8 Schedule

Introduction

Planning a project schedule and the overall process of schedule management primarily relies on technical project management skills. How do you manage a project schedule? For this question, many people immediately think about software or a Gantt chart. Yes, software is a valuable tool. It can save time with scheduling, analyzing what-if scenarios, performing status reporting, and other things. But you need to understand the details behind the data.

This chapter, along with additional exercises on the RMC Resources page (rmcls.com/rmc-resources), will help you thoroughly understand the process of planning and managing a project schedule. Historically, exam questions related to scheduling have required the knowledge of how to draw a network diagram. Agile questions may require you to know how to build a story map.

RMC RESOURCES

Although the process to plan and manage a schedule is straightforward, you need to know options for developing and compressing a project schedule. A project schedule must be realistic before the work to build the product begins. For the exam, assume you have the authority and responsibility to create a realistic schedule. The exam is written with this assumption although it is not always true in real life.

Definitions Related to Plan and Manage Schedule

This is some basic estimating and schedule-related vocabulary that will be used in upcoming sections, where we will cover each concept in more detail.

Dependencies

Dependencies are logical relationships between activities in a project. The most obvious dependency example is: "Activity A must be completed before activity B can start." There are other types of dependencies, which are covered later in this chapter.

Float

Float represents schedule flexibility. Most simply, float is the amount of time an activity can be delayed without delaying the end date of the project. The definition in practice is a little more involved than this, however. There are several different types of float, which are covered later in this chapter.

Leads and Lags

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. For example, a three-day lag time after pouring concrete is needed before constructing the frame for a building.

Critical Path

The critical path is the *shortest path* to finishing the project. Projects are complex and have many workstreams. The critical path is important because it is the one workstream that has no float (schedule flexibility). Since the critical path has no float, any activity along it that is finished late represents a risk of the project finishing late.

QUICKTEST

- Dependencies
- Float
- Leads and lags
- Critical path
- Milestone
- Schedule model
- Schedule Management process
- Schedule management plan
- Precedence diagramming method (PDM)
- Dependencies
  - Mandatory
  - Discretionary
  - External
  - Internal
- Network diagram
- Analogous estimating
- Bottom-up estimating
- Parametric estimating
- Single-point estimating
- Three-point estimating
  - Triangular distribution
  - Beta distribution
- Activity standard deviation
- Affinity estimating
- T-shirt sizing
- Planning Poker®
- Alternative analysis
- Reserve analysis
- Contingency reserves
- Management reserves
- Fist of five
- Basis of estimates
- Critical path method
- Fast tracking
- Crashing
- Monte Carlo analysis
- Resource leveling
- Resource smoothing
- Agile release planning
- Cumulative flow diagram
- Velocity
- Project schedule
- Milestone chart
- Bar chart
- Schedule baseline
- Reestimating

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Milestones

Identified points in the project schedule where particular objectives should be met are called milestones. They are not work activities and have no duration but they do fall on certain dates. Initial milestones are documented in the project charter. The project manager can also insert milestones as checkpoints to help control the project. A milestone list is a project document, often created as an abbreviated view of the schedule. If a milestone in the schedule is reached and any of the planned work is not complete, the project is not progressing as planned, i.e., the project is behind schedule.

Examples A completed design, a company-required checkpoint, a phase gate, or an iteration completion point.

Schedule Model

The schedule is always a model of sorts because it is subject to changes based on constant monitoring and controlling of the project. The project calendar (or schedule), plus all the associated planning documents is referred to as the schedule model. At first it is a working model of the schedule, along with artifacts like the activity attributes and estimates and the project schedule network diagram (once it is created). An agile equivalent would include the release map and other release planning artifacts, the prioritized backlog plus the current iteration plan.

As the project schedule is approved the schedule model becomes the current approved version of the schedule along with these other schedule-related artifacts. For both agile and plan-driven approaches the project's historical planned and actual results data and analyses inform the current schedule model.

