource Smoothing.** A technique that adjusts the activities of a schedule model such that the requirements for resources on the project do not exceed certain predefined resource limits. In resource smoothing, as opposed to resource leveling, the project's critical path is not changed and the completion date may not be delayed. In other words, activities may only be delayed within their free and total float. Thus resource smoothing may not be able to optimize all resources.

6.6.2.5 Modeling Techniques

Examples of modeling techniques include, but are not limited to:

- **What-If Scenario Analysis.** What-if scenario analysis is the process of evaluating scenarios in order to predict their effect, positively or negatively, on project objectives. 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 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.** Simulation involves calculating multiple project durations with different sets of activity assumptions, usually using probability distributions constructed from the three-point estimates (described in Section 6.5.2.4) to account for uncertainty. The most common simulation technique is Monte Carlo analysis (Section 11.4.2.2), in which a distribution of possible activity durations is defined for each activity and used to calculate a distribution of possible outcomes for the total project.

6.6.2.6 Leads and Lags

Described in Section 6.3.2.3. Leads and lags are refinements applied during network analysis to develop a viable schedule by adjusting the start time of the successor activities. Leads are used in limited circumstances to advance a successor activity with respect to the predecessor activity, and lags are used in limited circumstances where processes require a set period of time to elapse between the predecessors and successors without work or resource impact.

6.6.2.7 Schedule Compression

Schedule compression techniques are used to shorten the schedule duration without reducing the project scope, in order to meet schedule constraints, imposed dates, or other schedule objectives. Schedule compression techniques include, but are not limited to:

- **Crashing.** A technique used to shorten the schedule duration for the least incremental cost by adding resources. Examples of crashing include approving overtime, bringing in additional resources, or paying to expedite delivery to activities on the critical path. Crashing works only for activities on the critical path where additional resources will shorten the activity's duration. Crashing does not always produce a viable alternative and may result in increased risk and/or cost.
- **Fast tracking.** A schedule compression technique in which activities or phases normally done in sequence are performed in parallel for at least a portion of their duration. An example is constructing the foundation for a building before completing all of the architectural drawings. Fast tracking may result in rework and increased risk. Fast tracking only works if activities can be overlapped to shorten the project duration.

6.6.2.8 Scheduling Tool

Automated scheduling tools contain the schedule model and expedite the scheduling process by generating start and finish dates based on the inputs of activities, network diagrams, resources and activity durations using schedule network analysis. A scheduling tool can be used in conjunction with other project management software applications as well as manual methods.

6.6.3 Develop Schedule: Outputs

6.6.3.1 Schedule Baseline

A schedule baseline is the approved version of a schedule model that can be changed only through formal change control procedures and is used as a basis for comparison to actual results. It is accepted and approved by the appropriate stakeholders as the schedule baseline with baseline start dates and baseline finish dates. During monitoring and controlling, the approved baseline dates are compared to the actual start and finish dates to determine whether variances have occurred. The schedule baseline is a component of the project management plan.

6.6.3.2 Project Schedule

The outputs from a schedule model are schedule presentations. The project schedule is an output of a schedule model that presents linked activities with planned dates, durations, milestones, and resources. At a minimum, the project schedule includes a planned start date and planned finish date for each activity. If resource planning is done at an early stage, then the project schedule remains preliminary until resource assignments have been confirmed and scheduled start and finish dates are established. This process usually occurs no later than the completion of the project management plan (Section 4.2.3.1). A target project schedule model may also be developed with a defined target start and target finish for each activity. The project schedule presentation may be presented in summary form, sometimes referred to as the master schedule or milestone schedule, or presented in detail. Although a project schedule model can be presented in tabular form, it is more often presented graphically, using one or more of the following formats, which are classified as presentations:

