3

The Project Planning Process Group

Terms you'll need to understand:

- ✓ Activity
- ✓ Activity attributes
- ✓ Activity list
- ✓ Activity on arrow diagram (AOA)
- ✓ Activity on node diagram (AON)
- ✓ Activity sequence
- ✓ Analogous estimating
- ✓ Arrow diagramming method (ADM)
- ✓ Bottom-up estimating
- ✓ Critical path
- ✓ Dependency
- ✓ Milestone list
- ✓ Network diagram

- ✓ Parametric estimating
- ✓ Precedence diagramming method (PDM)
- ✓ Project management methodology
- ✓ Project management plan
- ✓ Project management processes
- ✓ Project scope
- ✓ Resource breakdown structure
- ✓ Rolling wave planning
- ✓ Slack
- ✓ Three-point estimates
- ✓ WBS dictionary
- ✓ Work breakdown structure (WBS)

Techniques and concepts you'll need to master:

- ✓ General project planning steps
- ✓ The importance of the WBS
- ✓ The relationships between scope, activities, and resources
- ✓ Estimating activity duration using three methods
- ✓ Creating PDM and ADM diagrams
- ✓ Reading and interpreting project network diagrams
- ✓ Understanding dependencies between project activities
- ✓ Identifying the critical path
- ✓ Estimating cost and creating a budget

In Chapter 1, "Project Management Framework Fundamentals," the PMI concepts of processes, process groups, and knowledge areas were introduced. Recall that PMI defines a total of 44 project processes that describe activities throughout a project's life cycle. These processes are organized into nine knowledge areas and represent five process groups. One of the most prominent of the process groups is project planning, evident in that nearly half of the processes occur in this group. This process group contains 21 of the 44 processes. In case you might think that planning processes are localized to a particular area of your project, note that processes in the planning group span all nine knowledge areas. Let's look at project planning in more detail.

Understanding PMI's Project Planning Process Group

After you are ready to plan your project, you have passed through the *initiation processes*. Remember what that means? It means that you possess formal authorization to conduct the work of the project. But what work will you do? What exactly are you trying to accomplish?

To answer these questions, start from what you know. There are two outputs from the initiation process group. Always start with the information necessary to proceed. Recall that PMI refers to this initial information for each process as the process's inputs. So, start with the project charter and preliminary scope statement and refine the project documents from there. Figure 3.1 shows how the processes in the planning group are related.

NOTE
> Think of the project initiation progress group as the processes that answer the what and why questions. The project planning processes answer the how questions. The planning processes result in outputs that explain how the project will progress toward reaching its goals.

ALERT
> Because planning includes so many processes, be prepared to answer many questions in this area on the exam. As with all other process groups, make sure you know the inputs, tools, techniques, and outputs of each process. It helps to draw your own process flow. Just the act of physically drawing the process flow in each process group helps you remember how the processes relate to one another.

PMI is very explicit in stressing the importance of planning. Far too many projects suffer from the poor practice of starting work before anyone really knows what needs to be done. This almost always results in wasted effort and lost time. Proper planning requires good communication among the team

and sound leadership from the project manager. The result is a project team that is more informed and prepared to carry out the work required to meet the project's goals. You should expect to see several questions on the exam that require you to understand the importance of fully planning before starting work.
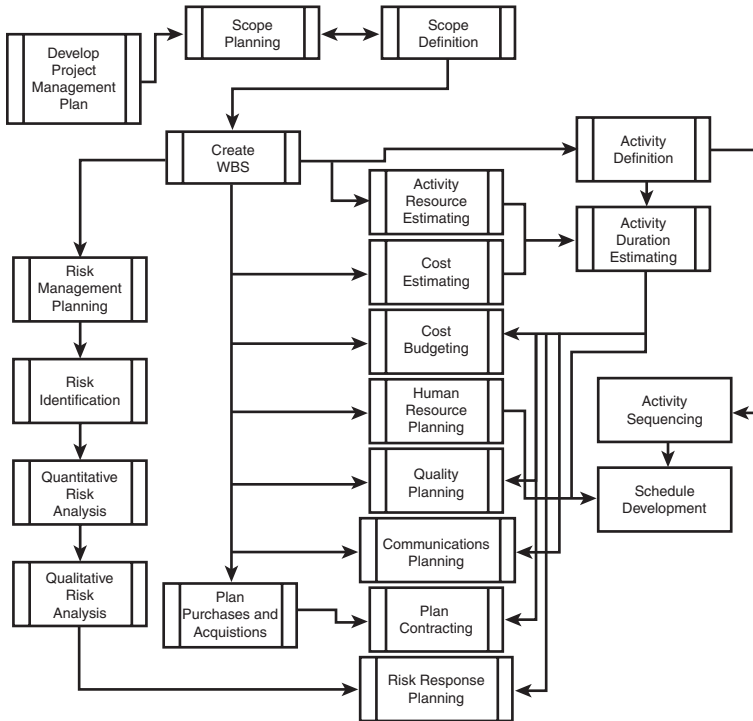

Figure 3.1   The planning process group process interactions.

