Schedule Management

SIX

This chapter can be difficult for those who do not realize that an unrealistic schedule is the project manager's fault. Yes, it's true! One of the key responsibilities of a project manager is ensuring that the needed end date for a project can be met and to create options to make it happen—all before project executing starts. If you know the many options for compressing a project schedule, and understand that a project schedule must be realistic before project executing begins, this chapter should not be difficult for you.

To answer schedule management questions correctly, you should thoroughly understand the process of scheduling a project. Although most project managers use some type of software to assist with scheduling, the exam has often required test takers to manually draw network diagrams to answer questions about network diagrams and scheduling. Therefore, you need to know some things that normally go on behind the scenes when using project management software.

Watch out! The term "project management software" can be misleading. Software can be extremely helpful and save you time scheduling, analyzing what-if scenarios, and performing status reporting functions, particularly on large projects, but you cannot rely on it to manage a project. When taking the exam—and when working on projects—you must recognize the limitations of software. Software does not take into account the unique nature of each project management process. Relying on software may limit your understanding of project management, which could cause you problems in identifying the best answer choices on the exam.

Make sure you recognize where each schedule management process falls within the project management process, and check your knowledge as you proceed through this chapter. Particularly if you rely on software on your projects, you may not have the knowledge and experience in schedule management, such as performing schedule analysis and creating network diagrams, that you will need to pass the exam.

QUICKTEST

- Schedule management process
- Schedule baseline
- Schedule compression
  - Crashing
  - Fast tracking
- Activity list
- Network diagram
- Dependencies
  - Mandatory
  - Discretionary
  - External
  - Internal
- Precedence diagramming method (PDM)
- Critical path
- Float (Schedule flexibility)
  - Total float
  - Free float
  - Project float
- Three-point estimating
  - Beta distribution
  - Triangular distribution
- Monte Carlo analysis
- Bar charts
- Schedule model
- Project management information systems (PMIS)
- Schedule management plan
- Critical path method
- Near-critical path
- Leads and lags
- Milestones, milestone list, and charts
- Resource breakdown structure (RBS)
- Reserve analysis
- Padding
- Analogous estimating
- Parametric estimating
- Heuristics
- Activity attributes
- Reestimating
- Rolling wave planning
- Progressive elaboration
- Alternatives analysis

Schedule Management SIX

INITIATING

- Select project manager
- Determine company culture and existing systems
- Collect processes, procedures, and historical information
- Divide large projects into phases or smaller projects
- Understand business case and benefits management plan
- Uncover initial requirements, assumptions, risks, constraints, and existing agreements
- Assess project and product feasibility within the given constraints
- Create measurable objectives and success criteria
- Develop project charter
- Identify stakeholders and determine their expectations, interest, influence, and impact
- Request changes
- Develop assumption log
- Develop stakeholder register

PLANNING

(This is the only process group with a set order.)

- **Determine development approach, life cycle, and how you will plan for each knowledge area**
- Define and prioritize requirements
- Create project scope statement
- Assess what to purchase and create procurement documents
- Determine planning team
- Create WBS and WBS dictionary
- **Create activity list**
- **Create network diagram**
- Estimate resource requirements
- **Estimate activity durations and costs**
- **Determine critical path**
- **Develop schedule**
- Develop budget
- Determine quality standards, processes, and metrics
- **Determine team charter and all roles and responsibilities**
- Plan communications and stakeholder engagement
- Perform risk identification, qualitative and quantitative risk analysis, and risk response planning
- **Go back—iterations**
- Finalize procurement strategy and documents
- Create change and configuration management plans
- **Finalize all management plans**
- **Develop realistic and sufficient project management plan and baselines**
- Gain formal approval of the plan
- Hold kickoff meeting
- **Request changes**

EXECUTING

- Execute work according to the project management plan
- Produce product deliverables (product scope)
- Gather work performance data
- Request changes
- Implement only approved changes
- Continuously improve; perform progressive elaboration
- Follow processes
- Determine whether quality plan and processes are correct and effective
- Perform quality audits and issue quality report
- Acquire final team and physical resources
- Manage people
- Evaluate team and individual performance; provide training
- Hold team-building activities
- Give recognition and rewards
- Use issue logs
- Facilitate conflict resolution
- Release resources as work is completed
- Send and receive information, and solicit feedback
- Report on project performance
- Facilitate stakeholder engagement and manage expectations
- Hold meetings
- Evaluate sellers; negotiate and contract with sellers
- Use and share project knowledge
- Execute contingency plans
- Update project management plan and project documents

MONITORING & CONTROLLING

- **Take action to monitor and control the project**
- **Measure performance against performance measurement baseline**
- **Measure performance against other metrics in the project management plan**
- **Analyze and evaluate data and performance**
- **Determine if variances warrant a corrective action or other change request(s)**
- **Influence factors that cause change**
- **Request changes**
- Perform integrated change control
- Approve or reject changes
- **Update project management plan and project documents**
- Inform stakeholders of all change request results
- Monitor stakeholder engagement
- Confirm configuration compliance
- **Create forecasts**
- Gain customer's acceptance of interim deliverables
- Perform quality control
- Perform risk reviews, reassessments, and audits
- Manage reserves
- Manage, evaluate, and close procurements
- Evaluate use of physical resources

CLOSING

- Confirm work is done to requirements
- Complete final procurement closure
- Gain final acceptance of product
- Complete financial closure
- Hand off completed product
- Solicit customer's feedback about the project
- Complete final performance reporting
- Index and archive records
- Gather final lessons learned and update knowledge bases

Rita's Process Chart™
Schedule Management
Where are we in the project management process?

The following should help you understand how each part of schedule management fits into the overall project management process:

The Schedule Management Process	Done During
Plan Schedule Management	Planning process group
Define Activities	Planning process group
Sequence Activities	Planning process group
Estimate Activity Durations	Planning process group
Develop Schedule	Planning process group
Control Schedule	Monitoring and controlling process group

Plan Schedule Management PAGE 179

Process Plan Schedule Management
Process Group Planning
Knowledge Area Schedule Management

The Plan Schedule Management process involves documenting how you will plan, manage, and control the project to the schedule baseline, and how you will manage schedule variances. Many project managers just work on the project and hope the project meets the deadline, but proper schedule management requires you to develop and follow a plan, measuring progress along the way. So as part of planning, you need to determine in advance what the measures of performance will be, how and when you will capture the data you need to evaluate schedule performance, how you will use the data to keep the project on track, and what you will do when variances occur. Plan Schedule Management answers questions such as: "Who will be involved, and what approach will we take to plan the schedule for the project?" and "What processes and procedures will we use to create the schedule?"

The project life cycle and development approach agreed on in the Develop Project Management plan process (in integration management) will influence the level and type of schedule management planning you will do on a project. You will also consider existing enterprise environmental factors. Is there a work authorization system in place for the project to use? Does the organization have a preferred project management software to use for scheduling? If not, will the work of the project include creating a work authorization system or selecting a scheduling software product? How does the company culture and the overall structure of the organization impact the work of scheduling the project?

Also keep in mind that expert judgment and data analysis techniques, such as alternatives analysis, may be used in planning the methodology you will use to arrive at a final schedule. To plan the schedule, you might also need to review the project charter or hold meetings that include the project sponsor, team members, and other stakeholders.

Schedule Management Plan PAGE 181

The key output of this process is a schedule management plan, which can be formal or informal. It is part of the project management plan, and it helps make the estimating and schedule development process faster by specifying the following:

- The scheduling methodology and scheduling software to be used on the project
- Rules for how estimates should be stated; for example, should estimates be in hours, days, or weeks? Should estimators identify both the effort (the amount of labor involved in completing an activity; for example, 12 hours) and duration (the amount of work periods the effort will span; for example, 1.5 days) needed to complete an activity?
- A schedule baseline for measuring against as part of project monitoring and controlling
- A threshold for acceptable variance

- Performance measures that will be used on the project, to identify variances early
- A plan for how schedule variances will be managed
- A process for determining whether a variance must be acted upon
- Identification of schedule change control procedures
- Types of reports required on the project relating to schedule
- Formats and frequency of project reporting
- The length of releases and iterations (in an adaptive life cycle)

Define Activities PAGE 183

Process Define Activities
Process Group Planning
Knowledge Area Schedule Management

This process involves taking the work packages created in the WBS and decomposing them into the activities that are required to produce the work package deliverables and thus achieve the project objectives. The activities should be at a level small enough to estimate, schedule, monitor, and control. These activities are then sequenced in the next process: Sequence Activities. (Note that breaking down the project work into the work packages in the WBS is part of scope management, and the identification of activities is part of schedule management.)

Defining activities is not always done as a separate process. Many project managers combine this effort with creating a WBS and WBS dictionary; they decompose work packages into the activities required to produce them, rather than stopping at the work package level.

So what do you need in order to define activities? The schedule management plan, created in the previous process, gives you important information about the approved methodology for scheduling. The scope baseline (project scope statement, WBS, and WBS dictionary) from scope management provides information about what is included in your project scope. This is the work you will now break down into project activities. You may also refer to organizational process assets including existing templates, historical information, such as activity lists from other similar projects, and any standards, such as a prescribed scheduling methodology. Involving the team in this process helps define the activities completely and accurately and therefore makes the estimates, created later in the planning process, more accurate.

TRICKS OF THE TRADE® Decomposition is used in the Define Activities process in schedule management, as well as in the Create WBS process in scope management. When you see the term used on the exam, it is important to look at the context of what is being decomposed. When deliverables are being decomposed into smaller deliverables, or work packages, you know the question is referring to the Create WBS process. When work packages are being decomposed into the activities to produce them, the question is referring to the Define Activities process. Be sure to choose answer choice that aligns with the appropriate process.

Rolling Wave Planning[1]

Have you ever worked on a project that seemed to have too many unknown components to adequately break down the work and schedule it? Be careful—when that is the case, you might really have more than one project (see the definition of a project in the Project Management Framework chapter). Or, it might simply be a project for which it is better to not plan the entire project to the smallest detail in advance, but instead to plan to a higher level and then develop more detailed plans when the work is to be done. This practice is called "rolling wave planning" and is a form of progressive

elaboration. Remember that progressive elaboration refers to the process of clarifying and refining plans as the project progresses. With this method, you plan activities to the detail needed to manage the work just before you are ready to start that part of the project. This technique is used to varying degrees on both change-driven and plan-driven projects.

Iterations of rolling wave planning during the project may result in additional activities being added, and in the further elaboration of other activities. Therefore, rolling wave planning may create the need for updates to the project management plan, specifically the schedule, scope, and/or cost baselines. These changes require integrated change control, beginning with a change request.

But remember—the option of rolling wave planning does not eliminate the need to ensure all the scope that can be known is known before starting work!

Milestones The Define Activities process also involves determining milestones to use on the project. Milestones are significant events within the project schedule. They are not work activities, and have no duration. For example, a completed design, customer-imposed due dates for interim deliverables, or a company-required checkpoint, phase gate, or stage gate could be milestones. Initial milestones are documented in the project charter. The project manager can also insert milestones as checkpoints to help control the project. If a milestone in the schedule is reached and any of the planned work has not been completed, it indicates the project is not progressing as planned. The milestone list is part of the project documents.

When completed, the Define Activities process results in an activity list, which includes all activities required to complete the project, and activity attributes, or details regarding project activities. At this time, known attributes may be limited to the activity name and ID number. As the project progresses, additional attributes—such as planned completion date, leads and lags, and predecessor and successor activities—may be added.

Define Activities is one of only a few planning processes with an output of change requests specifically listed in the *PMBOK® Guide*. Refer back to the discussion of rolling wave planning, and you will see that, as the project progresses, early planning efforts may need to be iterated, potentially resulting in changes to the project baselines.

Sequence Activities PAGE 187

Process Sequence Activities
Process Group Planning
Knowledge Area Schedule Management

The next process involves taking the activities and sequencing them in the order in which the work will be performed. The result is a network diagram (also referred to as a project schedule network diagram), which is illustrated in figure 6.1. There are several exercises designed to help you learn how to draw and interpret network diagrams later in this chapter.

If you need extra help understanding how to create and interpret network diagrams, please visit the website that accompanies this book: rmcls.com/extras.

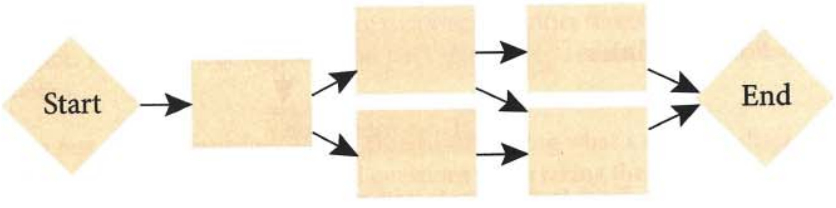


FIGURE 6.1 *Network diagram*

For the exam, know that in its pure form, the network diagram shows just dependencies (logical relationships). If activity duration estimates (estimates) and leads and lags are added to the diagram later in the schedule management process, it can also show the critical path. If plotted out against time (or placed against a calendar-based scale), the network diagram is a time-scaled schedule network diagram.

Factors that may influence dependencies in the sequencing of activities include the assumption log, activity attributes, and milestone list.

Methods to Draw Network Diagrams[2]

In the past, the arrow diagramming method[3] (ADM) and the graphical evaluation and review technique (GERT)[4] method were commonly used to draw network diagrams. Today most network diagrams are created using the precedence diagramming method (PDM).

Precedence Diagramming Method (PDM)[5]

In this method, nodes (or boxes) are used to represent activities, and arrows show activity dependencies, as shown in figure 6.2.

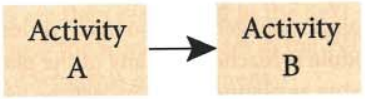


FIGURE 6.2 *Precedence diagramming method*

This type of drawing can have four types of logical relationships between activities (see fig. 6.3):

- **Finish-to-start (FS)** An activity must finish before the successor can start. This is the most commonly used relationship. Example: You must finish digging a hole before you can start the next activity of planting a tree.
- **Start-to-start (SS)** An activity must start before the successor can start. Example: You must start designing and wait for two weeks' lag in order to have enough of the design completed to start coding.
- **Finish-to-finish (FF)** An activity must finish before the successor can finish. Example: You must finish testing before you can finish documentation.
- **Start-to-finish (SF)** An activity must start before the successor can finish. This dependency is rarely used.