- **Bar charts.** These charts, also known as Gantt charts, represent schedule information where activities are listed on the vertical axis, dates are shown on the horizontal axis, and activity durations are shown as horizontal bars placed according to start and finish dates. Bar charts are relatively easy to read, and are frequently used in management presentations. For control and management communications, 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 6-21 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 6-21.
- **Project schedule network diagrams.** These diagrams are commonly presented in the activity-on-node diagram format showing activities and relationships without a time scale, sometimes referred to as a pure logic diagram, as shown in Figure 6-11, 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 6-21.These diagrams, with activity date information, usually show both the project network logic and the project's critical path schedule activities. This example also shows how each work package is planned as a series of related activities. Another presentation of the project schedule network diagram is a time-scaled logic diagram**.** These diagrams include a time scale and bars that represent the duration of activities with the logical relationships. It is optimized to show the relationships between activities where any number of activities may appear on the same line of the diagram in sequence.

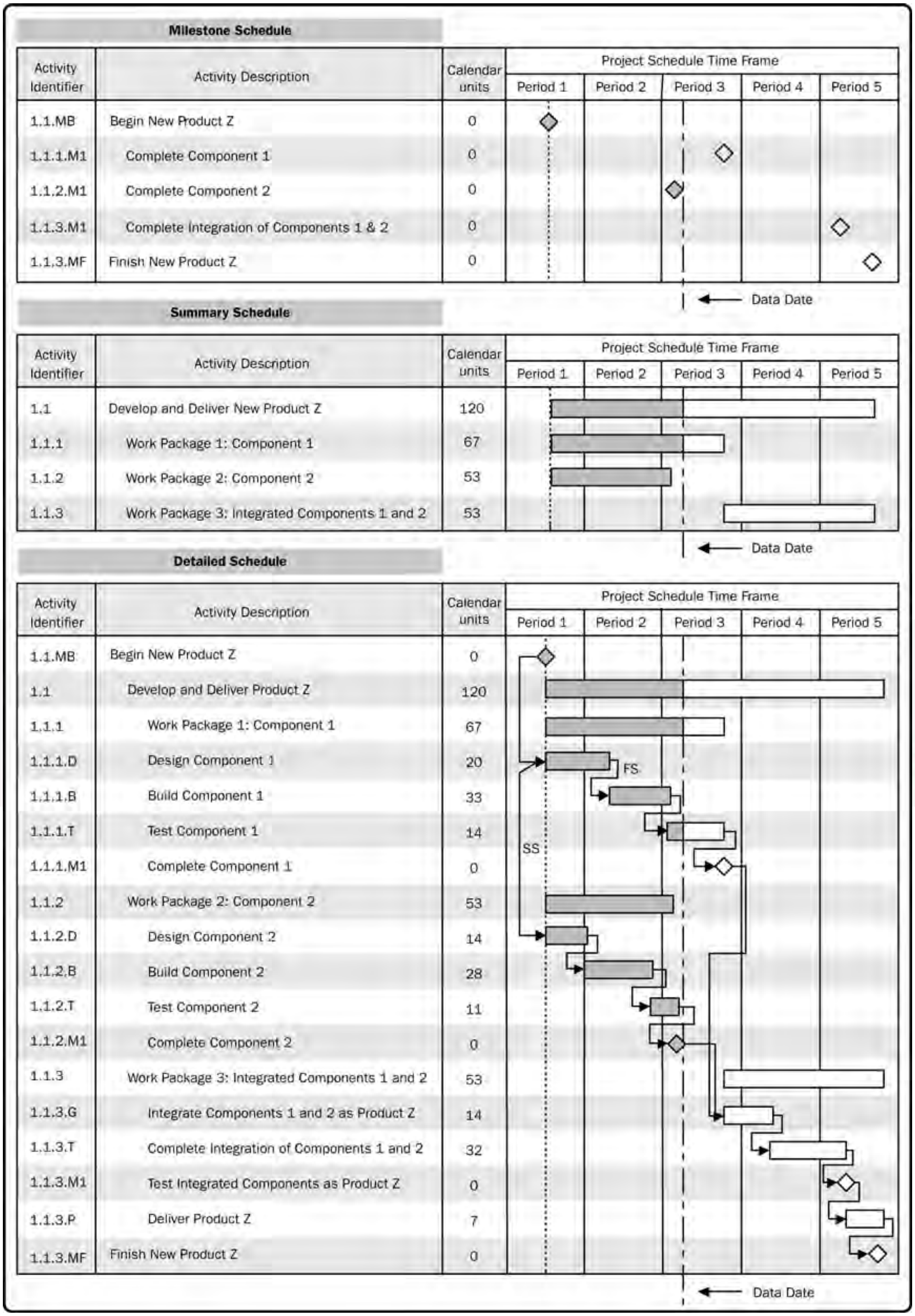

Figure 6-21. Project Schedule Presentations —Examples

Figure 6-21 shows schedule presentations for a sample project being executed, with the work in progress reported through the data date, a point in time when the status of the project is recorded, which is sometimes also called the as-of date or status date. For a simple project schedule model, Figure 6-21 reflects schedule presentations in the forms of (1) a milestone schedule as a milestone chart, (2) a summary schedule as a bar chart, and (3) a detailed schedule as a project schedule network diagram. Figure 6-21 also visually shows the relationships among the three different levels of schedule presentation.

6.6.3.3 Schedule Data

The schedule data for the project schedule model is the collection of information for describing and controlling the schedule. The schedule data 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, or resource-leveled, with or without imposed dates; and