Because planning is such a large process group, the material is divided into two separate chapters. This chapter covers the general concepts of planning and the processes that relate to the development of project baselines, including the following topics:

➤ Cost

➤ Schedule

➤ Scope

Chapter 4, "Elements of Project Planning," covers the remaining project planning processes that support project planning by applying more details to the baselines. Topics covered in Chapter 4 include these topics:

➤ Communications

➤ Human resources

➤ Procurement

➤ Quality

➤ Risk

Exploring Key Aspects of the Planning Processes

This chapter looks at the first four types of key planning processes. The main purpose of planning is to provide a framework to gather information to produce a project management plan. In fact, the plan itself is really a collection of other plans. The majority of activities in the planning group center around developing the supporting documents that comprise the final project management plan. As more detailed information is learned about the project, the overall plan becomes more complete and the confidence in the project increases.

Planning is an iterative group of processes as well. As the project progresses it often becomes necessary to modify the plan due to any number of reasons. Unexpected results, delays, outside factors, and internal factors can all require additional planning. Any scope changes will also likely require one or more planning processes to be revisited. Don't assume that planning is only accomplished once. The exam requires that you understand how planning is iterative throughout a project.

The following list details some fundamental planning process items you need to understand for the exam:

➤ **Project management plan**—One process in the planning group addresses the project management plan. The develop project management plan process is the high-level process that provides direction for developing subsidiary plans and compiling their information into the final project plan.

➤ **Scope**—Three processes address scope planning. These direct the refinement of the preliminary scope statement and break down the high-level goals of the project into smaller, more manageable chunks.

➤ **Activity**—Five processes deal with activity planning. After the work of the project is expressed in small, manageable chunks, the activity-related processes are oriented with defining the activity details, integrating with project resources, and sequencing the project activities.

➤ **Cost**—Two processes address cost planning. These processes collect estimates and organize them into a project budget.

Each of these processes is looked at individually in the next section.

Developing the Project Management Plan

The *project management plan process* covers all activities that identify and direct the actions of many other processes in the planning process group. Developing the project management plan includes coordinating the development of the subsidiary plans and incorporating them into the complete project plan. The main purpose of the project management plan is to define how the project is to progress from its beginning to completion.

In short, the project management plan provides the high-level gameplan for how the project moves through its life cycle. PMI defines many potential subsidiary plans that make up the overall project management plan. These subsidiary plans provide the specific details for managing each aspect of the project from initiation through closure. The subsidiary project management plans could include

➤ Communication management plan

➤ Cost management plan

➤ Process improvement plan

➤ Procurement management plan

➤ Project scope management plan

➤ Quality management plan

➤ Risk management plan

➤ Schedule management plan

➤ Staffing management plan

NOTE

This list of subsidiary plans is a great outline of a project. Use the list as a table of contents when you consider what should be in a project management plan.

One of the more common mistakes inexperienced project managers make is to confuse a project plan with a project schedule. The output from many common project management software packages do not qualify as a project plan. They are a good start, but a true project plan is made up of much more information than just scheduling information. This process requires a focused effort to create a plan that incorporates all known information about a project. Table 3.1 shows the inputs, tools, techniques, and outputs for the develop project management plan process.

Table 3.1 Develop Project Management Plan Inputs, Tools, Techniques, and Outputs		
Inputs	**Tools and Techniques**	**Outputs**
Preliminary project scope statement	Project management methodology	Project management plan
Project management processes	Project management information system	
Enterprise environmental factors	Expert judgment	
Organizational process assets		

Scope Management

Scope management is the set of processes that ensures that the requirements of the customer are captured in a specification of work that ensures its delivery, that all the project work is done, and that only the work required to complete the project is done. In other words, scope management makes sure that the project is completed without expending any unnecessary effort.

Scope planning defines the document that states how the scope will be specified, controlled, and verified. The project team develops the scope management plan for each project. More complex projects require a more detailed scope planning process. Table 3.2 shows the inputs, tools, techniques, and outputs for the scope planning process.

Table 3.2 Scope Planning Inputs, Tools, Techniques, and Outputs		
Inputs	**Tools and Techniques**	**Outputs**
Enterprise environmental factors	Expert judgment	Project scope management plan
Organizations process assets	Templates, forms, and standards	
Preliminary project scope statement		
Project management plan		

The next process, *scope definition*, is the process that refines the preliminary scope statement and clearly states what the project will and will not accomplish. The supporting documents are reviewed to ensure the project will satisfy the stated goals and the resulting scope should state the stakeholders' needs and clearly communicate the expectations for the performance of the project. Table 3.3 shows the inputs, tools, techniques, and outputs for the scope planning process.

Table 3.3 Scope Definition Inputs, Tools, Techniques, and Outputs		
Inputs	**Tools and Techniques**	**Outputs**
Organizational process assets	Product analysis	Project scope statement
Project charter	Alternative identification	Requested changes
Preliminary project scope statement	Expert judgment	Project scope management plan (updates)
Project scope management plan	Stakeholder analysis	
Approved change requests		

Work Breakdown Structure: A Common and Dangerous Omission

Many inexperienced project managers move too quickly from the scope statement to the activity sequencing processes. This practice is a mistake and often leads to activity omissions and inaccurate plans. PMI stresses the importance of first creating a *work breakdown structure (WBS)*, and then moving to activity management processes.

The WBS provides the project manager and project team with the opportunity to decompose the high-level scope statement into much smaller, more manageable units of work, called *work packages*. The resulting WBS should provide a complete list of all work packages required to complete the project (and nothing more). Table 3.4 shows the inputs, tools, techniques, and outputs for the create WBS process.