Schedule Process Overview

As with all project management processes, you will need to understand how to plan and manage the project schedule from several perspectives. The Schedule Management process from the Process Groups model is one way to speak about project scheduling, and the Plan and Manage Schedule task in the Process domain of the *Examination Content Outline* (ECO) is another. Remember that while much of the Process Groups model can be applied to any project life cycle and development approach, agile has its own methods and practices. You will also want to understand agile scheduling practices, and how they are similar and how they are the different from plan-driven practices.

The *Examination Content Outline* and Process Groups Model

Think About It. Take time now with the ECO and the following diagram to think through the Process Groups model's Schedule Management process as it relates to the Plan and Manage Schedule task from the ECO's domain I (Process).

- In the Process Groups model, these are all planning functions:
  - ✓ Define activities
  - ✓ Sequence activities
  - ✓ Estimate activity durations
- Then you are ready to develop the schedule—also a planning function.
- Throughout the project you are using earned value measurement (EVM) to control the schedule (including procurement schedules) and manage changes to it. EVM is covered in more detail in "Budget and Resources," as it is used for tracking progress on scope, schedule, and cost together.

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ECO	Process Groups Model	PMBOK® Guide
Domain II	Schedule Management	Domain 2.4 Planning Domain 2.7 Measurement Domain 2.8 Uncertainty
Task 6 Plan and Manage Schedule	Plan Schedule Management Define Activities Sequence Activities Estimate Activity Durations Develop Schedule — Planning Control Schedule — Monitoring & Controlling	

Can you see how other ECO tasks support Plan and Manage Schedule? For example, supporting ECO processes are Manage Conflict and Negotiate Project Agreements (People domain I, tasks 1 and 8). Also think about the supporting roles of Promote Team Performance through the Application of Emotional Intelligence, and Ensure Team Members/ Stakeholders Are Adequately Trained (People domain I, tasks 14 and 5). Think systematically as you review the ECO. Other ECO tasks also often play a role in planning and managing the project schedule.

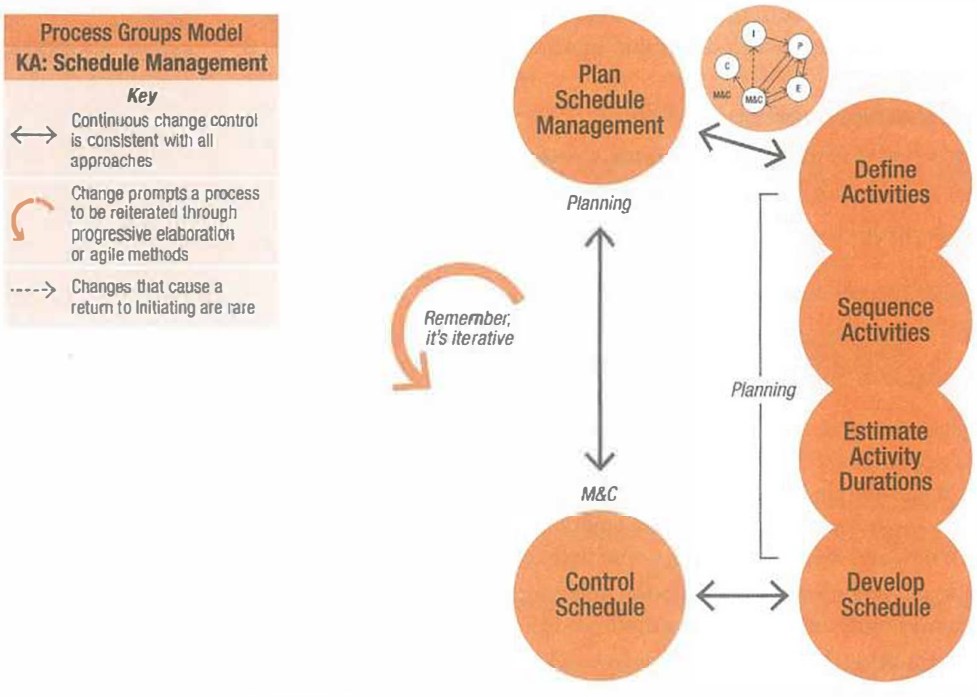

FIGURE 8.1 *Schedule management process*

Desired Outcomes of Schedule Management

For the exam, unless the question indicates otherwise, assume that schedule management has been properly planned according to the concepts presented in this chapter related to planning and managing the schedule. Having a plan means that when a problem arises the first option is to look to the plan for how to handle it. The following should be expected of a properly planned and managed project:

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- All or most deliverables are completed and delivered in the planned timeframes, within budget and with the agreed quality attributes.
- The number of changes to the project and product requirements are within the project manager and team's expectations.
  - ✓ More changes are expected on agile projects than on plan-driven projects. Negotiating scope to keep the project on schedule on agile projects is also expected as scope is understood to be the more flexible constraint.
  - ✓ A significant number of changes to requirements on plan-driven projects should be evaluated for possible issues with stakeholders or the clarity of the scope and requirements definitions.
- Stakeholder behaviors and relationships indicate project outputs are largely accepted and stakeholders seem satisfied at a given point.
- The cadence of development, testing, and implementation is appropriate to the specific project and to the development approach and life cycle selected.
- Measurements indicate the project is performing as planned. Reviewing past forecasts against present project performance indicates the project is largely or wholly on schedule.
- Project benefits can be realized in the timeframe they were planned for.

Plan 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. You also need to determine in advance and ensure a common understanding about:

- What the **measures** of performance will be
- How and when to **capture data** to **evaluate** performance
- How you will **use the data** to keep the project on track
- What you will do when **variances** occur

Process Groups Model
PG: Planning
Process: Plan Schedule Management

ECO
Domain II
Task 6 Plan and manage schedule

PMBOK® Guide
Domain 2.4 Planning

Plan Schedule Management answers questions such as:

- Who will be involved, and what approach will be taken to plan the schedule for the project.
- What processes and procedures will be used to create the schedule?

Did you remember that hybrid and agile approaches take a more short-term view of scope and schedule than traditional approaches? Teams form a general plan and then schedule and perform project work in iterations. They then re-evaluate to determine the next best steps based on actual progress. Agile teams also continually refine the schedule as new details emerge. This approach is best when trying something new. When the work is new and scope is emerging rather than stable, discovery is a better guide for progress than detailed analysis.

When work and environments are familiar and predictable, it is possible to accurately schedule work in advance. A hybrid approach uses traditional scheduling methods in some areas of the project while using agile methods in others.

Example A traditional approach is typically used to build an office building. A realistic hybrid option is to start and finish the building's most durable aspects using a traditional approach, and then customizing the inside spaces iteratively as office space is leased.

To plan the project's schedule, the project manager will also need to:

- Review the project charter
- Use expert judgment
- Use data analysis techniques, such as alternatives analysis
- Hold meetings that include the:
  - ✓ project sponsor
  - ✓ team members
  - ✓ other stakeholders

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The project life cycle and development approach agreed on in Develop Project Management Plan (an Integration process) will influence the level and type of schedule management planning the project manager does. They may also consider using or creating enterprise environmental factors, such as:

- A work authorization system for the project
- A preferred project management scheduling software, which the organization may already have
- The impact of the company culture and overall structure on the project schedule

Schedule Management Plan What is the key output of this process? A formal or informal schedule management plan (part of the project management plan). It helps make estimating and schedule development faster by specifying the following:

- Scheduling methodology and software
- Rules for how estimates will be stated (Examples: hours, days, story points)
- Whether to state both effort and duration
- How a schedule baseline to measure against will be stated
- Estimates for where changes may occur
- Change control procedures
- How schedule variances will be managed
- Performance measures that will help identify variances early
- Acceptable variance threshold(s)
- A process for determining whether a variance must be acted on
- Types, formats, and frequency of reports needed
- Length of iterations and releases for agile

Define Activities

The Define Activities process involves doing the following for the work packages created in the WBS (created as part of Plan and Manage Scope):

- Decomposing them into the activities that are required to produce the work packages
- Making sure decomposition is at a level small enough to:
  - ✓ Estimate
  - ✓ Schedule
  - ✓ Monitor and control
- Prepare to sequence these activities in the next process

Process Groups Model
PG: Planning
Process: Define Activities

ECO
Domain II
Task 6 Plan and manage schedule

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Domain 2.4 Planning

The Context for Defining Activities

Project managers often combine the Define Activities effort with creating a WBS and WBS dictionary. The project manager and team decompose work packages into the activities required to produce them, rather than stopping at the work package level. So, what is needed in order to define activities?