- Scheduling of contingency reserves.

Schedule data could also include such items as resource histograms, cash-flow projections, and order and delivery schedules.

6.6.3.4 Project Calendars

A project calendar identifies working days and shifts that are available for scheduled activities. It distinguishes time periods in days or parts of days that are available to complete scheduled activities from time periods that are not available. A schedule model may require more than one project calendar to allow for different work periods for some activities to calculate the project schedule. The project calendars may be updated.

6.6.3.5 Project Management Plan Updates

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

- Schedule baseline (Section 6.6.3.1),
- Schedule management plan (Section 6.1.3.1).

6.6.3.6 Project Documents Updates

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

- **Activity resource requirements.** Resource leveling can have a significant effect on preliminary estimates for the types and quantities of resources required. If the resource-leveling analysis changes the project resource requirements, then the project resource requirements are updated.
- **Activity attributes.** Activity attributes (Section 6.2.3.2) are updated to include any revised resource requirements and any other revisions generated by the Develop Schedule process.
- **Calendars.** The calendar for each project may consist of multiple calendars, project calendars, individual resource calendars etc., as the basis for scheduling the project.

- **Risk register.** The risk register may need to be updated to reflect opportunities or threats perceived through scheduling assumptions.

6.7 Control Schedule

Control Schedule is the process of monitoring the status of project activities to update project progress and manage changes to the schedule baseline to achieve the plan. The key benefit of this process is that it provides the means to recognize deviation from the plan and take corrective and preventive actions and thus minimize risk. The inputs, tools and techniques, and outputs of this process are depicted in Figure 6-22. Figure 6-23 depicts the data flow diagram of the process.