Table 3.4 Create WBS Inputs, Tools, Techniques, and Outputs		
Inputs	**Tools and Techniques**	**Outputs**
Organizational process assets	Work breakdown structure templates	Project scope statement (updates)
Project scope statement	Decomposition	Work breakdown structure
Project scope management plan		WBS dictionary
Approved change requests		Scope baseline
		Project scope management plan (updates)
		Requested changes

The *PMI Practice Standard for Work Breakdown Structures* is the guide you need to use for the PMP exam. This is an example of information on the exam that goes beyond the PMBOK. You can find the WBS Practice Standard in the publications section of the PMI website (www.pmi.org).

In creating the WBS, the project team repeatedly decomposes the work of the project into smaller and smaller units of work, resulting in a collection of small work packages. The process continues until the resulting work packages are simple enough to reliably estimate in terms of duration and required resources. Don't go overboard, though. When you have work packages that are manageable and represent a single work effort, stop the process. Each project is different, so this process results in different levels of detail for each project.

The last main feature of the WBS is that it is organized in a hierarchical fashion. The highest level is the project. Under the project, the children that represent project phases, divisions, or main deliverables are listed. Each child process or task is then divided into further levels of detail until the lowest level, the work package, is reached. Figure 3.2 depicts a sample WBS with multiple levels.
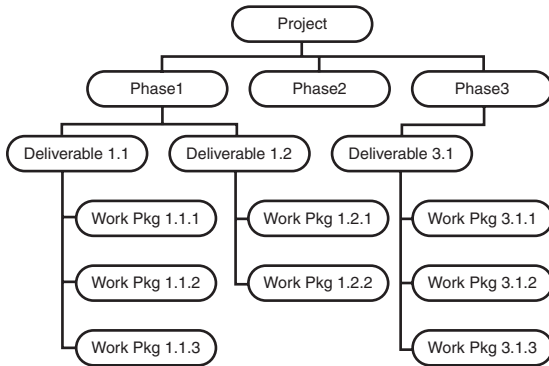
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                        ┌─────────────┐
                        │   Project   │
                        └─────────────┘
              ┌──────────────┼──────────────┐
        ┌──────────┐   ┌──────────┐   ┌──────────┐
        │  Phase1  │   │  Phase2  │   │  Phase3  │
        └──────────┘   └──────────┘   └──────────┘
        ┌──────┴──────────────┐        ┌────────────┐
  ┌─────────────┐  ┌─────────────┐  ┌─────────────┐
  │Deliverable 1.1│ │Deliverable 1.2│ │Deliverable 3.1│
  └─────────────┘  └─────────────┘  └─────────────┘
        │                │                │
  ┌──────────────┐ ┌──────────────┐ ┌──────────────┐
  │Work Pkg 1.1.1│ │Work Pkg 1.2.1│ │Work Pkg 3.1.1│
  └──────────────┘ └──────────────┘ └──────────────┘
        │                │                │
  ┌──────────────┐ ┌──────────────┐ ┌──────────────┐
  │Work Pkg 1.1.2│ │Work Pkg 1.2.2│ │Work Pkg 3.1.2│
  └──────────────┘ └──────────────┘ └──────────────┘
        │                                 │
  ┌──────────────┐                 ┌──────────────┐
  │Work Pkg 1.1.3│                 │Work Pkg 3.1.3│
  └──────────────┘                 └──────────────┘
```

Figure 3.2   Sample work breakdown structure.

In addition to the WBS itself, another output of the create WBS process is the WBS dictionary. The *WBS dictionary* is a document that supports the WBS by providing detailed information for each work package. The WBS dictionary can contain many types of information, including

➤ Work package name or identifier

➤ Accounting control account

➤ Description of work

➤ Technical specifications

➤ Quality requirements

➤ Owner or responsible party assignment

➤ Required resources

Activity Planning—From WBS to Project Schedule

The next section of the planning processes address those steps required to develop the project schedule. This is the part of the project plan that might be most familiar to new project managers. Many automated project management tools help create schedules by keeping track of activities, resources, durations, sequencing, and constraints. Although the schedule is an integral part of the project plan, it is only one part. Don't start working on the schedule until you have a proper WBS. Starting to work before completing the WBS usually results in doing more work than is necessary. A good WBS

reduces task redundancy and helps ensure all work performed is in the scope of the project. In fact, the WBS is a required input to activity planning.

Defining Activities

The first process in the activity planning section is *activity definition*. This process starts with the WBS and identifies the activities required to produce the various project deliverables. Activities are viewed from the perspective of the work packages. You ask the question, "What activities are required to satisfy this work package requirement?" The resulting information from this process is used next to organize the activities into a specific sequence. Table 3.5 shows the inputs, tools, techniques, and outputs for the activity definition process.

Table 3.5 Activity Definition Inputs, Tools, Techniques, and Outputs		
Inputs	**Tools and Techniques**	**Outputs**
Enterprise environmental factors	Decomposition	Activity list
Organizational process assets	Templates	Activity attributes
Project scope statement	Rolling wave planning	Milestone list
Work breakdown structure	Expert judgment	Requested changes
WBS dictionary	Planning component	
Project management plan		