- The schedule management plan gives the project manager important information about the agreed scheduling methodology
- The traditional scope baseline (scope statement, WBS, and WBS dictionary), or the project's product backlog for agile projects
- Story cards for agile projects

This is the work the project manager will now break down into project activities. Collaborating with the team helps define activities completely and accurately and later will make the estimates more accurate. The project manager may refer to organizational process assets, including:

- Existing templates,
- Historical information such as:
  - ✓ Activity lists
  - ✓ Issue lists from other similar projects
- Standards, such as prescribed scheduling methodologies

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TRICKS OF THE TRADE While reading exam questions remember to identify: "Where am I in the project management process?" Decomposition is used in schedule, scope, and cost management. When you see the term "decomposition" on the exam, look for context. If deliverables are being decomposed with the team into smaller deliverables (or work packages) the question is referring to the Create WBS process (in scope management) and a predictive approach. If work packages are being broken down into activities to produce them, the question is referring to Define Activities (for schedule management).

TRICKS OF THE TRADE With an agile approach, the team helps to define the activities and the product owner sequences the work by prioritizing stories in the backlog. The team helps identify dependencies, develop estimates, and provide input on what is achievable. Development of the schedule is a joint effort.

Sequencing Activities

Once work package activities are defined, the next process involves sequencing them in the order in which the work should be performed. The result is a project schedule network diagram. A simple network diagram is illustrated in figure 8.2. There is practice work designed to help you learn how to draw and interpret network diagrams later in this chapter.

Process Groups Model
PG: Planning
Process: Sequence Activities

ECO
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Task 6 Plan and manage schedule

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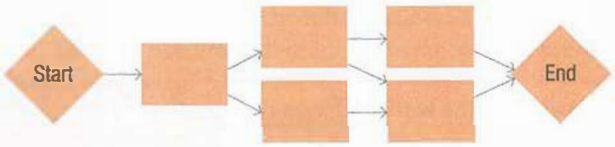

FIGURE 8.2 *Network diagram*

For the exam, know this about a network diagram:

- In its simplest form, it just shows dependencies between activities.
- If activity duration estimates and leads and lags are added to the diagram, it can also show the critical path, which is the shortest path to finishing the project.
- If plotted out against time (is made calendar-based), the network diagram is a time-scaled schedule network diagram.

Inputs that may influence dependencies in the sequencing of activities include the:

- Assumption log
- Activity list
- Activity attributes
- Milestone list

Precedence Diagramming Method (PDM)

This method uses nodes (or boxes) to represent activities, and arrows to show dependencies. In figure 8.3, for example, activity B is dependent on the completion of activity A.

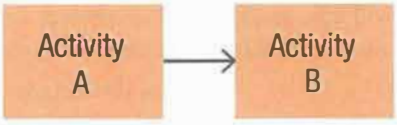

FIGURE 8.3 *Precedence diagramming method*

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Logical Relationships

There can be four types of logical relationships between activities, as shown in figure 8.4.

- **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. An example of this type is, "The first shift security guard cannot leave until the second shift security guard arrives."