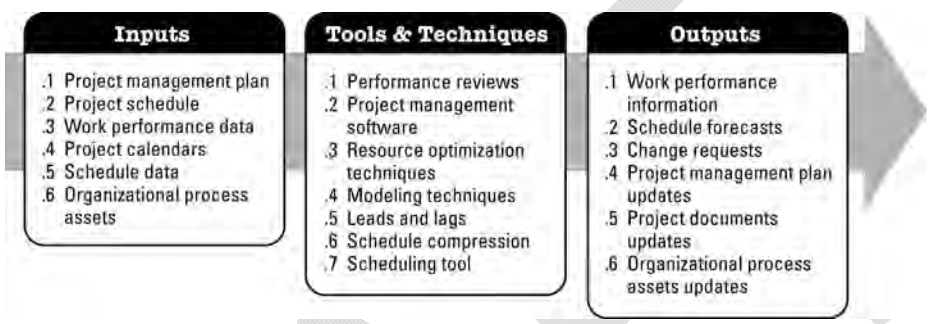

Figure 6-22. Control Schedule: Inputs, Tools & Techniques, and Outputs

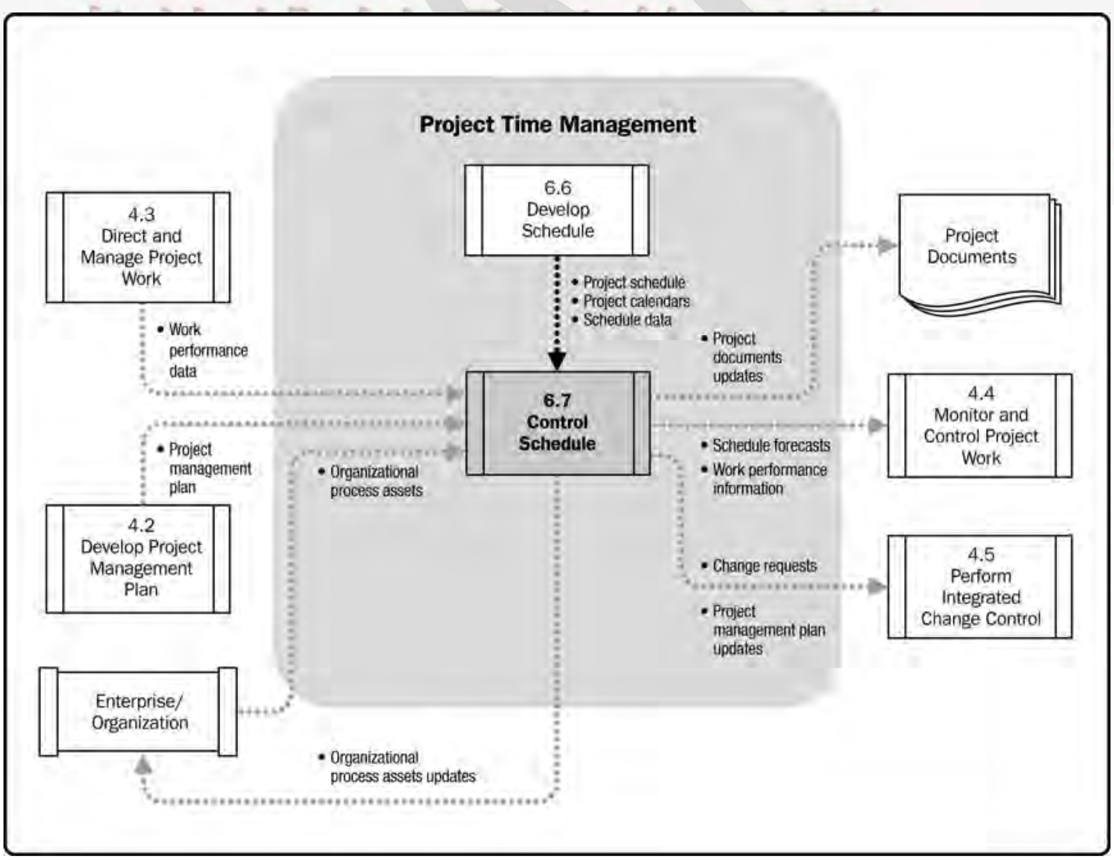

Figure 6-23. Control Schedule Data Flow Diagram

Updating the schedule model requires knowing the actual performance to date. Any change to the schedule baseline can only be approved through the Perform Integrated Change Control process (Section 4.5). Control Schedule, as a component of the Perform Integrated Change Control process, is concerned with:

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

If any agile approach is utilized, control schedule is concerned with:

- Determining the current status of the project schedule by comparing the total amount of work delivered and accepted against the estimates of work completed for the elapsed time cycle,
- Conducting retrospective reviews (scheduled reviews to record lessons learned) for correcting processes and improving, if required,
- Reprioritizing the remaining work plan (backlog),
- Determining the rate at which the deliverables are produced, validated, and accepted (velocity) in given time per iteration (agreed work cycle duration, typically two weeks or one month),
- Determining that the project schedule has changed, and
- Managing the actual changes as they occur.