Sometimes it is difficult to know everything about a project during the planning stage. It is common to learn more about the project as you work through the project life cycle. This is called *progressive elaboration* and it affects the planning process. If you don't know everything about the project, you can't plan the whole project to the level of detail necessary. For large projects, it is common to plan the entire project at a high level. The project starts with detailed plans in place for the work packages that are near the beginning of the project. As the time draws near to begin additional work, the more detailed, low-level plans for those work packages are added to the project plan. The planning process is revisited multiple times to ensure that the detailed plans contain the latest information known about the project. This practice is called *rolling wave planning* because the planning wave always moves to stay ahead of the work execution wave.

Sequencing Activities

The next process is that of arranging the activities list from activity definition into a discrete sequence. Some activities can be accomplished at any time throughout the project. Other activities depend on input from another activity or are constrained by time or resources. Any requirement that restricts the start or end time of an activity is a *dependency*. This process identifies all relationships between activities and notes restrictions imposed by these relationships.

For example, when building a car you cannot install the engine until the engine has been built and delivered to the main assembly line. This is just one simple example of how activities may be dependent on one another. This process is one that can benefit from the use of computer software to assist in noting and keeping track of inter-activity dependencies. Table 3.6 shows the inputs, tools, techniques, and outputs for the activity sequencing process.

Table 3.6 Activity Sequencing Inputs, Tools, Techniques, and Outputs		
Inputs	**Tools and Techniques**	**Outputs**
Project scope statement	Precedence diagramming method (PDM)	Project schedule network diagrams
Activity list	Arrow diagramming method (ADM)	Activity list (updates)
Activity attributes	Schedule network templates	Activity attributes (updates)
Approved change requests	Dependency determination	Requested changes
	Applying leads and lags	

Network Diagrams

One of the more important topics to understand when planning project activities is creating network diagrams. *Network diagrams* provide a graphical view of activities and how they relate to one another. The PMP exam tests your ability to recognize and understand two types of network diagrams: the *precedence diagramming method (PDM)* and the *arrow diagramming method (ADM)*. Make sure you can read each type of diagram and use the information it presents.

Precedence Diagramming Method

The PDM shows nodes, representing activities, connected by arrows that represent dependencies. To represent that activity B is dependent on activity A

(in other words, activity A must be complete before activity B starts), simply draw an arrow from A to B. PDM diagrams are also referred to as activity-on-node (AON) diagrams because the nodes contain the activity duration information. (You don't have enough information yet to complete all the information presented here. You'll fill in the duration information during activity duration estimating.) In fact, nodes generally contain several pieces of information, including

➤ **Early start**—The earliest date the activity can start

➤ **Duration**—The duration of the activity

➤ **Early finish**—The earliest date the activity can finish

➤ **Late start**—The latest date the activity can start

➤ **Late finish**—The latest date the activity can finish

➤ **Slack**—Difference between the early start and the late start dates

Figure 3.3 shows an example of a PDM diagram.

Precedence Diagramming Method (PDM)

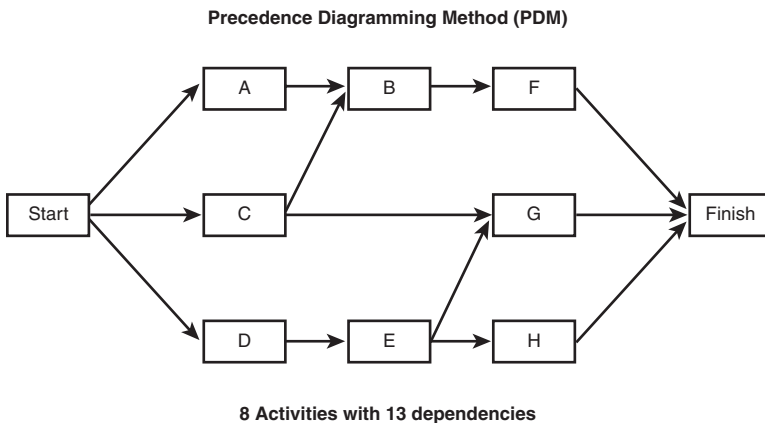
8 Activities with 13 dependencies

Figure 3.3   The precedence diagramming method.

The PDM diagram in Figure 3.3 shows eight activities, labeled A–H. The arrows show how some activities are dependent on other activities. For example, activity B cannot start until activities A and C are complete. To show this dual dependency, you draw an arrow from A to B and another arrow from C to B.

You can represent four types of dependencies with a PDM diagram:

➤ **Finish-to-start (the most common dependency type)**—The successor activity's start depends on the completions of the successor activity.

➤ **Finish-to-finish**—The completion of the successor activity depends on the completion of the predecessor activity.

➤ **Start-to-start**—The start of the successor activity depends on the start of the predecessor activity.

➤ **Start-to-finish**—The completion of the successor activity depends on the start of the predecessor activity.

> *Carefully consider the various types of dependencies. Some can be confusing (especially start-to-finish). On the exam, you will be asked to evaluate the scheduling impact to changes in start or end dates. The overall impact to the project depends on the type of relationship between activities. Don't skip over the dependencies too quickly. Take the time to really read the question before you construct your diagrams.*

Arrow Diagramming Method

The arrow diagramming method (ADM) is similar to the PDM, except that all dependencies are finish-to-start. Also, durations are generally depicted on the arrows. For this reason, the ADM diagram is also called the activity-on-arrow (AOA) diagram. Figure 3.4 shows an example of an ADM diagram.
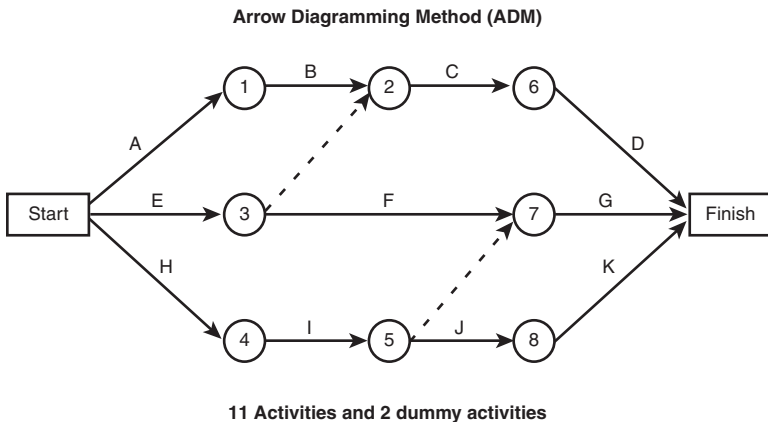
Arrow Diagramming Method (ADM)