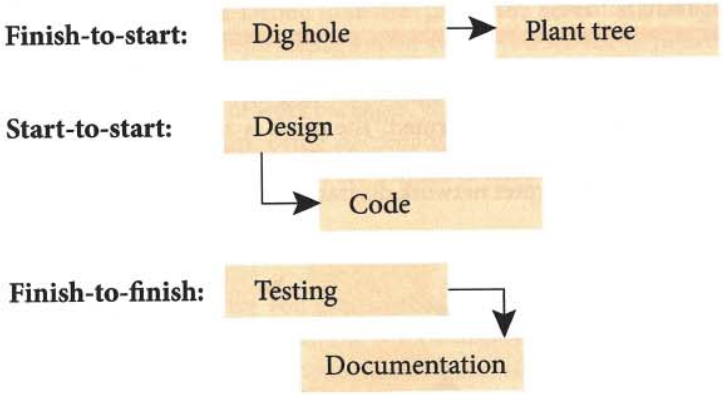


FIGURE 6.3 *Finish-to-start, start-to-start, and finish-to-finish dependencies*

Types of Dependencies[6] The sequence of activities is determined based on the following dependencies:

- **Mandatory dependency (hard logic)** A mandatory dependency is inherent in the nature of the work (for example, you must design before you can construct) or is required by a contract.
- **Discretionary dependency (preferred, preferential, or soft logic)** This is the way an organization has chosen to have work performed. There are other ways it could be done, but this is the preferred approach. Whereas you cannot easily change the other types of dependencies, you can change a discretionary dependency if necessary. Discretionary dependencies are important when analyzing how to compress the schedule to decrease the project duration (fast track the project).
- **External dependency** This dependency is based on the needs or desires of a party outside the project (for example, government or suppliers).
- **Internal dependency** This dependency is based on the needs of the project and may be something the project team can control.

More than one dependency can be identified for the same work. Combinations include mandatory external, mandatory internal, discretionary external, and discretionary internal.

The project team identifies mandatory and discretionary dependencies; the project manager identifies external and internal dependencies. (Remember, when we use the term "project manager" in this book, we're referring to anyone doing project management activities on the project, which could include not just the lead project manager but also supporting members of the project management team.)

Leads and Lags PAGE 192 A lead may be used to indicate that an activity can start before its predecessor activity is completed. For example, web page design might be able to start five days before the database design is finished. A lag is waiting time inserted between activities, such as needing to wait three days after pouring concrete before constructing the frame for a house. When project activities are first being sequenced, the duration of the activities, and required leads and lags, may be uncertain.

Also keep in mind, when creating complex project schedule network diagrams that include leads and lags as well as other dependencies, an automated scheduling system that is part of the PMIS can be used. This is especially helpful on large projects.

Project Schedule Network Diagram PAGE 194 A project schedule network diagram is an image depicting the flow of project activities in the logical order in which they will be performed. All activities after Start should be connected to at least one predecessor activity. All activities on the network diagram before Finish should be connected to at least one successor activity. In addition to sequencing activities, the network diagram helps you to plan which activities can be completed in parallel and to see where leads or lags are required. Of course, the more complex the project, the more likely it is that activities will overlap. When an activity has one or more activities directly preceding it, this is referred to as path convergence. When an activity has one or more successor activities directly following it, this is referred to as path divergence. Both path convergence and path divergence are indicators of greater risk within the impacted activities.

Now it's time to test your knowledge. Rather than just knowing what a network diagram is, you will be expected to answer harder, more sophisticated questions when taking the exam. You need to have worked with network diagrams to accurately answer such questions. See how you do with the next exercise.

Exercise Describe how the network diagram can help you on the project.

Answer You should know that network diagrams can be used in many ways. For example, they can be used to:

- Help justify your time estimate for the project.
- Aid in effectively planning, organizing, and controlling the project.
- Show interdependencies of all activities, and thereby identify riskier activities.
- Show workflow so the team will know what activities need to happen in a specific sequence.
- Identify opportunities to compress the schedule in planning and throughout the life of the project (explained later in this chapter).
- Show project progress (when used for controlling the schedule and reporting).

Project schedule network diagrams may also be referred to as network diagrams or activity network diagrams.

In addition to a network diagram, the Sequence Activities process may result in updates to project documents such as the activity list, activity attributes, assumption log, and the milestone list. Sequencing the activities can also reveal new risks, resulting in changes to the risk register.

TRICKS OF THE TRADE

Things to Know about Estimating for the Exam The Estimate Activity Durations and the Estimate Costs process (see the Cost Management chapter) as well as the Estimate Activity Resources process (see the Resource Management chapter) all involve estimating. The following are important points to understand about estimating for the exam:

- Management plans provide the approach for estimating.
- The project manager and team may use one or many techniques to estimate project work.
- Estimating should be based on a WBS to improve accuracy.
- Duration, cost, and resource estimates are interrelated; for example, duration and resource estimates could impact cost estimates.
- Identified risks must be considered when estimating the duration, cost, and resource requirements of project work.

- Estimating duration, cost, and resource requirements may uncover additional, previously unidentified risks.
- Whenever possible, estimating should be done by the person doing the work (or the person most familiar with the work) to improve accuracy.
- Historical information from past projects (part of organizational process assets) is key to improving estimates.
- Estimates are more accurate if smaller-size work components are estimated.
- A project manager should never just accept constraints from management, but should instead analyze the needs of the project, develop estimates with input from the team members doing the work when possible, and reconcile any differences to produce a realistic plan.
- The project manager may periodically recalculate the estimate to complete (ETC) for the project to make sure adequate time, funds, and resources, are available for the project.
- Plans based on estimates should be revised, with approved changes, during completion of the work, as necessary.
- There is a process for creating the most accurate estimate possible.
- Padding estimates is not an acceptable project management practice.
- The project manager must meet any agreed-upon estimates.
- Estimates must be reviewed when they are received from team members or sellers to see if they are reasonable and to check for padding and risks.
- Estimates must be kept realistic through the life of the project by reestimating and reviewing them periodically.
- Estimates can be impacted by reducing or eliminating risks.
- The project manager has a professional responsibility to provide estimates that are as accurate as feasible and to maintain the integrity of those estimates throughout the life of the project.

In the past, the exam has focused on the practices required to produce good estimates, more than it has focused on calculations. Therefore, make sure you take some time to think about these points. Remember, incorrect project management practices will be listed as choices on the exam. Project managers who do not adequately understand and manage their projects in this way have difficulty on the exam.

Estimate Activity Durations PAGE 195

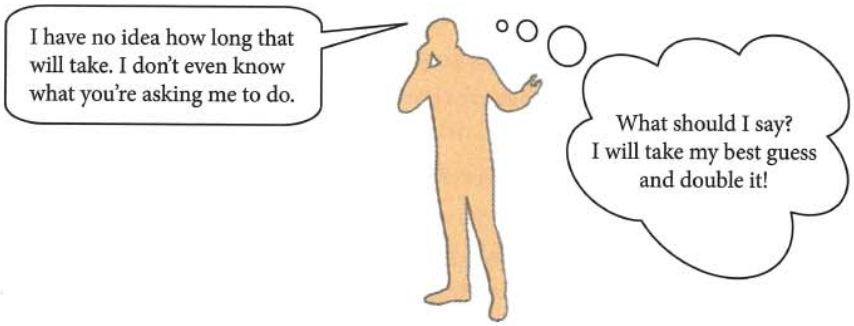
Process Estimate Activity Durations
Process Group Planning
Knowledge Area Schedule Management

When the activities have been defined and sequenced, the next step is to estimate how long each activity will take. This is the Estimate Activity Durations process. When possible, the estimators should be those who will be doing the work. On large projects, however, the estimators are more often the members of the project management team, as it is known during planning, who are most familiar with the work that needs to be done. To come up with realistic time estimates, these individuals need to have access to the following inputs:

- **Activity list and activity attributes** The relevant inputs may include the time for required leads or lags between activities, which must be factored into duration estimates.
- **Assumption log** Assumptions or constraints that contribute to risk within the activities to be estimated can be found in the assumption log.
- **Lessons learned register**[7] Information relevant to estimating the duration of schedule activities include lessons learned from earlier in the current project or from past, similar projects performed by the organization.

- **Resource breakdown structure**[8] Created in the Estimate Activity Resources process of Resource Management, the resource breakdown structure represents categories of resources required for the project.
- **Resource requirements** These requirements indicate the skill levels of resources required to perform specific project work.
- **Project team assignments** Project team assignments should include the number and experience level of individuals who have been committed to the project.
- **Resource calendars** These calendars provide information on when key resources with specialized skills needed for project activities will be available. If the resources are not available within the timeframe of your project, you may need to add extra time to some activity estimates, allowing for less experienced resources to do the work.
- **Risk register** The risk register may include identified threats and/or opportunities that should be reflected in the estimates.

Now let's think about how estimating works on your projects for a moment. Do your team members feel like this?



This response is an example of padding. Do you consider this practice normal or appropriate? It is not. Many project managers rely on this practice, but padding undermines the professional responsibility of a project manager to develop a realistic schedule and budget. This is another point that is essential to understand for the exam.

So what is wrong with padding? A pad is extra time or cost added to an estimate because the estimator does not have enough information.

In cases where the estimator has many unknowns and the information required to clarify the unknowns is unavailable, the potential need for additional time or funds should be addressed with reserves through the risk management process. Through risk management, the uncertainties are turned into identifiable opportunities and threats (risks). They should not remain hidden; instead, estimators need to identify and openly address uncertainties with the project manager.

What happens if all or many of your estimates are padded? Quite simply, you have a schedule or budget that no one believes. And if that is the case, why even bother creating a schedule or a budget? In the real world, we need the schedule and the budget to manage the project against. So we need them to be as believable and realistic as possible, and we need to adhere to them. To be a successful project manager, you need to be able to meet the agreed-upon project completion date and budget. It is important to understand that padding is a sign of poor project management and that it can damage your reputation and the credibility of the project management profession as a whole.

You may see questions on the exam that include padding as a solution to an estimating scenario. Just remember, padding is never a viable way to plan a project or to solve a problem—on the exam or in the real world!

In a properly managed project, the estimators have a WBS and may even have helped create it. They also have a description of each work package (the WBS dictionary) and may have helped create that as well. They may even have helped create the activity list from the work packages. They know there will be time and cost reserves on the project that will be determined through actual calculations—not arbitrary guesses—to address identified risks or unknowns. With all that information, they should not need to pad their estimates!

If you allow padding on your projects now, and consider it to be an appropriate practice, please make sure you reread this section and carefully review the Risk Management chapter. You need to recognize the difference between padding and creating reserves, and understand how padding can be detrimental to your project. The exam questions in this area are designed to identify those who make common project management errors, such as padding.

How Is Estimating Done? As stated earlier in this chapter, those who will be doing the work, or those most familiar with the activities to be done, should create the activity estimates. They may use one or many techniques, which were identified in the schedule management plan.

Before we discuss estimating techniques, let's look at the project manager's role in this process. If other people are creating the estimates, then what is the project manager doing?

The role of the project manager in estimating is to:

- Provide the team with enough information to properly estimate each activity.
- Let those doing the estimating know how refined their estimates must be.
- Complete a sanity check of the estimates.
- Prevent padding.
- Formulate a reserve (more on this later—in the reserve analysis discussion in this section and in the Risk Management chapter).
- Make sure assumptions made during estimating are recorded for later review.

Now let's look at estimating techniques that may be used on a project.

One-Point Estimating When estimating time using a one-point estimate, the estimator submits one estimate per activity. For example, the person doing the estimating says that the activity will take five weeks. The time estimate may be based on expert judgment or historical information, or it could be just a guess. As a result, this technique can be problematic.

Although one-point estimating is often not the best method to use, it is an easy way to illustrate how to draw network diagrams and find the critical path. Using one-point estimates also allows for quick calculation on the exam and demonstrates that you understand concepts such as the critical path. You may see references to one-point estimating on the exam, as shown in the exercises later in this chapter.

One-point estimating can have the following negative effects on the project:

- Being limited to making a one-point estimate may encourage people to pad their estimates.
- A one-point estimate doesn't provide the project manager with important information about risks and uncertainties they need in order to better plan and control the project.
- One-point estimating can result in a schedule that no one believes in, thus decreasing buy-in to the project management process.
- When a person uses one-point estimating to develop an estimate that an activity will take 20 days and it is completed in 15 days, it can make the person who provided the estimate look unreliable.

Analogous Estimating[9] (Top-Down) PAGE 200 Applicable to duration, cost, and resource estimating, analogous estimating uses expert judgment and historical information to predict the future. Management or the sponsor might use analogous estimating to create the overall project constraint/estimate given to the project manager as the project is chartered. The project manager may use analogous estimating at the project level, using historical data from past, similar projects. (For example, the last five projects similar to this one each took eight months, so this one should as well.) Analogous estimating can also be used at the activity level, if the activity has been done on previous projects and if there is substantial historical data to support the accuracy of such an estimate. (For example, the last two times this activity was completed each took three days; since we have no other information to go on, we will use three days as the estimate for this activity and review the estimate when more details become available.) Be aware for the exam that analogous estimating can be done at various times, and the level of accuracy depends on how closely the project or activity matches the historical data used.

Parametric Estimating PAGE 200 Parametric estimating involves creating a mathematical equation using data from historical records or other sources, such as industry requirements or standard metrics, to create estimates. The technique analyzes relationships between historical data and other variables to estimate duration or cost. It can be applied to some or all the activities within a project. For example, when estimating activity duration, the estimator may use measures such as time per line of code, time per linear meter, or time per installation. When used in cost estimating, the measures include cost as one of the variables. So the measures would be cost per line of code, cost per linear meter, etc.

An estimator might create parametric estimates using the following:

- **Regression analysis[10] (scatter diagram)** This diagram tracks two variables to see if they are related; the diagram is then used to create a mathematical formula to use in future parametric estimating (see fig. 6.4).
- **Learning curve** Example: The 100th room painted will take less time than the first room because of improved efficiency.

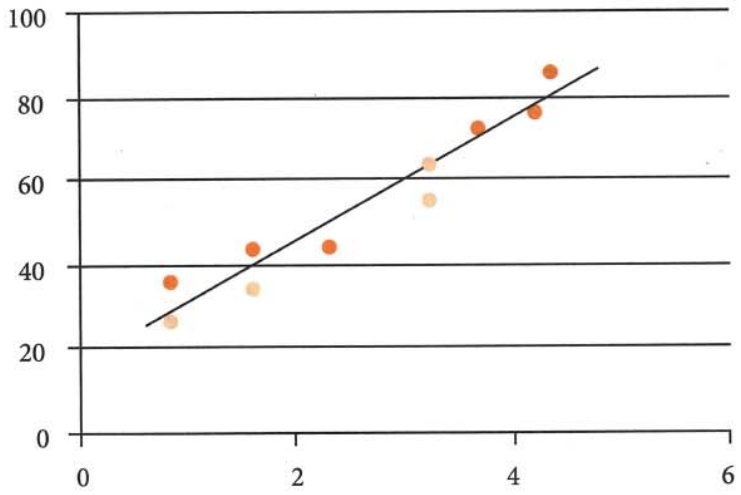


FIGURE 6.4 *Regression analysis (scatter diagram)*

Heuristics[11] A heuristic means a generally accepted rule, or best practice. An example of a heuristic is the 80/20 rule. A schedule heuristic might be, "Design work is always 15 percent of the total project length." The results of parametric estimating can become heuristics.