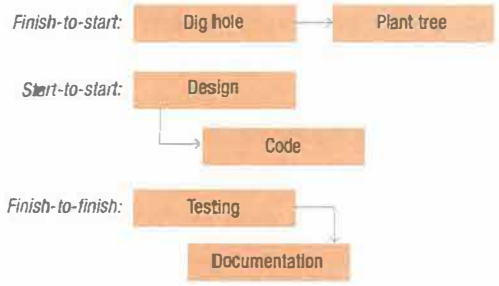

FIGURE 8.4 *Finish-to-start, start-to-start, and finish-to-finish dependencies*

Types of Dependencies

The sequence of activities is also determined based on these dependencies:

- **Mandatory dependency** (hard logic) A mandatory dependency is inherent in the nature of the work or is required by a contract. Example: You must design before you can construct.
- **Discretionary dependency** (preferred, preferential, or soft logic) This means there are other ways it could be done, but this is the approach the organization has chosen to perform the work. Discretionary dependencies are the most flexible type, and they are important when analyzing how to compress the schedule to decrease the project duration (i.e., to fast track it).
- **External dependency** This type of dependency is based on the factors relating to a party outside the project (for example, government or suppliers).
- **Internal dependency** This type of dependency is based on needs internal to 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
- Discretionary internal

Dependencies in Hybrid Environments

Digital products have different characteristics than traditional, physical products. Consider how a contractor builds a house. They wouldn't complete the interior of the house before they built the roof, would they? Of course not. The roof needs the walls, the walls need a foundation, and the foundation needs land and permits in place. The dependencies are static, well understood, and slow to change. Techniques like network diagrams, critical path analysis, and detailed Gantt charts are valuable and necessary.

In the digital product space, however, there are many more options and possibilities. Good IT architecture allows services to be swapped out easily and promotes isolating changes. This means there are far fewer dependencies on digital projects. This coupled with more requirements renders much of the traditional dependency analysis and dependency management redundant, unreliable, and wasteful. Therefore, many of these techniques are not used in software-heavy digital projects. Instead, project managers work with product owners to define what the priorities are, and they work with the teams on how best to build them. Typically, features can be implemented and evaluated independently of each other.

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For example, using a hybrid approach to build an energy trading system for an electrical operator, the product owner may use a traditional approach to create an initial sequence of features to be developed. Then they may reorder the remaining features once the initial product is in place. The product owner may reorder these features again after the regulatory body responses get integrated, and again later as additional features come on board. This would all require extensive schedule rework with traditional network diagrams and Gantt charts. By comparison, reordering the backlog at this stage of a hybrid project is much less work.

Project Schedule Network Diagram

A schedule network diagram is an artifact of planning and managing the project schedule. It is an illustration depicting the flow of project activities in the logical order in which they will be performed (see figure 8.11). Here are some guidelines to understand about schedule network diagrams:

- The project manager needs the activities list and to know the dependencies between activities. Later, after they have all the duration estimates for each activity, they can add that data to the network diagram.
- All activities after the **Start** should be connected to at least one predecessor activity (except the first one in each workstream after **Start**).
- All activities on the network diagram before the **Finish** should be connected to at least one successor activity.
- The network diagram helps the project manager plan which activities can be completed in parallel and to see where leads or lags are required.
- The more complex the project, the more likely it is that activities will overlap.
- **Path convergence** An activity having two or more activities directly preceding it on different paths is referred to as path convergence.
- **Path divergence** An activity having two or more successor activities directly following it on different paths is referred to as path divergence.
- Both path convergence and divergence are indicators of risk within the impacted activities.

Example Using the simple example in figure 8.2, here is how to build a network diagram.

1. Put **<Start>** and **<End>** in shapes that distinguish them from the nodes (named activities).
2. From **<Start>**, create the first rectangle and label it **Activity A**.
3. Draw a line from **Activity A** and add another node, labeling this second node **Activity B**. The line indicates a dependency connection between the two
4. Draw a line from Activity B and add another node, labeling this third node Activity C.
5. Add an <End> and draw a line from Activity C to <End>.
6. Repeat the process to add the second path (add Activities D and E; add lines between them and then a line to <End>. The network diagram is ready for the activity duration estimate data.

Complex project schedule network diagrams that include leads and lags as well as other dependencies are best done with an automated scheduling system that is part of the PMIS. You will be expected to answer questions on the exam related to interpreting information these diagrams provide. You need to have worked with network diagrams to accurately answer such questions.

In summary, network diagrams can be used to:

- Help justify the project manager's 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 and help with forecasting. This is used for controlling the schedule and reporting, and is related to earned value measurement (EVM). EVM is related to scope, schedule, and cost, and is covered in the "Budget and Resources" chapter.