6.7.1 Control Schedule: Inputs

6.7.1.1 Project Management Plan

Described in Section 4.2.3.1. The project management plan contains the schedule management plan and the schedule baseline. The schedule management plan describes how the schedule will be managed and controlled. The schedule baseline is used as a reference to compare with actual results to determine if a change, corrective action, or preventive action is necessary.

6.7.1.2 Project Schedule

Described in Section 6.6.3.2. Project schedule refers to the most recent version with notations to indicate updates, completed activities, and started activities as of the indicated data date.

6.7.1.3 Work Performance Data

Described in Section 4.3.3.2. Work performance data refers to information about project progress such as which activities have started, their progress (e.g., actual duration, remaining duration, and physical percent complete), and which activities have finished.

6.7.1.4 Project Calendars

Described in Section 6.6.3.4. A schedule model may require more than one project calendar to allow for different work periods for some activities to calculate the schedule forecasts.

6.7.1.5 Schedule Data

Described in Section 6.6.3.3. Schedule data will be reviewed and updated in the Control Schedule process.

6.7.1.6 Organizational Process Assets

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

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

6.7.2 Control Schedule: Tools and Techniques

6.7.2.1 Performance Reviews

Performance reviews measure, compare, and analyze schedule performance such as actual start and finish dates, percent complete, and remaining duration for work in progress. Various techniques may be used, among them:

- **Trend analysis.** Trend analysis examines project performance over time to determine whether performance is improving or deteriorating. Graphical analysis techniques are valuable for understanding performance to date and for comparison to future performance goals in the form of completion dates.
- **Critical path method (Section 6.6.2.2).** Comparing the progress along the critical path can help determine schedule status. The variance on the critical path will have a direct impact on the project end date. Evaluating the progress of activities on near critical paths can identify schedule risk.
- **Critical chain method (Section 6.6.2.3).** Comparing the amount of buffer remaining to the amount of buffer needed to protect the delivery date can help determine schedule status. The difference between the buffer needed and the buffer remaining can determine whether corrective action is appropriate.
- **Earned value management. (Section 7.4.2.1).** Schedule performance measurements such as schedule variance (SV) and schedule performance index (SPI), are used to assess the magnitude of variation to the original schedule baseline. The total float and early finish variances are also essential planning components to evaluate project time performance. Important aspects of schedule control include determining the cause and degree of variance relative to the schedule baseline (Section 6.6.3.1), estimating the implications of those variances for future work to completion, and deciding whether corrective or preventive action is required. For example, a major delay on any 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. For projects not using earned value management, similar variance analysis can be performed by comparing planned activity start or finish dates against actual start or finish dates to identify variances between the schedule baseline and actual project performance. Further analysis can be performed to determine the cause and degree of

variance relative to the schedule baseline and any corrective or preventative actions needed.

6.7.2.2 Project Management Software

Project management software for scheduling provides the ability to track planned dates versus actual dates, report variances to and progress made against the schedule baseline, and to forecast the effects of changes to the project schedule model.

6.7.2.3 Resource Optimization Techniques

Described in Section 6.6.2.4. Resource optimization techniques involve the scheduling of activities and the resources required by those activities while taking into consideration both the resource availability and the project time.

6.7.2.4 Modeling Techniques

Described in Section 6.6.2.5. Modeling techniques are used to review various scenarios guided by risk monitoring to bring the schedule model into alignment with the project management plan and approved baseline.