Three-Point Estimating[12] PAGE 201 Statistically, there is a very small probability of completing a project on exactly any one date. As we know, things do not always go according to plan. Therefore, it is often best to state estimates in a range using three-point estimates. Analyzing what could go right (opportunities) and what could go wrong (threats) can help estimators determine an expected range for each activity. By analyzing this range of time or cost estimates, the project manager can better understand the potential variation of the activity estimates. With the three-point technique, estimators give an optimistic (O), pessimistic (P), and most likely (M) estimate for each activity. Three-point estimating allows more consideration of both the uncertainty of estimating and the risks associated with the activities being estimated. A wide range between the optimistic and pessimistic estimates can indicate uncertainty—and therefore risk—associated with the activity.

Ultimately, three-point estimates can be used to calculate a risk-based expected duration estimate for an activity by taking either a simple average or a weighted average of three estimates. See the following information and formulas.

Triangular Distribution (Simple Average) A simple average of the three-point estimates can be calculated using the formula (P + O + M)/3. The use of simple averaging gives equal weight to each of the three-point estimates when calculating the expected activity duration or cost. Using this formula, the risks (P and O estimates) are considered equally along with the most likely (M) estimate.

Beta Distribution (Weighted Average)[13] The use of beta distribution (a weighted average) gives stronger consideration to the most likely estimate. Derived from the program evaluation and review technique (PERT),[14] this technique uses a formula to create a weighted average for the work to be done: (P + 4M + O)/6. Since the most likely estimate is multiplied by 4, it weights the average toward that estimate. This method of estimating leverages the benefits of risk management in reducing the uncertainty of estimates. When a good risk management process is followed, the most likely estimates are more accurate because risk response plans have been developed to deal with identified opportunities and threats that have been factored into the pessimistic and optimistic estimates.

For the exam, it's important to know the formulas for both triangular and beta distribution and to understand that if you are asked to calculate the activity duration or cost, you will need to read the situation carefully to determine which formula to use. Terms like "simple" or "straight" refer to triangular distribution, "weighted" refers to beta distribution. Knowing this will help you choose the correct formula.

You may be asked to perform calculations using the formulas, or to analyze information to determine which calculation is best for the situation presented. If the scenario indicates that you don't have a lot of experience or historical info, you would use triangular distribution, which provides a straight average. Beta distribution is used when there are historical data or samples to work with. The exercises that follow can help you prepare for three-point estimating questions on the exam. But first, review the formulas, shown again in figure 6.5.

You must memorize these formulas and remember that they can be used for both time and cost estimates.

Expected activity duration (triangular distribution)	Expected activity duration (beta distribution)
$\frac{P + M + O}{3}$	$\frac{P + 4M + O}{6}$

Legend: P = Pessimistic, M = Most likely, O = Optimistic

FIGURE 6.5 *Triangular distribution and beta distribution formulas for three-point estimating*

Exercise Calculate the expected activity duration using triangular distribution. It is best to calculate to three decimal places. All estimates are in hours.

Activity	P	M	O	Expected Activity Duration (Triangular Distribution)
A	47	27	14	
B	89	60	41	
C	48	44	39	
D	42	37	29	

Answer

Activity	P	M	O	Expected Activity Duration (Triangular Distribution)
A	47	27	14	29.333
B	89	60	41	63.333
C	48	44	39	43.666
D	42	37	29	36

Exercise Calculate the expected activity duration using beta distribution. Calculate to three decimal places. All estimates are in hours.

Activity	P	M	O	Expected Activity Duration (Beta Distribution)
A	47	27	14	
B	89	60	41	
C	48	44	39	
D	42	37	29	

Answer

Activity	P	M	O	Expected Activity Duration (Beta Distribution)
A	47	27	14	28.167
B	89	60	41	61.667
C	48	44	39	43.833
D	42	37	29	36.500

Compare the answers in the "Expected Activity Duration (Beta Distribution)" column to the answers in the "Expected Activity Duration (Triangular Distribution)" column in the previous exercise. Notice that the results are not significantly different. However, if you do not select the right formula for a question that requires the calculation of expected activity duration, you could end up choosing the wrong answer.

These exercises are provided for understanding and do not necessarily represent the complexity of questions on the exam. Most of the questions on the exam relating to three-point estimating are relatively simple and may require assessment, but not calculations.

Activity standard deviation[15] is the possible range for the estimate. For example, an activity estimate of 30 hours that has a standard deviation of +/– 2 is expected to take between 28 hours and 32 hours. The formula for beta activity standard deviation is P – O/6. Calculation using these formula is not a focus of the exam, but understanding and interpreting standard deviation in a situational question is important.

Although there is a standard deviation formula for triangular distribution, it's complicated and is unlikely to be on the exam so we are not showing it here. What you need to remember for the exam is that the greater the standard deviation, the greater the risk.

To establish a range for an individual activity estimate using weighted (beta) averaging, you need to know the beta expected activity duration (EAD) and the beta activity standard deviation (SD). You calculate the range using beta EAD +/– SD. The start of the range is beta EAD – SD, and the end of the range is beta EAD + SD. Review the following table to see how the information is presented. Keep in mind that the exam scenario may include information for you to do the same evaluation with triangular distribution.

Activity	P	M	O	Expected Activity Duration (Beta Distribution)	Beta Activity Standard Deviation	Range of the Estimate
A	47	27	14	28.167	5.500	22.667 to 33.667, or 28.167 +/– 5.500
B	89	60	41	61.667	8.000	53.667 to 69.667, or 61.667 +/– 8.000
C	48	44	39	43.833	1.500	42.333 to 45.333, or 43.833 +/– 1.500
D	42	37	29	36.500	2.167	34.333 to 38.667, or 36.500 +/– 2.167

Note that the formulas we've been discussing relate to activities, rather than the overall project, and that the exam concentrates on using three-point estimating to find ranges for activity duration and cost estimates. You can also use this information to calculate the overall project estimate and the project standard deviation to help manage a project successfully. Consider how these ranges might affect the estimate of the overall project duration and cost, and use this knowledge to effectively address variations on your project.

For the exam, you should be able to do simple calculations using the formulas, understand that estimates of time (or cost) should be in a range, and interpret the information to answer situational questions. You may also see beta total project duration (for example, the project duration is 35 months plus or minus 3 months) used in questions that require you to evaluate the situation, rather than complete a calculation, to answer the questions correctly. Remember that, just like with an activity, the greater the range for the project as a whole, the greater the risk.

Why do project managers need to understand expected durations, range estimates, and standard deviations? The main purpose is to use these concepts to better monitor and control projects. These calculations help you know the potential variances on your project and determine appropriate courses of action.

You can use estimate ranges and standard deviation to assess risk. Looking back at the table presenting beta standard deviation in this section, which activity has the most risk? The answer is Activity B. It has the widest range and the highest standard deviation, and is therefore likely to have the greatest risk. These calculations are based on the pessimistic, optimistic, and most likely estimates for an activity. The further away from the mean these estimates are, the more that could go right or wrong and affect the activity. Therefore, you can assess and compare the risk of various activities by looking at activity ranges and standard deviations.

Don't forget that these concepts also apply to cost. Let's say you have estimated that a portion of your project will cost $1 million with a standard deviation of $200,000. You need to decide whether to use a fixed-price contract to outsource that piece of the project work. The standard deviation indicates there is a 40 percent range in the cost estimate for the work. Therefore, you would not likely choose a fixed-price contract, since this large standard deviation suggests there is not a firm definition of the scope of the work to be done. (See the Procurement Management chapter for information about types of contracts.)

Bottom-Up Estimating PAGE 202 This technique involves creating detailed estimates for each part of an activity (if available) or work package (if activities are not defined). Doing this type of estimating well requires an accurate WBS. The estimates are then rolled up into control accounts and finally into an overall project estimate.

Make sure you have a general understanding of these estimating concepts. If you are still struggling with this topic, review this section again.

Data Analysis PAGE 202

Estimate Activity Durations uses two forms of data analysis; alternatives analysis and reserve analysis.

Alternatives Analysis When activity estimates are not acceptable within the constraints of the project, alternatives analysis is used to look more closely at the variables that impact the estimates. For example, comparing options such as outsourcing work versus completing it internally to meet a schedule constraint, or purchasing testing software to decrease the time of manually testing components. Alternatives analysis involves evaluating the impact of each option on project constraints, including financial investment versus time saved and level of risk. This process will result in the determination of the best approach to completing project work within the constraints.

Reserve Analysis Now let's connect the topics of estimating and risk management. Estimating helps to identify more risks. Risk management reduces the uncertainty in time and cost estimates. This is accomplished by evaluating and planning for significant opportunities and threats, including how they will be dealt with if they occur. Risk management saves the project time and money!

Project managers have a professional responsibility to establish a reserve to accommodate the risks that remain after the risk management planning processes are completed. Often in the risk management process, an initial reserve is estimated, the Plan Risk Responses process is performed to reduce the risk, and then a revised reserve is created. This is another example of the iterative nature of project planning.

As described in the Risk Management chapter, two types of reserves can be added to the project schedule: contingency reserves and management reserves.[16]

Contingency reserves for schedule are allocated for the identified risks remaining after the Plan Risk Responses process (known unknowns). These reserves are included in the project schedule baseline.

Significant risks to critical path activities may be managed by allocating a specific amount of schedule reserve. The amount of this schedule reserve is based on the impact of identified risks on the activity as well as the contingency plans to deal with it.

The expected values of each contingency plan are added together to create a schedule contingency reserve. The project manager employs the contingency plan and uses the contingency reserve when identified risks occur. This keeps the project within the schedule baseline. (See the Risk Management chapter for a more detailed discussion of reserves.)

Management reserves are additional funds and time to cover unforeseen risks that could impact the project's ability to meet the schedule. (These risks are referred to as unknown unknowns.) Management reserves are not part of the schedule baseline. These reserves may not be applied at the project manager's discretion, but rather require approval of a formal change request. The Risk Management chapter explains how these reserves are calculated.

For the exam, you should understand the major difference between the practice of creating reserves and the practice of padding. In creating reserves, the project manager has the information necessary to reliably calculate what additional time or funds the project may need, whereas with padding, team members arbitrarily determine how much of a pad they want to attach to their estimates.

Decision-Making PAGE 203 Involving team members in estimating can be beneficial on many levels. Those doing the work are most likely to have a good understanding of the time required to complete the effort. Additionally, including team members in the estimating process increases their buy-in to the resulting schedule.

Voting is a method that can be used during decision-making—giving every participant the opportunity to weigh in on a decision regarding an activity estimate or amount of reserve needed. On plan-driven projects, voting may result in a decision based on plurality, majority, or unanimity. A voting technique commonly used on change-driven projects is "fist of five," also called "fist to five". In this variation, team members are asked to physically show their level of support for a decision. A closed fist indicates a zero (no support) and an open fist indicates five (full support). Team members who are not supportive, and showed two or fewer fingers in the vote, are allowed to share why they are not in support of the option. Voting is repeated until everyone in the group indicates their support by showing at least three fingers.

When the Estimate Activity Durations process is completed, you will of course have estimates, including reserves. But remember that you may also update or make changes to the project documents, including activity attributes, assumption log, and lessons learned register as a result of this process.

Another output of this process is the basis of estimates. The basis of estimates is an explanation of how the estimates were derived, what assumptions and constraints were included, and what risks were taken into consideration in the estimation process. Basis of estimates also includes the confidence level of the estimators, expressed as a range, such as plus or minus 20 percent within which the actual project results are expected to fall.

Process for Achieving a Realistic Schedule or Budget Project managers often complain about unrealistic schedules and budgets and put the blame on senior management. They do not realize that a major reason for having a project manager on a project is to make the schedule and budget realistic. How do you go about achieving a realistic schedule or budget? Let's think about the process logically.

If you need more help with scheduling or handling unrealistic schedules, visit rmcls.com for free tips and information about courses on these topics.

First, you analyze the work needed to complete the project. You then estimate the duration and cost of the work, and calculate an end date and budget for the project. You try to optimize that date and budget, and then compare your results to the any schedule or budget constraints. If there is a difference, you analyze the project and provide options on how to change it to meet schedule and budget constraints or negotiate a change to the end date or budget; in other words, you balance the constraints. This is your professional responsibility as a project manager!

Do you follow the process we just described? If not, take some time now to truly understand it, and think about how you can implement these practices on your projects.

Develop Schedule PAGE 205

Process Develop Schedule
Process Group Planning
Knowledge Area Schedule Management

After network diagram and activity duration estimates are completed, it is time to put this information into the scheduling software within the project management information system (PMIS) to create a schedule model.[17] The schedule model includes of all the project data that will be used to calculate the schedule, such as the activities, duration estimates, dependencies, and leads and lags. The project schedule is the output of the schedule model, and it consolidates all the schedule data. Representations of the schedule include bar charts and milestone charts. The approved project schedule is the baseline (a version of the schedule model that can only be changed with change control procedures), and is part of the project management plan.

The schedule is calendar-based, approved, and realistic as it includes all the activities needed to complete the work of the project, as well as contingency reserves to manage risk events. Consider what is involved in creating a schedule, and complete the following exercises. Hint: Think about the outputs of the previous schedule management processes!

Exercise Let's start at the beginning. What do you need before you can develop a schedule for your project?

Answer To develop a schedule, you need to have:

- Historical records of previous, similar projects including lessons learned
- Components of the project management plan needed to develop a realistic schedule (schedule management plan and scope baseline)
- Defined activities (activity list and attributes)
- Milestone list
- Assumption log
- The order in which the work will be done (network diagram)
- Basis of estimates
- An estimate of the duration of each activity (activity duration estimates)
- An estimate of the resources needed (resource requirements)
- An understanding of the availability of resources (resource calendars)
- The required resources by category (resource breakdown structure)
- A company calendar identifying working and nonworking days
- A list of resources already assigned to specific project activities by management or agreement/contract (project team assignments)
- A list of risks that could impact the schedule (risk register)

Exercise As a project manager, you need to use the estimating data and other inputs to create a schedule that you will be able to stake your reputation on meeting. What do you need to do to create such a schedule?