11 Activities and 2 dummy activities

Figure 3.4   The arrow diagramming method.

The ADM diagram in Figure 3.4 shows 11 activities, labeled A–K. Unlike the PDM diagram, activities are labeled on the arrow, not the nodes.

Dependencies are noted in a similar fashion to the PDM diagram, but there is another type of activity in ADM diagrams. Look at the dependency between node 3 and node 2. The arrow has a dotted line, which means the activity has no duration and is called a *dummy* activity. The purpose of dummy activities is simply to allow you to depict dependencies. In Figure 3.4 activity C cannot start until activity E has completed. Likewise, activity G cannot start until activity I has completed.

After you are comfortable with the main types of network diagrams, you need to understand how to use them. Let's talk about a few basic scheduling concepts and look at how network diagrams help you understand project schedules, starting with a few project tasks. Table 3.7 lists the tasks for a project along with the predecessors, duration, and earliest start date.

Table 3.7	Project Task Information		
Activity	**Predecessor**	**Duration**	**Earliest Start Date**
A	None	5	9/5/05
B	A	2	9/10/05
C	A	3	9/10/05
D	B	7	9/12/05
E	C	4	9/13/05
F	D	1	9/19/05
G	E, F	2	9/20/05

Now use the sample PDM node template to create a PDM diagram for the project. Figure 3.5 shows the sample PDM node template.

Early Start	Duration	Early Finish
	Task name	
Late Start	Slack	Late Finish

Figure 3.5 The sample PDM node template.

The completed network diagram should look like the diagram in Figure 3.6.
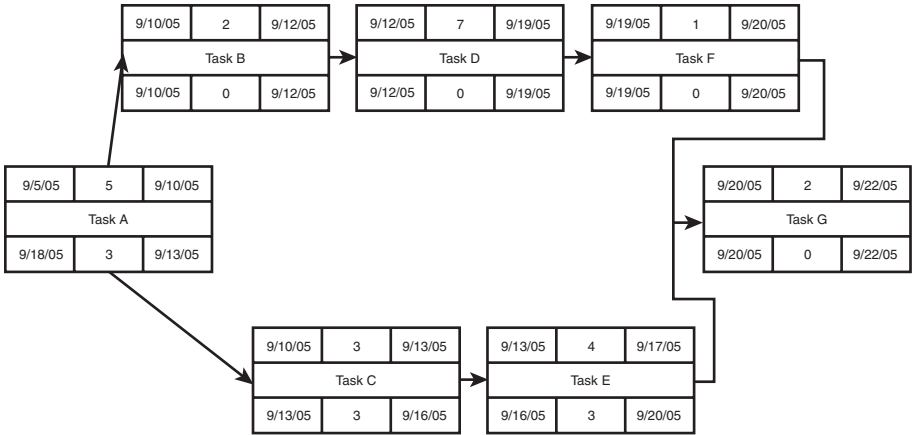
9/10/05	2	9/12/05
	Task B	
9/10/05	0	9/12/05

9/12/05	7	9/19/05
	Task D	
9/12/05	0	9/19/05

9/19/05	1	9/20/05
	Task F	
9/19/05	0	9/20/05

9/5/05	5	9/10/05
	Task A	
9/18/05	3	9/13/05

9/20/05	2	9/22/05
	Task G	
9/20/05	0	9/22/05

9/10/05	3	9/13/05
	Task C	
9/13/05	3	9/16/05

9/13/05	4	9/17/05
	Task E	
9/16/05	3	9/20/05

Figure 3.6   The completed sample PDM diagram.

Estimating Activity Resources

Now you have a list of activities and their relative dependencies. The next process associates activities with the resources required to accomplish the work. This process lists each type and amount, or quantity, of each required resource. Every activity requires resources of some sort. Activity resources can include

➤ Equipment

➤ Money

➤ Materials and supplies

➤ People

Table 3.8 shows the inputs, tools, techniques, and outputs for the activity resource estimating process.

Table 3.8 Activity Resource Estimating Inputs, Tools, Techniques, and Outputs		
Inputs	**Tools and Techniques**	**Outputs**
Enterprise environmental factors	Expert judgment	Activity resource requirements
Organizational process assets	Alternatives analysis	Activity attributes (updates)
Activity list	Published estimating data	Resource breakdown structure
Activity attributes	Project management software	Resource calendar (updates)
Resource availability	Bottom-up estimating	Requested changes
Project management plan		

Two of the tools and techniques warrant further discussion. One of the techniques you use when estimating activity resources is *alternative analysis*. Analyzing the various alternatives provides an opportunity to consider other sources or ways to achieve the desired result for an activity. Alternatives might be more desirable than the initial expected approach due to cost savings, higher quality, or earlier completion. Another important outcome of alternative analysis is that in case the primary source becomes unavailable, you might have already identified a replacement method to complete the work. Suppose your main supplier of industrial fittings suffers a catastrophic fire. If your alternative analysis identified another source, you might be able to continue the project with minimal disruption.

The second item is bottom-up estimating. Recall that one of the purposes of creating the WBS is to decompose project work into work packages that are small enough to reliably estimate for duration and resource requirements. Using the WBS, you can provide estimates for mid- and high-level work by aggregating the estimates for the work packages that make up the desired work. Because this process starts at the lowest level of work (the work package) to create the estimate, it is called *bottom-up estimating*. This type of estimating tends to be fairly accurate because the estimates come from the people doing the actual work. The alternative is *top-down estimating*. Top-down estimates generally come from management or a source that is higher up than the people actually doing the work. The estimates are really educated guesses on the amount of resources required for a collection of work packages and tend to be less reliable than bottom-up estimates.

Estimating Activity Durations

After the resource estimates are established for each of the activities, it's time to assign duration estimates. The *activity duration estimating process* assigns the number of work periods that are needed to complete schedule activities. Each estimate assumes that the necessary resources are available to be applied to the work package when needed. Table 3.9 shows the inputs, tools, techniques, and outputs for the activity duration estimating process.

Table 3.9 Activity Duration Estimating Inputs, Tools, Techniques, and Outputs		
Inputs	**Tools and Techniques**	**Outputs**
Enterprise environmental factors	Expert judgment	Activity duration estimates