6.7.2.5 Leads and Lags

Adjusting leads and lags is applied during network analysis to find ways to bring project activities that are behind into alignment with the plan. For example, on a project to construct a new office building, the landscaping can be adjusted to start before the exterior work of the building is complete by increasing the lead time in the relationship. Or, a technical writing team can adjust the start of editing the draft of a large document immediately after the document is completed by eliminating or decreasing lag time.

6.7.2.6 Schedule Compression

Described in Section 6.6.2.7. Schedule compression techniques are used to find ways to bring project activities that are behind into alignment with the plan by fast tracking or crashing schedule for the remaining work.

6.7.2.7 Scheduling Tool

Schedule data is updated and compiled into the schedule model to reflect actual progress of the project and remaining work to be completed. The scheduling tool (Section 6.6.2.8) and the supporting schedule data are used in conjunction with manual methods or other project management software to perform schedule network analysis to generate an updated project schedule.

6.7.3 Control Schedule: Outputs

6.7.3.1 Work Performance Information

The calculated SV and SPI time performance indicators for WBS components, in particular the work packages and control accounts, are documented and communicated to stakeholders.

6.7.3.2 Schedule Forecasts

Schedule forecasts are estimates or predictions of conditions and events in the project's future based on information and knowledge available at the time of the forecast. Forecasts are updated and reissued based on work performance information provided as the project is executed. The information is based on the project's past performance and expected future performance, and includes earned value performance indicators that could impact the project in the future.

6.7.3.3 Change Requests

Schedule variance analysis, along with review of progress reports, results of performance measures, and modifications to the project scope or project schedule may result in change requests to the schedule baseline, scope baseline, and/or other components of the project management plan. Change requests are processed for review and disposition through the Perform Integrated Change Control process (Section 4.5). Preventive actions may include recommended changes to eliminate or reduce the probability of negative schedule variances.

6.7.3.4 Project Management Plan Updates

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

- **Schedule baseline.** Changes to the schedule baseline are incorporated in response to approved change requests (Section 4.4.3.1) related to project scope changes, activity resources, or activity duration estimates. The schedule baseline may be updated to reflect changes caused by schedule compression techniques.
- **Schedule management plan.** The schedule management plan may be updated to reflect a change in the way the schedule is managed.
- **Cost baseline.** The cost baseline may be updated to reflect approved change requests or changes caused by compression techniques.

6.7.3.5 Project Documents Updates

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

- **Schedule Data.** New project schedule network diagrams may be developed to display approved remaining durations and approved modifications to the schedule. In some cases, project schedule delays can be so severe that development of a new target schedule with forecasted start and finish dates is needed to provide realistic data for directing the work, measuring performance, and measuring progress.
- **Project Schedule.** An updated project schedule will be generated from the schedule model populated with updated schedule data to reflect the schedule changes and manage the project.
- **Risk Register.** The risk register, and risk response plans within it, may also be updated based on the risks that may arise due to schedule compression techniques.

6.7.3.6 Organizational Process Assets Updates

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

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

7

PROJECT COST MANAGEMENT

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

Figure 7-1 provides an overview of the following Project Cost Management processes:

7.1 Plan Cost Management—The process that establishes the policies, procedures, and documentation for planning, managing, expending, and controlling project costs.