Answer Let's go beyond the *PMBOK® Guide*. The Develop Schedule process really includes everything you need to do to develop a finalized schedule that is bought into, approved, realistic, and formal. This is what developing the schedule is all about. What do you need to do to get it to that level?

- Work with stakeholders' priorities.
- Look for alternative ways to complete the work.
- Look for impacts on other projects.
- Take into consideration the skill levels and availability of resources assigned to the team by management, or agreed-upon through negotiations in the Acquire Resources process in resource management.
- Apply leads and lags to the schedule.
- Compress the schedule by crashing, fast tracking, and reestimating.
- Adjust components of the project management plan as necessary (for example, change the WBS to reflect planned risk responses).
- Input the data into a scheduling tool and perform calculations to determine the optimum schedule.
- Simulate the project using Monte Carlo and other analysis techniques to determine the likelihood of completing the project as scheduled.
- Optimize resources if necessary.
- Give the team a chance to approve the final schedule; they should review the calendar allocation of their estimates to see if they are still feasible.
- Conduct meetings and conversations to gain stakeholder buy-in and formal management approval.

The Develop Schedule process is iterative and can occur many times over the life of the project (at least once per project life cycle phase on a large project). The Develop Schedule process is a source of problems on the exam for many project managers. The exam will test you as an expert in handling schedule development during project planning and whenever there are changes to the project.

Schedule Network Analysis PAGE 209

Schedule network analysis is used to create the schedule model, and, ultimately, to finalize the project schedule. This analysis may use one or more of the following techniques:

- Critical path method
- Schedule compression
- What-if/Monte Carlo analysis
- Resource optimization
- Agile release planning

Critical Path Method[18] PAGE 210

The critical path method involves determining the longest duration path through the network diagram, the earliest and latest an activity can start, and the earliest and latest it can be completed. To use this method, you need to understand the following basic concepts.

Critical Path The critical path is the longest duration path through a network diagram, and it determines the shortest time it could take to complete the project.

The easiest way to find the critical path is to identify all paths through the network and add the activity durations along each path. The path with the longest duration is the critical path. Be careful that you do the exercises that follow and practice doing this manual work for the exam.

Near-Critical Path[19] In addition to the critical path, you should be familiar with the concept of a near-critical path. This path is closest in duration to the critical path. Something could happen that shortens the critical path or lengthens the near-critical path to the point where the near-critical path becomes critical. The closer in length the near-critical and critical paths are, the more risk the project has. You need to focus time and effort monitoring and controlling activities on both the critical and near-critical paths (yes, there can be more than one) so there is no delay to project completion.

Float[20] **(Schedule Flexibility)** You should understand float and be able to calculate it manually for the exam. Note that the terms "float" and "slack" mean the same thing. Slack is an older term for this concept, and is rarely used in project management. It is unlikely that you will see the term "slack" used on the exam.

The three types of float to know for the exam are:

- **Total float** Total float is the amount of time an activity can be delayed without delaying the project end date or an intermediary milestone, while still adhering to any imposed schedule constraints. This is the primary type of float, but there are others.
- **Free float** Free float is the amount of time an activity can be delayed without delaying the early start date of its successor(s) while still adhering to any imposed schedule constraints.
- **Project float** Project float (also referred to as positive total float) is the amount of time a project can be delayed without delaying the externally imposed project completion date required by the customer or management, or the date previously committed to by the project manager.

Activities on the critical path have zero float. Critical path activities that are delayed or have an imposed completion date can result in negative float. This must be addressed before the project begins, as the project manager is responsible to ensure that the project schedule is realistic and achievable. Negative float analysis results in options to bring the schedule back within the baseline.

Float is an asset on a project, as it provides schedule flexibility. If you know where you have float, you can use it to help organize and manage the project. Do you do this on your projects? If not, study this section carefully.

When you know the critical path and any near-critical paths, you can use float as a way to focus your management of a project and to achieve better allocation of resources. For example, if you have a resource who is not very experienced but whom you must use for the project, you can assign them (assuming they have the skill set) to work on the activity with the most float. This gives you some level of security; even if their activity takes longer, the project is less likely to be delayed.

Knowing the float also helps team members juggle their work on multiple projects. They of course need to get approval from the project manager for any delays from the plan, but the amount of float tells them how much time flexibility they may have for each activity they are working on.

Sometimes the exam questions are presented in such a way that you can simply see the amount of float, but other times you will need to calculate it. Float is calculated using either of the following equations:

- Float = Late start (LS) – Early start (ES)
- Float = Late finish (LF) – Early finish (EF)

Either formula gets you the same answer. Do you want to remember them without any further study? Just know the following:

TRICKS OF THE TRADE "There is a start formula and a finish formula, and we always begin late." Notice that the formula uses either two start or two finish data elements and each begins with late.

Start Formula (Used in Forward Pass)	Finish Formula (Used in Backward Pass)
Float = LS – ES	Float = LF – EF

You determine whether to use the start or finish formula based on the information available. For example, if an exam question states that you have a late start of 30, an early start of 18, and a late finish of 34, how do you find the float? Using the previous trick, you know to subtract the two starts or the two finishes. Since you do not have two finishes, you use the equation 30 – 18, which equals 12.

Exercise Test yourself! How does the critical path help you as a project manager?

Answer The critical path:

- Helps prove how long the project will take
- Shows which activities have float and can therefore be delayed without delaying the project
- Provides information needed to compress the schedule during project planning and whenever there are changes
- Helps determine where to focus your project management efforts
- Helps determine which activities have more risk associated with them
- Helps determine if a delayed activity needs immediate attention

Using the Critical Path Method Now that we have discussed the basic concepts, let's look at how the critical path method works. We'll use the network diagram in figure 6.6 as an example. Note that the critical path is identified by the bold arrows.

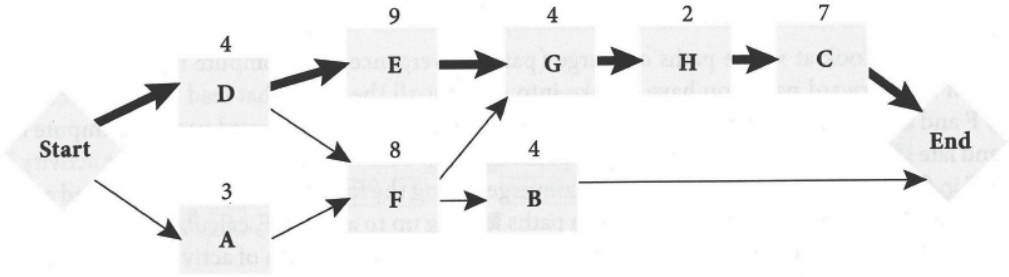


FIGURE 6.6 *Critical path method*

To determine the earliest and latest each activity can start and the earliest and latest each activity can be completed, you need to perform a forward and backward pass through the network diagram. The "early" figures are found by calculating from the beginning of the project to the end of the project, following the dependencies in the network diagram—a forward pass through the network diagram. The "late" figures are found by moving from the end of the project, following the dependencies to the beginning of the project—a backward pass.

The first activity in the diagram normally has an early start of zero. Some people, however, use 1 as the early start of the first activity. There is no right way to start calculating through network diagrams for the early and late starts; either method will get you the right answer. Just pick one method, and use it consistently. We use zero as the early start because it saves a bit of calculation and people consistently find it easier when learning this concept.

You can also access free tricks and tools, including an article about calculating the forward and backward passes in a network diagram (starting with zero or one) at rmcls.com.

Let's start with the forward pass. You need to move through the activities from the start until you reach the end, determining the early starts and early finishes, as illustrated in figure 6.7. This example uses zero as the early start for the first activities.

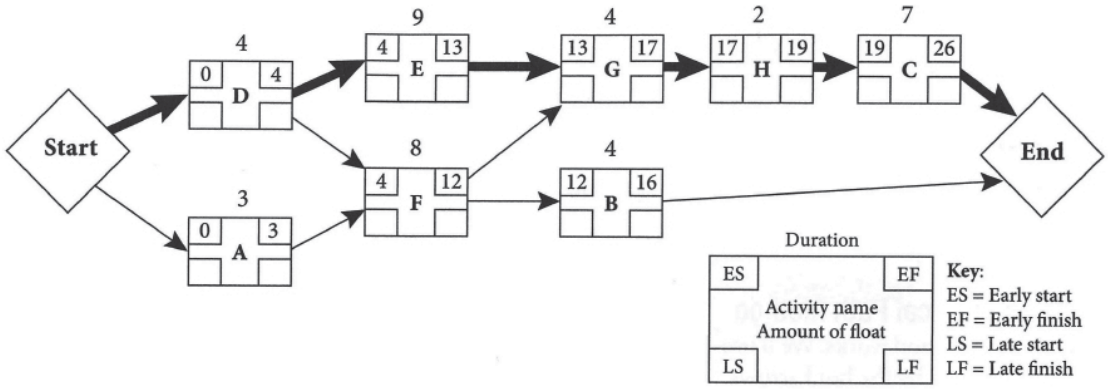


FIGURE 6.7 *Forward pass through network diagram*

It is important to look at where paths converge (path convergence). To compute the early start and the early finish in a forward pass, you have to take into account all the paths that lead into that activity (see activity F and activity G in figure 6.7). The same concept applies to the backward pass; to compute the late finish and late start you need to consider all the paths that flow backward into an activity (see activity D and activity F in figure 6.7). In this diagram, paths converge during the forward pass at activity F and at activity G. So you need to do the forward pass on both paths leading up to activity F, calculating the early finishes for activities D (EF = 4) and A (EF = 3). You then select the later early finish of activities D and A to use as the early start for activity F, since activity F cannot start until both activities D and A are complete. Therefore, the early start of activity F is 4. You use the same process for calculating the early finish of activities E (EF = 13) and F (EF = 12) before determining the early start of activity G (ES = 13).

Once you have completed the forward pass, you can begin the backward pass, computing the late finish and late start for each activity. The backward pass uses the duration of the critical path (in this case, 26) as the late finish of the last activity or activities in the network. See figure 6.8 for the late start and late finish data.

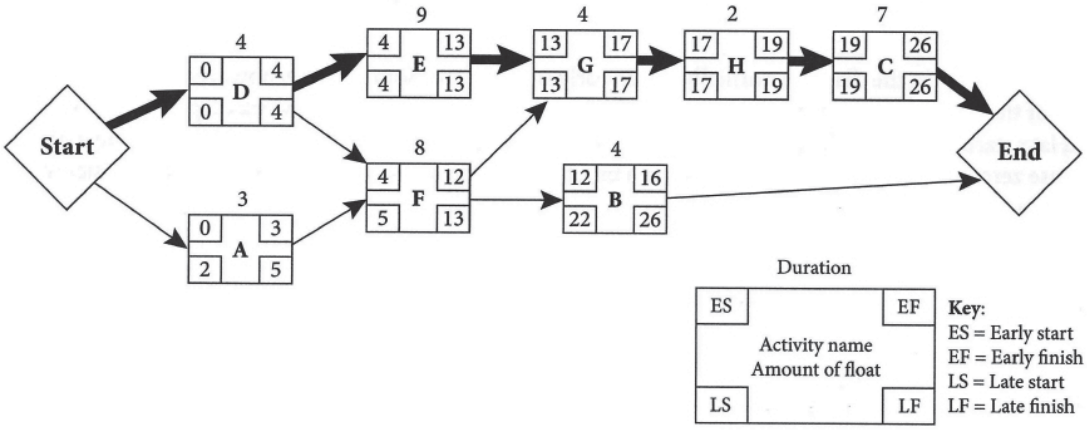


FIGURE 6.8 *Backward pass through network diagram*

Again, you need to be careful at points of convergence as you move through the network diagram. There is convergence at activity F and at activity D. You work from the end back to these by first computing the late start of activities B (LS = 22) and G (LS = 13). Select the earlier late start to use for the late finish of activity F, since activity F must be finished before either activity B or G can start.

Therefore, the late finish of activity F is 13. This same process should be used on activities E (LS = 4) and F (LS =5) before calculating the late finish for activity D (LF = 4).

Once you finish calculating the starts and finishes, you have the data required to calculate float. It's time to use those formulas. What was that trick again? "There is a start formula and a finish formula, and we always begin late." Therefore, the formulas are:

Start Formula (Used in Forward Pass)	Finish Formula (Used in Backward Pass)
Float = LS – ES	Float = LF – EF

If you want additional practice, there are more questions on float and critical path in RMC's PM FASTrack® exam simulator.

The activities with zero float are on the critical path (identified by the bold arrows). See figure 6.9 for the float of each activity.

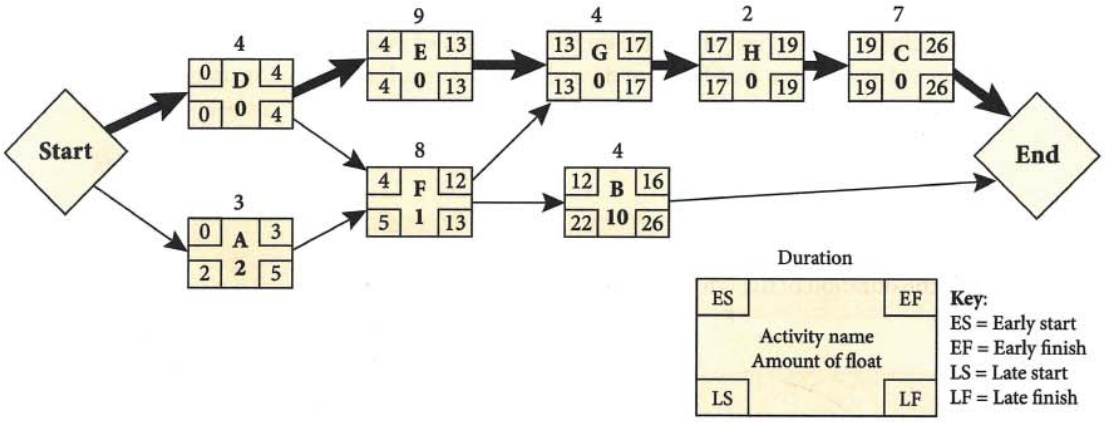


FIGURE 6.9 *Float of activities on network diagram*

The next few exercises should help you better understand these concepts. As you do the exercises, think about how knowing float helps you in managing your projects.

Be prepared for different types of exam questions. Some questions may be substantially similar to the following exercises, and others may be more situational and wordy. Not all questions will require you to draw a network diagram.

Exercise Test yourself. Draw a network diagram, and then answer the following questions.