Organizational process assets	Analogous estimating	Activity attributes (updates)

(continued)

Table 3.9 Activity Duration Estimating Inputs, Tools, Techniques, and Outputs (continued)		
Inputs	**Tools and Techniques**	**Outputs**
Project scope statement	Parametric estimating	
Activity list	Three-point estimates	
Activity attributes	Reserve analysis	
Activity resource requirements		
Resource calendar		
Project management plan		

In addition to expert judgment, three main techniques are used for project activity duration estimation. In many cases, using multiple techniques provides more accurate estimates. The three estimation techniques are

➤ **Analogous estimating**—This uses actual duration figures from similar activities. These activities can be from the same project or another project.

➤ **Parametric estimating**—This calculates duration estimates by multiplying the quantity of work by the productivity rate. This type of estimate works best for standardized, and often repetitive, activities.

➤ **Three-point estimates**—This uses three estimate values for each activity:

> ➤ **Most likely**—The duration most likely to occur.

> ➤ **Optimistic**—The duration of the activity if everything goes as planned, or better.

> ➤ **Pessimistic**—The duration of the activity in a worst-case scenario.

Developing the Project Schedule

The next step is to develop the actual project schedule. The *schedule development process* pulls all of the activity information together and results in the project's initial (baseline) schedule. As work is iteratively planned and accomplished and the project moves through its life cycle, changes to the schedule will likely occur. The schedule is a dynamic document and requires constant attention on the part of the project manager to ensure the project stays on track. Table 3.10 shows the inputs, tools, techniques, and outputs for the schedule development process.

Table 3.10 Schedule Development Inputs, Tools, Techniques, and Outputs		
Inputs	**Tools and Techniques**	**Outputs**
Organizational process assets	Schedule network analysis	Project schedule
Project scope statement	Critical path method	Schedule model data
Activity list	Schedule compression	Schedule baseline
Activity attributes	What-if scenario analysis	Resource requirements (updates)
Project schedule network diagrams	Resource leveling	Activity attributes (updates)
Activity resource requirements	Critical chain method	Project calendar (updates)
Resource calendar	Project management software	Requested changes
Activity duration estimates	Applying calendars	Project management plan (updates)
Project management plan	Adjusting leads and lags	
	Schedule model	

An important topic to understand with respect to project schedules is the critical path. Look back at the AON diagram in Figure 3.3. The critical path is the longest path from start to finish. It is calculated by adding up all of the durations along each path from start to finish. The reason it is called the critical path is that any delay (or increase in duration) of any activity on the critical path causes a delay in the project. It is critical that all activities on this path be completed on schedule.

Critical Path

Using the network diagram in Figure 3.6, you can calculate the project critical path. The *critical path* is the route with the longest total duration. This example shows two routes from task A to task G:

➤ Path A-B-D-F-G takes 17 days to complete. (Just add up all the durations: 5 + 2 + 7 + 1 + 2 = 17)

➤ Path A-C-E-G takes 14 days to complete.

From this diagram you can see that the longest path is A-B-D-F-G, and that is your critical path. Any delays in any of these tasks will delay the project.

Float

Take another look at Figure 3.6. This PDM diagram has several pieces of information filled in for each node that we have not discussed yet. The task name and duration are self-explanatory. What about the rest of the information, though? The main task of developing the project schedule is to relate each of the tasks and combine duration, resource requirements, and dependencies. You will need to make several passes through the network diagram to calculate the values necessary to create a project schedule.

In general, you will make two main passes through each path in your network diagram. The first pass starts with the initial project task (the project start task). The starting date of the initial task is its early start date. A task's *early start date* is the earliest you can start working on that task. In Figure 3.6, the early start date for task A is 9/5/05. The duration for task A is 5 days, so the earliest task A can finish is 9/10/05. To get the early finish date, just add the duration to the early start date. Now, the early finish date for task A becomes the early start date for any tasks that are dependent on task A (namely, task B and task C). Then, continue to follow each path until you reach the final task, calculating the new early end dates by adding the duration to the early start dates.

> **NOTE**
>
> Be sure you follow every path from the starting task to the ending task. There will likely be several paths that will get you there.