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

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

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

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

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

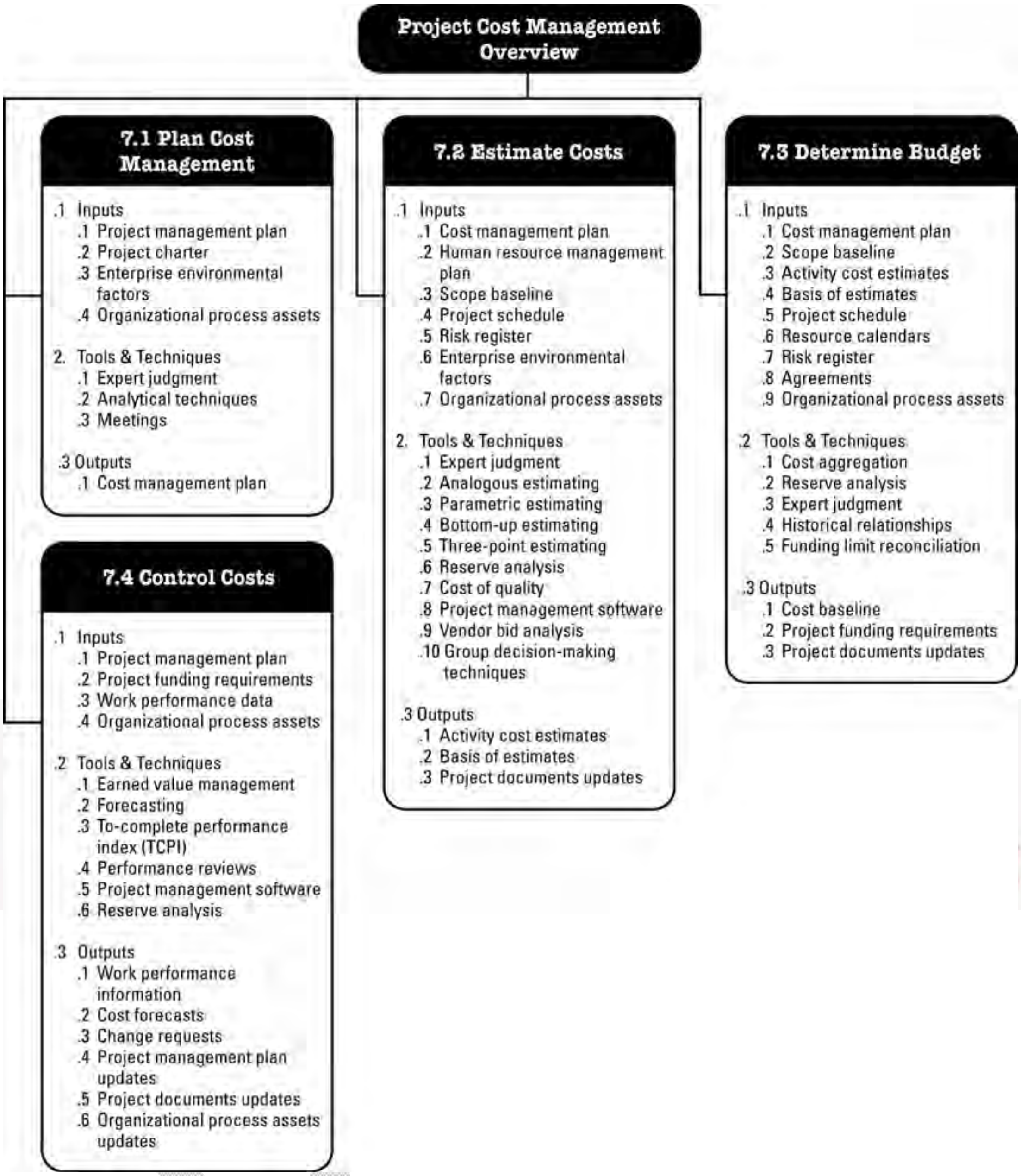

Figure 7-1. Project Cost Management Overview

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

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

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

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.

7.1 Plan Cost Management

Plan Cost Management is the process that establishes the policies, procedures, and documentation for planning, managing, expending, and controlling project costs. The key benefit of this process is that it provides guidance and direction on how the project costs will be managed throughout the project. The inputs, tools and techniques, and outputs of this process are depicted in Figure 7-2. Figure 7-3 depicts the data flow diagram of the process.

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