- You are the project manager for a new project and have figured out the following dependencies: Activity 1 can start immediately and has an estimated duration of 3 weeks.
- Activity 2 can start after activity 1 is completed and has an estimated duration of 3 weeks.
- Activity 3 can start after activity 1 is completed and has an estimated duration of 6 weeks.
- Activity 4 can start after activity 2 is completed and has an estimated duration of 8 weeks.
- Activity 5 can start after activity 4 is completed and after activity 3 is completed. This activity takes 4 weeks.

1. What is the duration of the critical path?

2. What is the float of activity 3?

3. What is the float of activity 2?

4. What is the float of the path with the longest float?

5. The resource working on activity 3 is replaced with another resource who is less experienced. The activity will now take 10 weeks. How will this affect the project?

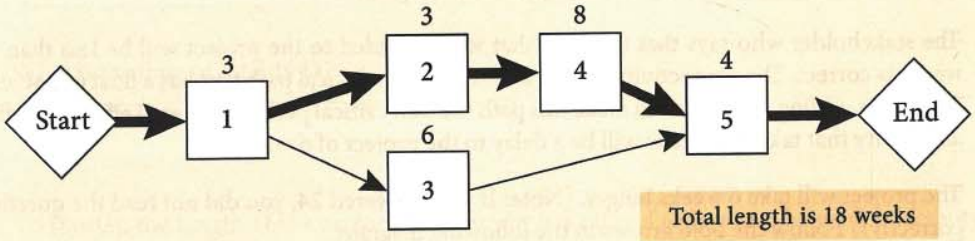
6. After some arguing between stakeholders, a new activity 6 is added to the project. It will take 11 weeks to complete and must be completed before activity 5 and after activity 3. Management is concerned that adding the activity will add 11 weeks to the project. Another stakeholder argues the time will be less than 11 weeks. Who is correct? Use the original information (without the change to activity 3 listed in the previous question) to answer this question.

7. Based on the information in question 6, how much longer will the project take?

Answer There are many ways to answer these questions. If you learned another way in your project management training and are comfortable with that method, use it. Here is a simple way to compute the answers.

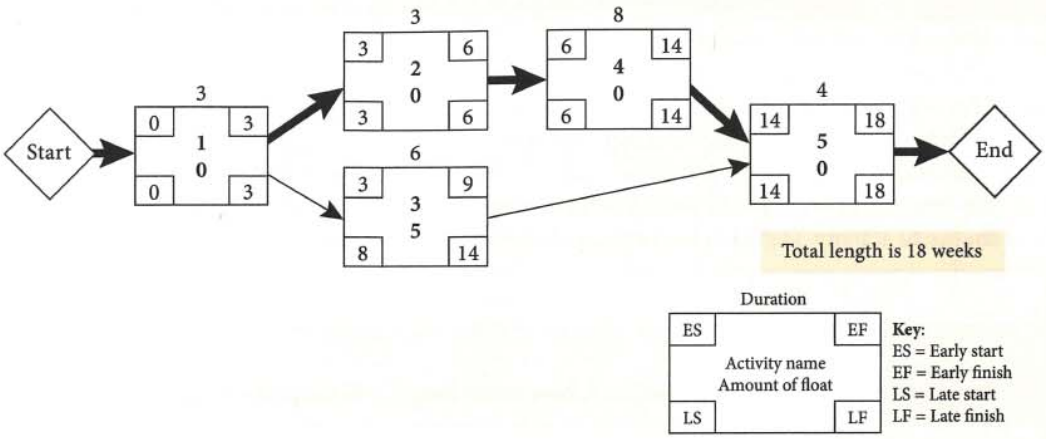
1. The length of the critical path is 18. There are two paths here:

Paths	Duration
Start, 1, 2, 4, 5, End	18
Start, 1, 3, 5, End	13



Start, 1, 2, 4, 5, End (shown with the bold arrows in the diagram) is the longest duration path and is therefore the critical path. The durations of the activities add up to 18, so the critical path is 18 weeks long.

2. The float of activity 3 is 5 weeks, per the following diagram, which shows how to calculate float using the forward and backward pass.



You can use either float formula to compute float. Late finish – Early finish = 14 – 9 = 5, or Late start – Early start = 8 – 3 = 5.

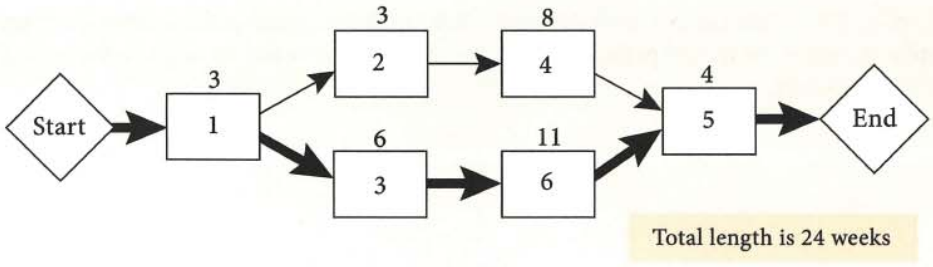
3. The float of activity 2 is zero; it is on the critical path. An activity on the critical path generally has no float.

4. The float of the path with the longest float is 5 weeks. There are only two paths in this example: Start, 1, 2, 4, 5, End and Start, 1, 3, 5, End. Only the non-critical path (Start, 1, 3, 5, End) will have float. You can calculate the float for this path by adding the float for each activity: 0 + 5 + 0 = 5. Therefore, the total float of the path with the longest float is 5.

5. The resource change on activity 3 will have no effect. The length of path activities 1, 3, and 5 is 13. Adding 4 more weeks to the length of activity 3 will make that path 17. Since that path is still shorter than the critical path, the critical path does not change. The length of the critical path is still 18 weeks because activity 3 is not on the critical path.

6. The stakeholder who says that the time that will be added to the project will be less than 11 weeks is correct. The new activity will be added to a non-critical path that has a float of 5 weeks. Therefore, adding 11 weeks will make this path the new critical path. The overall effect of adding an activity that takes 11 weeks will be a delay to the project of 6 weeks.

7. The project will take 6 weeks longer. (Note: If you answered 24, you did not read the question correctly!) Follow the bold arrows in the following diagram.



Exercise Use the data in this table to answer the questions that follow.

Activity	Preceding Activity	Estimate in Months
Start		0
D	Start	4
A	Start	6
F	D, A	7
E	D	8
G	F, E	5
B	F	5
H	G	7
C	H	8
End	C, B	0

1. What is the duration of the critical path?

2. What is the float of activity B?

3. What is the float of activity E?

4. What is the float of activity D?

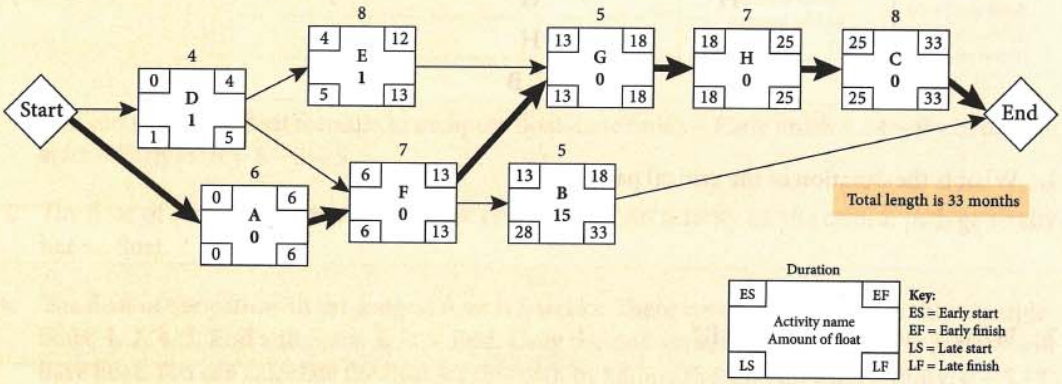
5. To shorten the length of the project, the sponsor has offered to remove the work of activity E from the project, making activity D the predecessor to activities G and F. What will be the effect?

Answer

1. The critical path (project duration) is 33 months.

Paths	Duration
Start, D, E, G, H, C, End	32
Start, D, F, G, H, C, End	31
Start, D, F, B, End	16
Start, A, F, G, H, C, End	33
Start, A, F, B, End	18

2. The float of activity B is 15 months, per the following diagram.



3. The float of activity E is one month. Once you have finished calculating using the long way, all the other answers are usually quick. Just look at the diagram to see the float of any activity.

   Watch out here for the float of activity E. The project must be completed by the end of month 33. Activity E must be completed before activities G, H, and C can start. So the late finish for E is 33 – 8 – 7 – 5, or 13.

   Activity E must be completed after activity D. So the early finish is 4 + 8, or 12. Float = Late finish – Early finish, so 13 – 12 = 1.

   Float = Late finish – Early finish, so 13 – 12 = 1.

4. The float of activity D is one month.

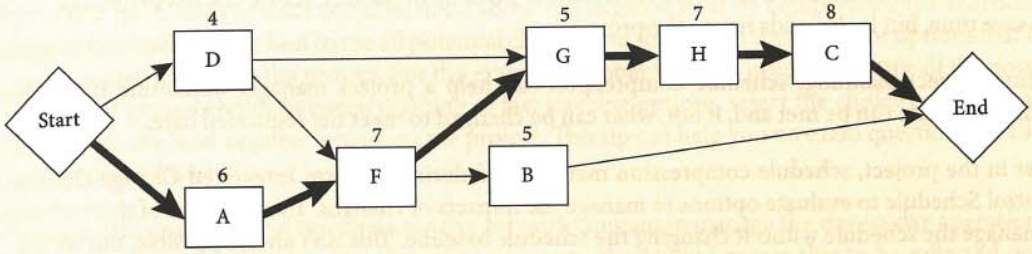
   Now let's look at using a calculation to determine the float for activity D. The project must be completed by the end of month 33. Activity D must be completed before activities E, F, G, H, C, and B can start. Looking backward through the dependencies, the late finish is 33 – 8 – 7 – 5, but then we run into a problem. Normally we would go along the critical path, but look at activities E and F. Activity E is longer than activity F, so we must go along the longest duration path, from activity G to activity E, making the late finish 33 – 8 – 7 – 5 – 8, or 5.

   Early finish is easier. There are no predecessors, so the early finish is the end of month 4.

   Float = 5 – 4, or 1 month.

5. Removing the work of activity E will have no effect on the critical path. The paths are now:

Paths	Duration
Start, D, G, H, C, End	24
Start, D, F, G, H, C, End	31
Start, D, F, B, End	16
Start, A, F, G, H, C, End	33
Start, A, F, B, End	18



You survived! Hopefully it was not too hard.

TRICKS OF THE TRADE® The following are good questions to test your knowledge about critical paths, float, and network diagrams:

- **Can there be more than one critical path?** Yes, you can have two, three, or many critical paths.
- **Do you want there to be?** No; having more than one critical path increases risk.
- **Can a critical path change?** Yes.
- **Can there be negative float?** Yes; it means you are behind.
- **How much float does the critical path have?** In planning, the critical path generally has zero total float. During project executing, if an activity on the critical path is completed earlier or later than planned, the critical path may then have positive or negative float. Negative float on the critical path requires corrective action or changes to the project to bring it back in line with the plan.
- **Does the network diagram change when the end date changes?** No, not automatically, but the project manager should investigate schedule compression options such as fast tracking and crashing the schedule to meet the new date. Then, with approved changes, the project manager should change the network diagram accordingly.
- **Would you leave the project with negative float?** No; you would compress the schedule. If schedule compression efforts do not result in zero or positive float, you need to request a change to adjust the baseline.

TRICKS OF THE TRADE® When you manually create a network diagram while taking the exam, label it with the question number, in case you want to go back to it later. You may be able to reuse the same network diagram to answer additional questions later in the exam.

It is easy to miss paths through a network diagram. When attempting to identify the critical path, carefully calculate the duration of each path, to ensure you look at all paths before determining which is critical.

Schedule Compression[21] PAGE 215 One of the most common problems on projects is an unrealistic timeframe. This problem can arise during project planning when management or the customer requires a completion date that cannot be met, or during project executing when the project manager needs to bring the project back in line with the schedule baseline or adjust the project for changes. As we discussed earlier, many project managers blame their sponsors or executives for unrealistic schedules, but project managers have a professional responsibility to push back, present options, and make sure the project is achievable by properly planning the project and using schedule network analysis techniques such as schedule compression.

Also keep in mind that schedule compression is a way to utilize float by fast tracking activities that are on the critical path. This means adjusting the network diagram so critical path activities that were originally planned to be completed in a series are replanned to be done in parallel. As we discuss below, fast tracking can save time, but it also adds risk to the project.

During project planning, schedule compression can help a project manager determine if the desired completion date can be met and, if not, what can be changed to meet the requested date.

Later in the project, schedule compression may be used during Perform Integrated Change Control and Control Schedule to evaluate options to manage the impacts of changes. The objective of this technique is to manage the schedule without changing the schedule baseline. This isn't always possible, but we try.

Fast Tracking This technique involves taking critical path activities that were originally planned in a series and doing them instead in parallel for some or all of their duration (see fig. 6.10). Fast tracking often results in rework, usually increases risk, and requires more attention to communication.

FIGURE 6.10 *Fast tracking*

For example, which activity in figure 6.11 would you fast track to shorten the project length?

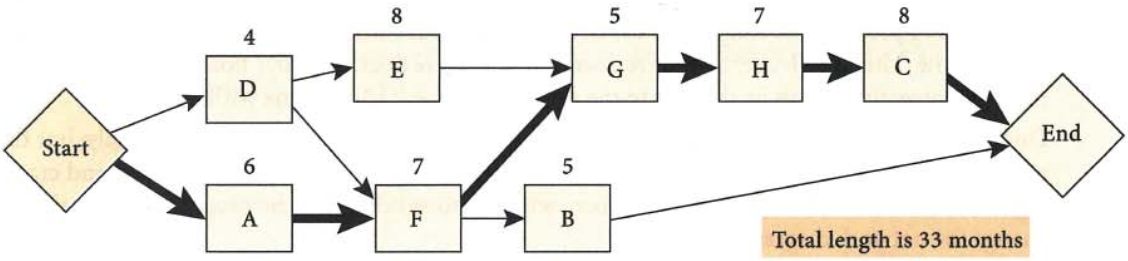


FIGURE 6.11 *Which activity would you fast track?*

Assuming the dependencies are discretionary, activity H could be fast tracked by making it occur at the same time as, or in parallel with, activity G. Any other pair of activities on the critical path could be fast tracked. Activities C and H could also be fast tracked by having part of activity C done concurrently with activity H.

Crashing[22] This technique involves adding or adjusting resources in order to compress the schedule while maintaining the original project scope. Crashing, by definition, always results in increased costs, and may increase risk. It trades time for money.