Now it's time for the second pass through your project to calculate the late start and late ending dates. This pass starts at the end and moves backward through the same paths you just followed in the forward pass. The first step in the backward pass is to record the late ending date. It is the same as the early ending date for the last task in the project. Then, subtract the duration to get the late start date. In Figure 3.6, the late ending date for task G is 9/22/05 and the late start date is 9/20/05. Next, move backward to each task on which your current task depends (for example, each task that has an arrow pointing to your current task). The late ending date for this predecessor task is the same as the late start date of the dependent task. In other words, the late ending date for task F and task E would be 9/20/05 (the late start date for task G). Continue backward through the project, subtracting the duration to calculate a new late start date.

After completing both the forward and backward passes, you should have all the early start times (ESTs), early finish times (EFTs), late start times (LSTs),

and late finish times (LFTs) filled in. To complete the network diagram entries, calculate the float for each task by subtracting the early start date from the late start date. The *float* represents the amount of time each task can be delayed without delaying the project.

Finally, add up the durations for each path from the start task to the finish task. The largest total represents the critical path of your project—there could be more than one critical path. Remember that tasks on the critical path all have a float of 0 and any delay of a task on the critical path results in an overall project delay.

Critical Cost Estimating Factors

The *cost estimating process* associates an expected cost of performing work to each activity. Cost estimates can include labor, materials, equipment, and any other direct costs for project activities. Based on the activity resource and duration estimates, the cost estimates express the cost, normally in monetary amounts, of completing the work of the project. As with all project documents, the cost estimates can change throughout the project as conditions change. Different events can cause the cost for any activity to go up or down and require the cost estimates for the project to change. Table 3.11 shows the inputs, tools, techniques, and outputs for the cost estimating process.

Table 3.11 Cost Estimating Inputs, Tools, Techniques, and Outputs		
Inputs	**Tools and Techniques**	**Outputs**
Enterprise environmental factors	Analogous estimating	Activity cost estimates
Organizational process assets	Determine resource cost rates	Activity cost estimates supporting detail
Project scope statement	Bottom-up estimating	Requested changes
Work breakdown structure	Parametric estimating	Cost management plan (updates)
WBS dictionary	Project management software	
Project management plan	Vendor bid analysis	
	Reserve analysis	
	Cost of quality	

Cost estimates are compiled into the project budget. The *cost budgeting process* aggregates the activity cost estimates into a single document for the project. The resulting project budget expands on the preliminary budget from the project charter and provides far more detail. Table 3.12 shows the inputs, tools, techniques, and outputs for the cost budgeting process.

Table 3.12 Cost Budgeting Inputs, Tools, Techniques, and Outputs		
Inputs	**Tools and Techniques**	**Outputs**
Project scope statement	Cost aggregation	Cost baseline
Work breakdown structure	Reserve analysis	Project funding requirements
WBS dictionary	Parametric estimating	Cost management plan (updates)
Activity cost estimates	Funding limit reconciliation	Requested changes
Activity cost estimates supporting detail		
Project schedule		
Resource calendars		
Contract		
Cost management plan		

Exam Prep Questions

1. You are a project manager newly assigned to a large project for your organization. The project charter has been signed and the preliminary scope statement has been accepted. What should you do next?

   ❑ A. Ask appropriate team members to submit WBS input.
   ❑ B. Initiate the scope planning process.
   ❑ C. Initiate the develop project management plan process.
   ❑ D. Begin the activity definition process.

2. As project manager, you are about to start the scope definition process. You have the project charter, the organizational process assets list, and the project scope management plan. Since there are no change requests in your project at this point, what must you have before you begin?

   ❑ A. Product analysis
   ❑ B. Preliminary project scope statement
   ❑ C. Updates to project scope management plan
   ❑ D. WBS

3. You are creating your WBS and find that you keep decomposing tasks into smaller and smaller units. How can you tell when you are done?

   ❑ A. Keep decomposing tasks until you reach an amount of work that is small enough to reliably estimate required resources and duration.
   ❑ B. Keep decomposing tasks until you reach an amount of work that can be accomplished in one hour.
   ❑ C. Keep decomposing work until you reach an amount of work that can be accomplished in your organization's basic work unit.
   ❑ D. Keep decomposing work until you reach a predetermined number of hierarchy levels to keep the WBS balanced.

4. What term is defined as the practice of planning activities based on how soon the tasks are scheduled to start, such that activities that are close to their start date are planned at a more detailed level than those farther in the future? This term also implies that as activities near their start date more detailed plans will be required.

   ❑ A. Progressive elaboration
   ❑ B. Rolling wave planning
   ❑ C. Planning component elaboration
   ❑ D. Milestone detail planning

5. Which type of network diagram allows you to depict four types of dependencies?

   ❑ A. Precedence diagramming method (PDM)
   ❑ B. Arrow diagramming method (ADM)
   ❑ C. Dependency diagramming method (DDM)
   ❑ D. Gannt chart diagram (GCD)

6. Which type of network diagram is also referred to a activity-on-arrow (AOA) diagrams?

   ❑ A. Precedence diagramming method (PDM)
   ❑ B. Arrow diagramming method (ADM)
   ❑ C. Dependency diagramming method (DDM)
   ❑ D. Gannt chart diagram (GCD)

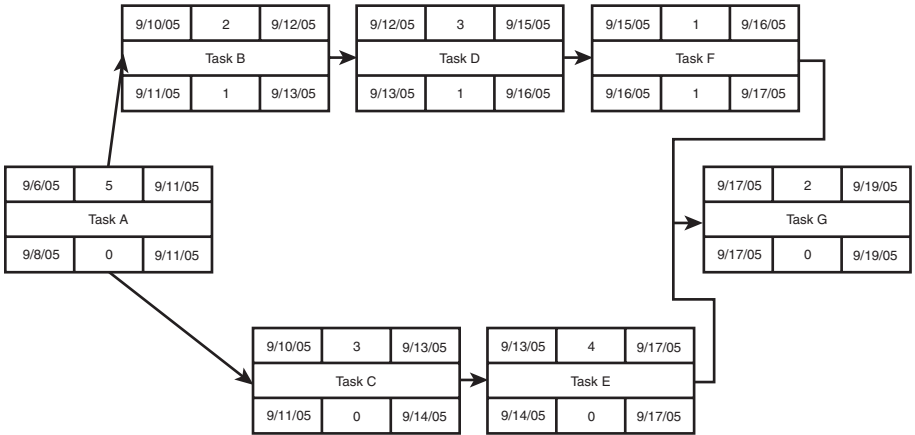Use Figure 3.7 for questions 7, 8, and 9.

Figure 3.7 A sample PDM diagram.

7. What is the critical path for this project, and what is the duration of the critical path?

   ❑ A. A-B-D-F-G, 13 days
   ❑ B. A-C-E-G, 14 days
   ❑ C. A-B-D-F-G, 14 days
   ❑ D. A-C-E-G, 13 days

8. How many days can task D be late in starting without affecting the project completion date?

   ❑ A. One day
   ❑ B. Two days
   ❑ C. Zero days
   ❑ D. Three days

9. If task C starts two days late, what is the effect on the project end date?

❑ A. The project ends one day late because there is slack of one day.

❑ B. The project is still two days early because tasks B, D, and F each have one day of slack.

❑ C. The project is two days late because task C is on the critical path.

❑ D. There is no effect on the project end date.

10. When developing the estimates for project phases, you choose to add the individual estimates for the activities that comprise each phase. What type of estimation method are you using?

❑ A. Parametric estimating

❑ B. Bottom-up estimating

❑ C. Top-down estimating

❑ D. Analogous estimating

Answers to Exam Prep Questions

1. Answer C is correct. The first process in the planning group is develop project management plan. Answers A, B, and D skip the first process and start subsequent processes prematurely.

2. Answer B is correct. The preliminary scope statement is an input you need before starting the scope definition process. Answer A is incorrect because product analysis is a tool and technique of scope definition, not an input. Answer C is incorrect because project management plan updates are an output, not an input. Answer D is incorrect because the WBS is an output of a subsequent process and would not be available at this point. Know your inputs, tools, techniques, and outputs of all processes.

3. Answer A is correct. A properly sized work package is one that is small enough to allow for reliable estimates for required resources and duration. Answers B, C, and D are incorrect because they assume you are working toward some artificial target that does not contribute to well-sized work packages.

4. Answer B is correct. Rolling wave planning is providing detailed plans for tasks that are about to start in the near future using the most current information and revisiting future activities when they near their starting dates. Answer A is incorrect because progressive elaboration is the reason many project details might not be known up front, not the practice of providing detailed plans as project activities near their start date. Answers C and D are incorrect because they are not valid project planning terms.

5. Answer A is correct. The precedence diagramming method (PDM) supports finish-to-start, finish-to-finish, start-to-start, and start-to-finish dependencies. Answer B is incorrect because the arrow diagramming method (ADM) only allows for finish-to-start dependencies. Answers C and D are incorrect because they are both nonexistent diagramming methods.

6. Answer B is correct. The arrow diagramming method (ADM) is also referred to as activity-on-arrow (AOA) diagramming method. Answer A is incorrect because the precedence diagramming method (ADM) is also referred to as activity-on-node (AON) diagramming method. Answers C and D are incorrect because they are both non-existent diagramming methods.

7. Answer B is correct. The path A-C-E-G is the longest direct path from start to finish. All other answers are incorrect because they either state the incorrect path or project duration.

8. Answer A is correct. Because task D is not on the critical path and has a slack of one day, it can start one day late (at most) without affecting the project end date.

9. Answer C is correct. Because task C is on the critical path, any delay of the task delays the project.

10. Answer B is correct. Bottom-up estimating is the process of calculating estimates by aggregating the individual estimates of activities that make up the desired activity group. Answer A is incorrect because parametric estimating uses a process of multiplying quantity of work by the productivity rate. Answer C is incorrect because top-down estimating starts with an estimate and decomposes the estimate into smaller units to apply to the individual work packages. Answer D is incorrect because analogous estimating uses similar work packages, not estimate aggregation.

Need to Know More?

Kerzner, Harold. *Project Management: A Systems Approach to Planning, Scheduling, and Controlling, Eighth Edition.* Indianapolis: John Wiley and Sons, 2003.

Project Management Institute. *A Guide to the Project Management Body of Knowledge, Third Edition.* Newton Square, PA: Project Management Institute, 2004.

Wysocki, Robert K. and McGary, Rudd. *Effective Project Management, Third Edition.* Indianapolis: John Wiley and Sons, 2003.