For example, in the network diagram in figure 6.11, a contract resource could supplement the internal resource's efforts on a critical path activity (assuming this is logical, based on the nature of the work). Another option to crash the project might be to buy a software application; the purchase adds cost to the project but helps the team work more efficiently, thus saving time.

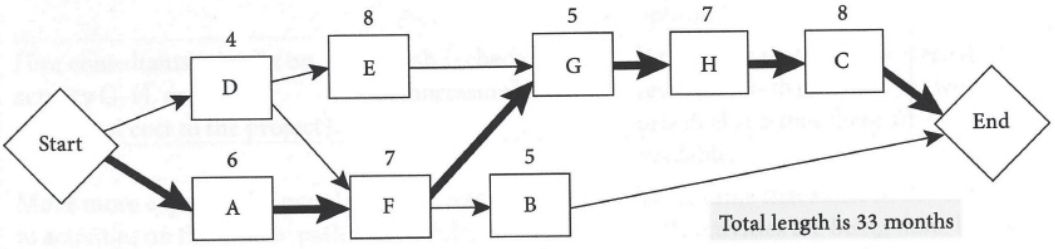
If you have negative project float (meaning the estimated completion date is after the desired date), would your first choice be to tell the customer the date cannot be met and to ask for more time? No; the first choice would be to analyze what could be done about the negative float by compressing the schedule. In crashing or fast tracking, it is best to see all potential choices and then select the option or options that have the least negative impact on the project. For the exam, remember that you need to identify all the possible options and, if given a choice between crashing or fast tracking options, select the choice or combination of choices with the least negative impact on the project. This tip can help you on exam questions that seem to have two right answers.

In the real world, many project managers use the network diagram to manage the day-to-day operations of the project and to make adjustments when changes occur. You should expect this to be reflected on the exam in terms of the number of questions involving network diagrams, calculations, and "What do you do in this situation?" scenarios.

Let's make sure you are prepared to deal with unrealistic schedules on the exam. This issue is so important that you can expect to see more than 10 questions about it. Most project managers have some gaps in their knowledge in this area, and it shows on their score sheets. To remedy this, let's try an exercise.

Exercise During project planning, the project duration is estimated to be 33 months. However, now you have been given a constraint of 30 months. Using the following network diagram, identify options for shortening the schedule to 30 months.

This is a general exercise with little detail. Make any assumptions you need to make in order to come up with as many options as possible.



Option	How to Achieve It	Explanation (Including Assumptions Made)

Option	How to Achieve It	Explanation (Including Assumptions Made)

Answer Did this situation make sense? If it did, you are in good shape. If not, you should study a little more. Notice how this analysis allows the project manager to proactively deal with the reality of the project and take action to be sure the project constraint can be met. The following are possible options for shortening the schedule.

Option	How to Achieve It	Explanation (Including Assumptions Made)
Reestimate.	Review risks.	Now it is time to look at the estimates and see which contain hidden risks. By reducing the risks, the estimate can be lowered, and the project finished faster. It is never an option to just cut 10 percent off of the estimate.
Execute activities H and C in parallel.	Fast track (schedule compression).	We assume that the dependency between activities H and C is a discretionary one.
Add resources from within the organization (at additional cost to the project) to activity G.	Crash (schedule compression).	We assume that adding resources to activity G would, in fact, be practical and that there are resources available.
Cut activity H.	Reduce scope.	Although not the first choice, as it will likely affect the customer, reducing scope should be considered an option.
Hire consultants to assist on activity G, H, or C (at additional cost to the project).	Crash (schedule compression).	We assume that adding external resources to these activities would be practical and that there are resources available.
Move more experienced people to activities on the critical path (activities G, H, or C).	Compress the schedule.	We assume that some of the critical path activities are being done by less experienced people.
Cut time.	Lower quality standards.	Do not get excited. Quality is a project constraint, and lowering quality standards is an option. In this case, it would probably be easier—and thus faster—to complete the project with the lowered quality standards.

Option	How to Achieve It	Explanation (Including Assumptions Made)
Say no; the project must have 33 months.	Stand your ground.	This is not a viable option until other alternatives are exhausted.
Get more work done with the same amount of resources.	Work overtime.	This is not an option during project planning. There are too many other ways to compress the schedule that do not have the negative effects of overtime. Save it for a last resort.

Which of the options listed is the best? To answer the question, think of the impacts on the project of each one. Is the best option to cut time by lowering quality standards? What are the impacts of cutting quality? Is there another option? Why not do what many project managers do—ask for more resources? But adding resources may also add cost. Why not work overtime? Most organizations are working at close to 100 percent capacity. Having your project team work overtime limits the possibility of resources responding to emergencies for any other project they are working on, thereby putting other projects at risk. Besides, how much overtime can a person take? Overtime is not free.

The best choice is to look at risks and then reestimate. Once it is known that the schedule (or budget) must be reduced, a project manager can investigate the activity estimates that contain the most unknowns, eliminate or reduce these risks, and thus decrease the estimate. Eliminate risks in the risk management process and everyone wins! If this is not enough, the project manager would continue the effort to shorten the schedule by using other schedule compression techniques.

Let's look at these concepts again with a few more exercises.

Exercise What are the impacts of the schedule-shortening options listed in the following table?

Option	General Impacts on the Project
Fast track	
Crash	
Reduce scope	
Cut quality	

Answer

Option	General Impacts on the Project
Fast track	• Always adds risk • May add management time for the project manager
Crash	• Always adds cost • May add management time for the project manager • May add risk
Reduce scope	• May save cost, resources, and time • May negatively impact customer satisfaction
	• May save cost, resources, and time • May increase risk
Cut quality	• Requires good metrics on current and desired levels of quality in order to be effective • May negatively impact customer satisfaction

Exercise Here is another chance to test yourself on schedule compression.

Activity	Original Duration (Months)	Crash Duration (Months)	Time Savings	Original Cost (Dollars)	Crash Cost (Dollars)	Extra Cost (Dollars)	Cost per Month
J	14	12	2	$10,000	$14,000	$4,000	$2,000
K	9	8	1	$17,000	$27,000	$10,000	$10,000
N	3	2	1	$25,000	$26,000	$1,000	$1,000
L	7	5	2	$14,000	$20,000	$6,000	$3,000
M	11	8	3	$27,000	$36,000	$9,000	$3,000

1. Imagine that this project has a project float of –3 months. Which activity or activities presented above would you crash to save three months on the project, assuming that the activities listed above represent critical path activities?

2. How much would it cost to crash this project?

Answer

1. The following activities could be crashed to save three months on the project:

Activities	Cost
J and K	$14,000
J and N	$5,000
K and L	$16,000
L and N	$7,000
M	$9,000

Crashing activities J and N is the least expensive option, and because there is nothing in the question to eliminate it, the option to crash activities J and N is the best answer. Any time you have negative project float, it means that the project is not going to meet its deliverable date. The answer, depending on how the question is worded, involves crashing or fast tracking the project and coming up with options, or telling the customer the date cannot be met.

2. Crashing activities J and N would result in the least added cost—only $5,000. The "Cost per Month" column in this exercise is a distractor; you can answer this question with just the "Activity," "Time Savings," and "Extra Cost" columns. Don't assume you will need all the data provided to you in questions on the exam.

Exercise

Consider the following question:

Question Management has told you to get the project completed two weeks early. What is the best thing for you to do?

A. Consult the project sponsor
B. Crash
C. Fast track
D. Advise management of the impact of the change

Answer

Did you get fooled by this question? Did you think you had to choose between crashing and fast tracking? There is no information provided to help you determine which one is better. Therefore, the best choice presented is D, advise management of the impact of the change.

The exam will include many such questions requiring you to know that a project manager needs to analyze first, create options to deal with the change, and then let management, the sponsor, the customer, or other parties know the impacts of their request (see the four-step process for handling changes in the Integration Management chapter). A project manager does not just say yes! Instead, after analyzing the change for its impact on all areas of the project (cost, risk, resources, etc.), they could say something like, "Yes, I would be happy to make the change, but the project will be delayed two weeks. And I will need two more resources, or the project will cost $25,000 more."

TRICKS OF THE TRADE® WARNING: For questions about changes to the network diagram, make sure you look for shifts to new critical paths caused by the changes to the network diagram or to activity durations.

Data Analysis/Simulation PAGE 213 In creating a finalized, realistic schedule, it is helpful to ask, "What if a particular factor changed on the project? Would that produce a shorter schedule?" The assumptions for each activity can change and, therefore, the activity durations can also change. One of the ways to calculate the effect of these changes is through what-if scenario analysis.

Monte Carlo Analysis[23] This technique uses computer software to simulate the outcome of a project, based on the three-point estimates (optimistic, pessimistic, and most likely) for each activity and the network diagram. The simulation can tell you:

- The probability of completing the project on any specific day
- The probability of completing the project for any specific cost
- The probability of any activity actually being on the critical path
- An indication of the overall project risk

Monte Carlo analysis is another way of putting together the details of three-point estimates into a project estimate. It is more accurate than other methods because it simulates the actual details of the project and calculates probability.

Monte Carlo analysis can help deal with "path convergence," places in the network diagram where multiple paths converge into one or more activities, thus adding risk to the project (see fig. 6.12). Monte Carlo analysis is also used as a risk management tool to quantitatively analyze risks (see the Risk Management chapter).

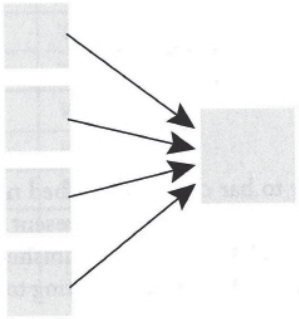


FIGURE 6.12 *Path convergence*

Resource Optimization[24] PAGE 211 Resource optimization refers to finding ways to adjust the use of resources. There are two techniques that can achieve this outcome.

- **Resource Leveling**[25] Resource leveling is used to produce a resource-limited schedule. Leveling lengthens the schedule and increases cost to deal with a limited number of resources, resource availability, and other resource constraints. A little-used function in project management software, this technique allows you to level the peaks and valleys of the schedule from one month to another, resulting in a more stable number of resources used on your project.

  You might level the resources if your project used 5 resources one month, 15 the next, and 3 the next, or some other up-and-down pattern that was not acceptable. Leveling could also be used if you did not have 15 resources available and preferred to lengthen the project (which is a result of leveling) instead of hiring more resources.

- **Resource Smoothing**[26] Resource smoothing is a modified form of resource leveling, where resources are leveled only within the limits of the float of their activities, so the completion dates of activities are not delayed.

Agile Release Planning PAGE 216 In agile—or change-driven—projects, work to develop the product of the project is broken down into iterations and releases. Agile release planning provides a high-level schedule that includes the frequency of releases and the number of iterations that will be completed as a part of each release. The planning efforts result in a timeline, which indicates the features to be included in each release.

Outputs of Develop Schedule PAGE 217

The Develop Schedule process results in the project schedule, the schedule baseline, schedule data, change requests, and updates to any related project documents. The following sections describe these outputs.

Project Schedule The project schedule is the result of the previous planning processes and the schedule network analysis that is performed as part of the Develop Schedule process. As planning progresses, the schedule will be iterated in response to risk management and other parts of project planning until an acceptable and realistic schedule can be agreed upon. The iterated and realistic schedule that results from this effort is called the schedule baseline, which becomes part of the project management plan.

The project schedule includes project activities with assigned dates for each activity, and includes milestones inserted by the project manager or management. The project schedule may be represented in formats such as bar charts or network diagrams.

The project schedule can be shown with or without dependencies (logical relationships) and can be shown in any of the following presentations created from the schedule model, depending on the needs of the project:

- Network diagram (described earlier in this chapter)
- Milestone chart
- Bar chart

Milestone Charts[27] These are similar to bar charts (described next), but they only show major events. Remember that milestones have no duration; they simply represent the completion of activities. Milestones, which may include "requirements are complete" or "design is finished," are part of the inputs to the Sequence Activities process. Milestone charts are good tools for reporting to management and to the customer. See the example in figure 6.13.

ID	Milestone	December	January	February	March	April
1	Start	12/14				
2	Requirements gathered		12/31			
3	Design complete			1/17		
4	Coding complete				2/15	
5	Testing complete					3/15
6	Implementation complete					4/4
7	End					4/15

FIGURE 6.13 *Milestone chart*

Bar Charts[28] Bar charts are weak planning tools, but they are effective for progress reporting and control. They are not project management plans. Figure 6.14 shows a sample bar chart.

ID	Activity Name	Duration	Start	Finish
1	Start	0 days	Mon 8/26	Mon 8/26
2	D	4 days	Mon 8/26	Thu 8/29
3	A	6 days	Mon 8/26	Mon 9/2
4	F	7 days	Mon 9/2	Tue 9/10
5	E	8 days	Fri 8/30	Tue 9/10
6	G	5 days	Wed 9/11	Wed 9/18
7	B	5 days	Wed 9/11	Wed 9/18
8	H	7 days	Wed 9/18	Thu 9/26
9	C	8 days	Fri 9/27	Tue 10/8
10	Finish	0 days	Tue 10/8	Tue 10/8

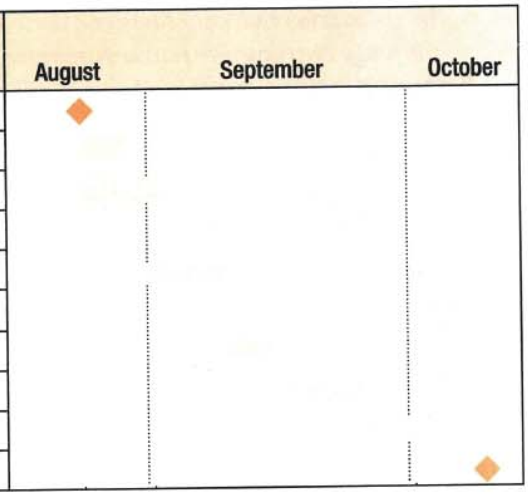


FIGURE 6.14 *Bar chart*

Notice that there are no lines between activities to show interdependencies, nor are assigned resources shown. Bar charts do not help organize the project as effectively as a WBS and network diagrams do. They are completed after the WBS and the network diagram in the project management process.

Understanding the Benefits of Different Presentation Formats No matter how much you know about project management, there are always questions on the exam that will be tricky if you have never thought about them before. The different types of schedule presentations can be one of those areas. Think through the next exercise. Make sure you look for anything you did not know, and organize your knowledge according to the exercise answers. You can get quite a few questions right on the exam if you know what each of the schedule presentations is used for.

Exercise Test yourself! Answer the following questions in the spaces provided.

Question	Answer
Under what circumstances would you use a network diagram?	
Under what circumstances would you use a milestone chart?	
Under what circumstances would you use a bar chart?	

Answer See the answers in the following table.

Question	Answer
Under what circumstances would you use a network diagram?	• To show interdependencies between activities
Under what circumstances would you use a milestone chart?	• To report to senior management
Under what circumstances would you use a bar chart?	• To track progress • To report to the team

Schedule Baseline PAGE 217 The schedule baseline is the version of the schedule model used to manage the project; it is what the project team's performance is measured against. Remember that the baseline can only be changed as a result of formally approved changes. Meeting the schedule baseline is one of the measures of project success. If the project can be done faster than the customer requested, there may be a difference between the schedule baseline and the end date required by the customer. This difference is project float.

Schedule Data Schedule data encompasses all the data used to create the schedule model, including milestones, project activities, activity attributes, duration estimates, dependencies, and the assumptions and constraints used in creating the schedule.

Change Requests This is another planning process with change requests as an output. As the project processes, any changes to the schedule may necessitate changes to other parts of the project management plan. Change requests are addressed through the integrated change control process.

Project Documents Updates The process of creating a final and realistic schedule could result in updates to project documents including duration estimates, resource requirements, activity attributes, risk register, assumption log, and the lessons learned register.

Control Schedule PAGE 222

Process Control Schedule
Process Group Monitoring & Controlling
Knowledge Area Schedule Management

Controlling the project was discussed in the Project Management Processes chapter, and is an important part of every knowledge area (scope, schedule, cost, quality, etc.). We will spend a little more time talking about it here. Control means measure; you measure against the plan. You need to stay in control of your project and know how it is performing compared to the plan. Do you do this on your projects? If not, pay particular attention to the concept of monitoring and controlling in this chapter and throughout this book. Make sure you understand that such actions are done as part of basic project management. When answering exam questions, you need to assume proper project management was done unless the question states otherwise. On properly managed projects, a project manager does not have to spend all their time dealing with problems, because most of those problems were prevented through appropriate planning and risk management. Project managers are measuring against the plan and taking action as needed to control the project.

The project (and the project manager) will be unsuccessful if the schedule baseline—the end date agreed to in planning and adjusted for approved changes—is not met. So monitoring and controlling efforts go beyond measuring; they also involve taking corrective and preventive action over and over again during the life of the project to keep the project in line with the plan. Do you do this? If not, why not? Without such work, all the efforts in planning to create a realistic schedule could be wasted.

Schedule control also means looking for the things that are causing changes and influencing the sources, or root causes, of the changes. For example, if there is one person or one piece of work causing a lot of changes, the project manager must do something about it, rather than let the issues and the high number of changes continue. A project manager must be proactive.

If the project can no longer meet the agreed-upon completion date, and achieving the completion date is a critical factor for success of the project, the project manager might recommend the termination of the project before any more company time is wasted. In other words, the project manager might have to influence directors and senior executives in the organization to control the project. Schedule control is more than just issuing updated schedules!

Make sure you really understand what is involved in schedule control. Think of protecting the hard work of all those involved in planning to make sure what was planned occurs as close to the plan as possible. Think of being constantly on the lookout for anything that might be affecting the schedule. This is what it means to control the schedule, and the project.

The following are some additional activities that can be used to control the schedule:

- Access the PMIS to review current work performance data and compare actual progress to what was planned.
- Reestimate the remaining components of the project partway through the project (see the following discussion).
- Conduct performance reviews by formally analyzing how the project is doing (see the "Earned Value Measurement" discussion in the Cost Management chapter).
- Perform data analysis (this can include earned value analysis, trend analysis, variance analysis, and what-if scenario analysis) of project performance.

- Confirm that critical path activities are being completed within the schedule baseline. If they are not, adjust the critical path by taking advantage of available float.
- Adjust future parts of the project to deal with delays, rather than asking for a schedule extension (using schedule compression techniques such as using leads and lags, crashing, and fast tracking).
- Consider making adjustments to optimize resources assigned to activities to improve the performance.
- Continue efforts to optimize the schedule.
- Adjust metrics that are not giving the project manager the information needed to properly understand performance and manage the project. Add new metrics if needed.
- Adjust the format or required content of reports as needed to capture the information necessary to control and manage the project (see the "Progress Reporting" discussion in the Cost Management chapter).
- Identify the need for changes, including corrective and preventive actions.
- Follow the change control process.

Efforts to control the schedule when the project is using a change-driven approach include:

- Comparing work actually completed to what was predicted to be complete within a given work cycle using an Iteration burndown chart
- Holding retrospectives to address possible process improvements
- Reprioritizing the backlog of work
- Identifying and managing changes as they arise

Reestimating One of the roles of a project manager is to make sure the project meets the project objectives. Although you did your best to understand the project well enough to estimate it sufficiently in planning, there are always changes that occur during a project that impact those plans. Therefore, it is standard practice to reestimate the remaining work at least once during the life of the project to make sure you can still satisfy the project objectives within the schedule, budget, and other project constraints, and to adjust the project if you cannot. Again, assume proper project management was done when answering questions on the exam unless the question provides specific information to indicate it was not.

The Control Schedule process results in work performance information, schedule forecasts, and sometimes change requests. For example, a change to the schedule might require additional resources or a change in scope. Such changes must be handled as part of the Perform Integrated Change Control process. Make sure you review this important process in the Integration Management chapter.

This process may also result in updates to the schedule management plan and performance measurement baseline in addition to project documents such as the assumption log, risk register, and lessons learned register, and changes to any other part of the project.

Practice Exam

1. A project manager is informed midway through project planning that she was given inaccurate data regarding new regulations affecting the required end date of her project. She may need to make a few adjustments, but she thinks she can still manage the project to complete it before the regulations take effect. She confirms this by analyzing the sequence of activities with the least amount of scheduling flexibility. What technique is she using?
   A. Critical path method
   B. Flowchart
   C. Precedence diagramming
   D. Work breakdown structure

2. A design engineer is helping to ensure that the dependencies within her area of expertise are properly defined on the project. The design of several deliverables must be complete before manufacturing can begin. This is an example of what type of dependency?
   A. Discretionary dependency
   B. External dependency
   C. Mandatory dependency
   D. Scope dependency

3. Your sponsor and stakeholders have made it clear they wish to be kept informed on the project status. There are many aspects of the project on which you will report, and you want to choose the most appropriate tool to use in each case. Which of the following are generally illustrated better by bar charts than network diagrams?
   A. Logical relationships
   B. Critical paths
   C. Resource trade-offs
   D. Progress or status

4. A heuristic is best described as a:
   A. Control tool
   B. Scheduling method
   C. Planning tool
   D. Generally accepted rule

5. Lag means:
   A. The amount of time an activity can be delayed without delaying the project finish date
   B. The amount of time an activity can be delayed without delaying the early start date of its successor
   C. Waiting time
   D. The product of a forward and backward pass

6. A project manager is new to the company but has 10 years of project management experience. She is given a medium-sized project and is asked to plan so it is finished as quickly as possible because the company has a large list of projects to complete in the coming year. She will be given another project to manage as soon as she has this one baselined. She needs to report on the longest time the project will take. Which of the following is the best project management tool to use to determine this?
   A. Work breakdown structure
   B. Network diagram
   C. Bar chart
   D. Project charter

7. Which of the following is correct?
   A. The critical path helps prove how long the project will take.
   B. There can be only one critical path.
   C. The network diagram will change every time the end date changes.
   D. A project can never have negative float.

8. A new project manager is walking you through the schedule she has created for her project. She asks you about the duration of a particular milestone, so she knows how to properly schedule it. What will you tell her about a milestone's duration?
   A. It is shorter than the duration of the longest activity.
   B. It is shorter than the activity it represents.
   C. It has no duration.
   D. It is the same length as the activity it represents.

9. Which of the following best describes the relationship between standard deviation and risk?
   A. There is no relationship.
   B. Standard deviation tells you if the estimate is accurate.
   C. Standard deviation tells you how uncertain the estimate is.
   D. Standard deviation tells you if the estimate includes a pad.

10. The float of an activity is determined by:
   A. Performing a Monte Carlo analysis
   B. Determining the waiting time between activities
   C. Determining lag
   D. Determining the length of time the activity can be delayed without delaying the critical path

11. To help them determine the schedule baseline, the team has drafted a network diagram. The project manager adds the time estimates for each activity to establish the critical path for the project. They discover the project has three critical paths. Which of the following best describes how this discovery will affect the project?
   A. It makes it easier to manage.
   B. It increases the project risk.
   C. It requires more people.
   D. It makes it more expensive.

12. The team is working on a project to develop or procure a customized software package that will be used by delivery drivers for a new chain of pizza restaurants. There are multiple stakeholders on this project. Because of other ongoing projects to design, build, and equip brick-and-mortar restaurant locations, you are informed that there is no rush to complete this software development work. If project time and cost are not as important as the number of resources used each month, which of the following is the best thing to do?
    A. Perform a Monte Carlo analysis.
    B. Fast track the project.
    C. Perform resource optimization.
    D. Analyze the life cycle costs.

13. You have identified a diverse group of stakeholders, and you will need to report information in a variety of ways to meet their different communications needs. When will you use a milestone chart instead of a bar chart?
    A. Project planning
    B. Reporting to team members
    C. Reporting to management
    D. Risk analysis

14. The organization is committed to rolling out a new cell phone accessory at an industry trade show in six months. The sponsor has made it clear that this product, to be created by your project team, must meet a long list of requirements, adhere to high quality standards, and, most importantly, be ready in time for the trade show. The sponsor has promised to commit as many resources as necessary for you to complete the project within these constraints. Your project management plan results in a project schedule that is too long. If the project network diagram cannot change but you have extra personnel resources, what is the best thing to do?
    A. Fast track the project.
    B. Level the resources.
    C. Crash the project.
    D. Perform Monte Carlo analysis.

15. Your team worked hard throughout project planning, thoroughly defining and estimating each activity required to complete the work. The resulting network diagram supported the end date that was approved by the team, management, and the stakeholders. As work has progressed, most milestones have been met. On two occasions, workarounds were needed to deal with the occurrence of unidentified risk events. With continued attention to detail, you have been successful in keeping the project on schedule and within budget. Now, an opportunity is identified that can only be realized if the project is completed two days ahead of schedule. Which of the following is the best thing to do when asked to complete a project two days earlier than planned?
    A. Tell senior management that the project's critical path does not allow the project to be finished earlier.
    B. Tell your manager.
    C. Meet with the team to look at options for crashing or fast tracking the critical path.
    D. Work hard and see what the project status is next month.

16. Although the customer agreed to the original project schedule, they are now asking for an earlier project finish. They are being pressured by their own customers. The project manager's sponsor thinks finishing early is not only a viable option but also a good idea for your organization because it will enable you to start another project sooner. In attempting to complete the project faster, the project manager looks at the cost associated with crashing each activity. The best approach to crashing would also include looking at the:
    A. Risk impact of crashing each activity
    B. Customer's opinion of which activities to crash
    C. Sponsor's opinion of which activities to crash and in what order
    D. Project life cycle phase in which the activity is due to occur

17. You are working collaboratively with the team to plan a project. You have obtained estimates from team members on the activities for which they each will be responsible. You are currently reaching agreement on the calendar dates for each activity. Which of the following processes are you working on?
    A. Sequence Activities
    B. Develop Schedule
    C. Define Scope
    D. Develop Project Charter

18. A project manager is in the middle of executing a large construction project when he discovers the time needed to complete the project is longer than the time available. What is the best thing to do?
    A. Cut product scope.
    B. Meet with management, and tell them the required date cannot be met.
    C. Work overtime.
    D. Determine options for schedule compression, and present management with the recommended option.

19. During project planning, you estimate the time needed for each activity and then total the estimates to create the project estimate. You commit to completing the project by this date. What is wrong with this scenario?
    A. The team did not create the estimate, and estimating takes too long using that method.
    B. The team did not create the estimate, and a network diagram was not used.
    C. The estimate is too long and should be created by management.
    D. The project estimate should be the same as the customer's required completion date.

20. You are a project manager on a $5,000,000 software development project. While working with your project team to develop a network diagram, you notice a series of activities that can be worked in parallel but must finish in a specific sequence. What type of activity sequencing method is required for these activities?
    A. Precedence diagramming method
    B. Arrow diagramming method
    C. Critical path method
    D. Operational diagramming method

21. You are a project manager on a US $5,000,000 software development project. While working with your project team to develop a network diagram, your data architects suggest that quality could be improved if the data model is approved by senior management before moving on to other design elements. They support this suggestion with an article from a leading software development journal. Which of the following best describes this type of input?
    A. Mandatory external dependency
    B. Discretionary external dependency
    C. External regulatory dependency
    D. Heuristic

22. Based on the following, if you needed to shorten the duration of the project, which activity would you try to shorten?

Activity	Preceding Activity	Duration in Weeks
Start	None	0
A	Start	1
B	Start	2
C	Start	6
D	A	10
E	B, C	1
F	C	2
G	D	3
H	E	9
I	F	1
End	G, H, I	0

    A. Activity B
    B. Activity D
    C. Activity H
    D. Activity C

23. You have a project with the following activities: Activity A takes 40 hours and can start after the project starts. Activity B takes 25 hours and should happen after the project starts. Activity C must happen after activity A and takes 35 hours. Activity D must happen after activities B and C and takes 30 hours. Activity E must take place after activity C and takes 10 hours. Activity F takes place after Activity E and takes 22 hours. Activities F and D are the last activities of the project. Which of the following is true if activity B actually takes 37 hours?
    A. The critical path is 67 hours.
    B. The critical path changes to Start, B, D, End.
    C. The critical path is Start, A, C, E, F, End.
    D. The critical path increases by 12 hours.

24. A project manager has received activity duration estimates from his team. Which of the following does he need in order to complete the Develop Schedule process?
    A. Earned value analysis
    B. Schedule change control system
    C. Trend analysis
    D. Reserves

25. A project manager is taking over a project from another project manager during project planning. If the new project manager wants to see what the previous project manager planned for managing changes to the schedule, it would be best to look at the:
    A. Communications management plan
    B. Update management plan
    C. Staffing management plan
    D. Schedule management plan

26. A project manager is using weighted average duration estimates to perform schedule network analysis. Which type of mathematical analysis is being used?
    A. Critical path method
    B. Beta distribution
    C. Monte Carlo
    D. Resource leveling

27. The WBS, estimates for each work package, and the network diagram are completed. The next thing for the project manager to do is:
    A. Sequence the activities.
    B. Validate that they have the correct scope.
    C. Create a preliminary schedule and get the team's approval.
    D. Complete risk management.

28. A new product development project has four levels in the work breakdown structure and has been sequenced using the precedence diagramming method. The activity duration estimates have been received. What should be done next?
    A. Create an activity list.
    B. Begin the work breakdown structure.
    C. Finalize the schedule.
    D. Compress the schedule.

29. You are the project manager for a new product development project that has four levels in the work breakdown structure. The network diagram and duration estimates have been created, and a schedule has been developed and compressed. Which schedule management activity should you do next?
    A. Control the schedule.
    B. Determine dependencies.
    C. Analogously estimate the schedule.
    D. Gain approval.

30. A team member from research and development tells you that her work is too creative to provide you with a fixed single estimate for the activity. You both decide to use the average labor hours (from past, similar projects) to develop a prototype. This is an example of which of the following?
    A. Parametric estimating
    B. Three-point estimating
    C. Analogous estimating
    D. Monte Carlo analysis

31. As part of a project manager's due diligence, he reviews the schedule, focusing on each activity as its start time approaches. He also monitors activities as they progress. He is currently looking at an activity that has an early start (ES) of day 3, a late start (LS) of day 13, an early finish (EF) of day 9, and a late finish (LF) of day 19. In all likelihood, this activity:
    A. Is on the critical path
    B. Has a lag
    C. Is progressing well
    D. Is not on the critical path

32. The project is calculated to be completed four days after the desired completion date. You do not have access to additional resources. The project is low risk, the benefit-cost ratio is expected to be 1.6, and the dependencies are preferential. Under these circumstances, what is the best thing to do?
    A. Cut resources from an activity.
    B. Make more activities concurrent.
    C. Move resources from the preferential dependencies to the external dependencies.
    D. Remove an activity from the project.

33. A project manager for a small construction company has a project that was budgeted for $130,000 over a six-week period. According to the schedule, the project should have cost $60,000 to date. However, it has cost $90,000 to date. The project is also behind schedule, because the original estimates were not accurate. Who has the primary responsibility to solve this problem?
    A. Project manager
    B. Senior management
    C. Project sponsor
    D. Manager of the project management office

34. Senior management is complaining that they are not able to easily determine the status of ongoing projects in the organization. Which of the following types of reports would help provide summary information to senior management?
    A. Detailed cost estimates
    B. Project management plans
    C. Bar charts
    D. Milestone reports

35. Rearranging resources so that a constant number of resources is used each month is called:
    A. Crashing
    B. Floating
    C. Leveling
    D. Fast tracking

36. The team is helping the project manager estimate activities on their project. They are experienced and skilled, and many members have been with the company for some time. There are several activities they need to estimate that have not been previously done by the company. What is the best method of estimating these activities?
    A. Analogous estimating
    B. Three-point estimating
    C. Monte Carlo analysis
    D. Parametric estimating

37. During project executing, a large number of changes are made to the project. Several of the change requests have come from the customer, significantly changing the functionality of the originally requested product. Six project team members have been reassigned by management to a higher-priority project, and they have been replaced. As project work has progressed, many of the identified risks have occurred and have been successfully mitigated. However, three contingency plans have been adjusted and will be implemented if identified risks recur during the remainder of the project. The project manager should:
    A. Wait until all changes are known, and then print out a new schedule.
    B. Make sure the project charter is still valid.
    C. Change the schedule baseline.
    D. Talk to management before any changes are made.

Answers

1. **Answer** A
Explanation There are only two choices related to scheduling: critical path method and precedence diagramming. Precedence diagramming is a diagramming technique that deals with the relationship between activities, not schedule flexibility. The project manager is analyzing the critical path.

2. **Answer** C
Explanation No mention is made that the dependency comes from a source outside the project, so this is not an external dependency. Scope dependency is not a defined term. The key words in the question are "must be complete." Since the dependency is required, it could not be discretionary and therefore must be mandatory. The question defines a mandatory dependency.

3. **Answer** D
Explanation The bar chart is designed to show a relationship to time. This is best used when demonstrating progress or status as a factor of time.

4. **Answer** D
Explanation A heuristic is a generally accepted rule. Examples are cost per line of code and cost per square foot of floor space.

5. **Answer** C
Explanation Total float and free float are the time an activity can be delayed without impacting the entire project or the next activity. A forward or backward pass refers to a network analysis technique, not waiting time. Waiting time is the correct definition of lag.

6. **Answer** B
Explanation The bar chart may show an end date, but it is not used to determine dates. The project charter also may include a required end date but not a logical determination of how long the project will take. The network diagram shows dependencies between activities on the project activity list. The dependencies allow us to look at the various paths through the diagram to determine the longest duration (critical) path. The network diagram is the best answer.

7. **Answer** A
Explanation This question tests your knowledge about a number of topics. There can often be more than one critical path, but you might adjust the plan in order to decrease risk and have only one critical path. The network diagram may or may not change when the end date changes, depending on the amount of schedule reserve and the reason for the change to the schedule. You can have negative float if you are behind schedule. The critical path helps prove how long the project will take. This is the only correct statement of the choices given.

8. **Answer** C
Explanation A milestone represents the completion of a series of activities or work packages. Milestones represent significant events within the project schedule. They are not work activities, and they have no duration

9. **Answer** C
Explanation An estimate can have a wide range and still be accurate if the item estimated includes identified risks. There is no such thing as a pad in proper project management. An estimate might be inflated, but it is a calculated reserve to account for risks, not arbitrary padding. The standard deviation tells you the amount of uncertainty or risk involved in the estimate for the activity.

10. **Answer** D
Explanation The float of an activity is the length of time the activity can be delayed without delaying the critical path.

11. **Answer** B
Explanation Although having three critical paths could require more people or cost more, the answer that is always true is that it increases project risk. Because you need to manage three critical paths, there is more risk that something could happen to delay the project.

12. **Answer** C
Explanation Fast tracking affects both time and cost but may not help even out resource usage. Monte Carlo analysis and analysis of life cycle costs do not directly deal with resources. Resource optimization is the only choice that will definitely affect resources.

13. **Answer** C
Explanation Both types of charts are used in project planning. Team members need to see details, so they need a bar chart rather than a milestone chart. Risk analysis could make use of both charts. A milestone chart is used instead of a bar chart for any situation where you want to report in a less detailed way. Since bar charts can intimidate people with their complexity—and often show too much detail to be worthwhile on a management level—milestone charts are more effective for reporting to management.

14. **Answer** C
Explanation Leveling resources generally extends the schedule. Monte Carlo analysis does not directly address the constraints of this situation. To compress the schedule, you could either crash or fast track. However, the situation says that the network diagram cannot change. This eliminates fast tracking, which leaves crashing the project as the best answer.

15. **Answer** C
Explanation This is another question that asks about problem-solving. Neither telling your manager nor waiting to see the status next month will address the real problem. It would be inaccurate to report that the project cannot be finished earlier. Only meeting with the team to look for options for compressing the schedule (by crashing or fast tracking) relates to problem-solving.

16. **Answer** A
Explanation You may or may not need your customer's or your sponsor's input, but you will definitely need to include an analysis of risk.

17. **Answer** B
Explanation By the time this process is taking place, Develop Project Charter, Define Scope, and Sequence Activities would be completed. The process defined in the question is Develop Schedule.

18. **Answer** D
Explanation This question tests whether you know how to solve problems. Cutting product scope negatively affects the customer, and is therefore not best. A project manager's job is to determine options for meeting any end date; therefore, simply telling management the required date cannot be met is not correct. Working overtime is expensive and unnecessary when there are many other choices that could be considered first. Determining options for schedule compression would have the least negative effect on the project.

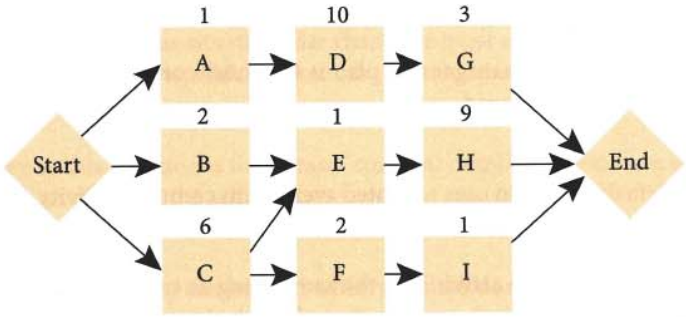
19. **Answer** B
Explanation Time estimates for the activities should be created by the team and should not be added together to create the project estimate. Some activities may take place concurrently; these would be identified in the network diagram.

20. **Answer** A
Explanation The question implies a finish-to-finish relationship between activities. The arrow diagramming method is not a commonly used diagramming method, and it does not support that type of relationship. Critical path is not a diagramming method, and operational diagramming method is a made-up term. The precedence diagramming method is most appropriate in this case.

21. **Answer** B
Explanation A heuristic is a general rule that can be used consistently. This situation is a unique occurrence in which a preferred method is being suggested. Dependencies are often described with two terms, either mandatory or discretionary, and either internal or external. The input in this scenario is discretionary, as it is a suggestion, rather than a required method of doing the work. Since the input comes from a source outside the organization, it is considered external.

22. **Answer** D
Explanation This is an example of a two-stage question you may find on the exam. First you need to draw the network diagram and find the critical path, and then make a decision. The network diagram would be:

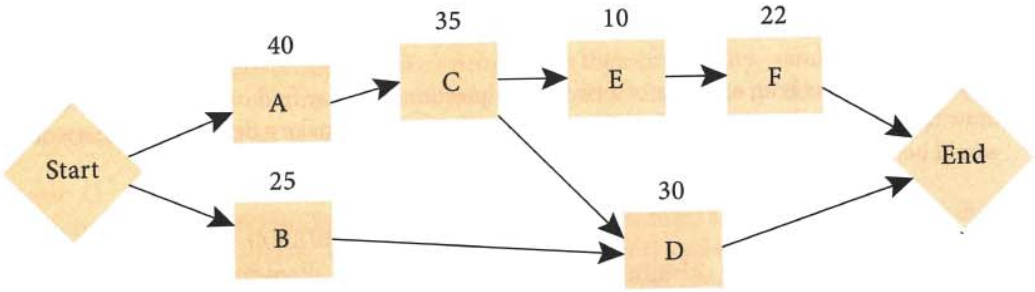
Paths	Duration in Weeks
Start, A, D, G, End	14
Start, B, E, H, End	12
Start, C, E, H, End	16
Start, C, F, I, End	9



The critical path is 16 (Start, C, E, H, End). Many people immediately look for the longest duration activity on the project to cut. Here activity D is the longest, at 10 weeks. However, that activity is not on the critical path, and cutting it would not shorten the project's duration. You must change the critical path. In this case, both activity C and activity H are on the critical path. If you have a choice, all things being equal, choose the earlier option. Therefore, activity C is the best answer.

23. **Answer** C
Explanation Did you notice how difficult this question was to read? Such wording is intentional—to prepare you for interpreting questions on the real exam. Looking at this situation, you see there are three paths through the network, as shown in the following table. If the duration of activity B changes from 25 to 37, the activity will take 12 hours longer. As the activity is only on the third path, it will only change the duration of that path from 55 to 55 + 12, or 67 hours. Since the duration of the critical path is 107 hours, the delay with activity B will have no impact on the project timeline or the current critical path.

Paths	Duration in Hours
Start, A, C, E, F, End	107
Start, A, C, D, End	105
Start, B, D, End	55



24. **Answer** D
Explanation The Develop Schedule process includes all work and uses all inputs needed to come up with a finalized, realistic schedule. As part of the Estimate Activity Durations process, reserves are created to cover identified and unknown schedule risks. All the other items are parts of Control Schedule and occur after the Develop Schedule process.

25. **Answer** D
Explanation The schedule management plan is the most correct answer. It includes plans for how schedule changes will be managed.

26. **Answer** B
Explanation Beta distribution uses weighted averages to compute activity durations.

27. **Answer** C
Explanation Sequencing the activities is the same thing as creating a network diagram, so that has already been done. The Validate Scope process is done during project monitoring and controlling, not during project planning. Since a schedule is an input to risk management, risk management comes after the creation of a preliminary schedule, and so that is not the next thing to do. Creating the preliminary schedule is next.

28. **Answer** D
Explanation The question is really asking, "What is done after the Estimate Activity Durations process?" The work breakdown structure and activity list are done before Estimate Activity Durations. The schedule is not finalized until after schedule compression. Therefore, compressing the schedule is done next.

29. **Answer** D
Explanation Notice how this question and the previous one seem similar. This is intended to prepare you for similar questions on the exam. Determining dependencies and analogously estimating the schedule should have already been completed. The situation described is within the Develop Schedule process of schedule management. Control Schedule is the next schedule management process after Develop Schedule, but the Develop Schedule process is not yet finished. Final approval of the schedule by the stakeholders is needed before one has a project schedule.

30. **Answer** A
Explanation Monte Carlo analysis is a modeling, or simulation, technique. Three-point estimating uses three time estimates per activity. One could use data from past projects to come up with the estimate (analogous estimating), but the best answer is parametric estimating because history is being used to calculate an estimate.

31. **Answer** D
Explanation There is no information presented about lag or progress. The activity described has float because there is a difference between the early start and late start. An activity that has float is probably not on the critical path.

32. **Answer** B
Explanation Cutting resources from an activity would not save time, nor would moving resources from the preferential dependencies to the external dependencies. Removing an activity from the project is a possibility, but because the dependencies are preferential and the risk is low, the best choice is to make more activities concurrent, as this would have less impact on the project.

33. **Answer** A
Explanation Did you get lost looking at all the numbers presented in this question? Notice that there are no calculations required, simply an understanding of what the problem is. This question describes schedule management, which is a responsibility of the project manager.

34. **Answer** D
Explanation Detailed cost estimates have nothing to do with the situation described. Project management plans include more detail than is necessary for the situation described, and may distract from the conversation if used in this situation. Bar charts are most effective for reporting to the team. The best answer is milestone reports, which present the right level of detail for upper management.

35. **Answer** C
Explanation The key to this question is the phrase "constant number of resources used each month." Only leveling has such an effect on the schedule.

36. **Answer** B
Explanation Analogous estimating can be used when you have done similar work previously. Monte Carlo analysis is a schedule development technique. Parametric estimating includes the use of history and productivity rates for the work, which would not be available if you had not done the activity before. Three-point estimating is the best method to use in this case because it allows you to estimate in a range—optimistic, pessimistic, and most likely.

37. **Answer** B

Explanation Waiting until all changes are known and then printing out a new schedule is a common error many project managers make. Instead, the project manager should be controlling the project throughout its completion. The situation in the question does not provide a reason to believe the schedule baseline must be changed. A project manager must be in control of the project, rather than consulting with management before making any changes. Whenever a large number of changes occur on a project, it is wise to confirm that the business case, as stated in the project charter, is still valid.