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Estimating Activity Durations

Process Groups Model
PG: Planning
Process: Estimate Activity Durations

ECO
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Domain 2.4 Planning

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, estimators should be those who will be doing the work, or on large projects, members of the project management team most familiar with the specific work to be done.

Both the Estimate Activity Durations and Estimate Costs (in the "Budget and Resources" chapter) processes involve estimating. Historically, the exam has focused on the methods required to produce good estimates more than on calculations.

Use this checklist to evaluate your understanding of activity and schedule estimating. Identify gaps that may impact how you answer exam questions. Keep track of items you currently do not do in your project work and pay extra attention to studying these topics. Remember, bad project management practices (like padding estimates, for example) may be listed as choices on the exam.

Think About It. Things to Know About Estimating for the Exam

- ☐ Management plans provide the approach to estimating.
- ☐ The project manager and team may use one or many techniques to estimate project work.
- ☐ Estimating should be based on small amounts of work, from a WBS or from story cards in agile. This improves accuracy.
- ☐ Duration, cost, and resource estimates are interrelated. Duration and resource estimates often impact cost estimates.
- ☐ Identified risks must be considered when estimating the duration, cost, and resource requirements of project work. Risk management actions are specific line items in a project contingency reserve (part of the budget). For agile risk management actions are represented as stories in the backlog.
- ☐ Estimating duration, cost, and resource requirements may uncover additional risks.
- ☐ Estimating should be done by those doing the work or those most familiar with it to improve accuracy.
- ☐ Historical information from past projects (part of organizational process assets) is often key to getting started and improving estimates.
- ☐ Estimates are more accurate on smaller-size work components.
- ☐ A project manager doesn't just accept management-given constraints. They evaluate project requirements, develop estimates with the team and reconcile differences, producing a realistic plan.
- ☐ The project manager may periodically recalculate the estimate to complete (ETC) for the project to ensure adequate time, funds, and resources for the project (getting needed approved changes). ETC and other project control metrics are discussed in the "Budget and Resources" chapter.
- ☐ Plans based on estimates should be revised, with approved changes, during completion of the work, as necessary.
- ☐ There is a process in the project management plan to create the most accurate estimate possible.
- ☐ Padding estimates is not an acceptable project management practice.
- ☐ The project manager must meet any agreed-upon estimates.
- ☐ Estimates (from team members or sellers) must be reviewed to ensure they are reasonable and do not contain padding or unidentified risks.
- ☐ Estimates must be kept realistic throughout the project by re-estimating periodically as needed.
- ☐ Estimates can be positively impacted by reducing or eliminating risks.
- ☐ The project manager has a professional accountability to (with the help of the team) provide estimates that are as accurate as feasible, and to maintain the integrity of those estimates throughout the project.

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Inputs to Good Activity Estimates

To arrive at realistic time estimates, these individuals need to have access to the following:

Activity List and Activity Attributes The relevant inputs may include the time for required leads or lags between activities, which must be factored in to duration estimates.

Assumption Log Assumptions or constraints that contribute to risk within the activities to be estimated should be found here.

Lessons Learned Register Information relevant to the duration of activities include lessons learned from earlier in the current project or from past, similar projects within the organization.

Resource Breakdown Structure Created in the Estimate Activity Resources process (of Resource Management), the resource breakdown structure shows categories of resources required for the project.

Resource Requirements These requirements indicate the skills needed from resources to perform specific project work.

Project Team Assignments 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 activities will be available. If the resources are not available within the timeframe of the project, the project manager needs to estimate time for those to allow 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.

The Knowledge to Avoid Padding A pad is extra time or cost added to an estimate because the estimator does not have enough information or feels insecure in their estimating. It is not a viable way to plan a project. What is wrong with padding? Think about how estimating works on your projects for a moment. Can you see how, if individual team members pad their estimates, the project estimates become increasingly unreliable? In turn, padding undermines the ability to create a realistic schedule and budget.

In cases where the information required to clarify the unknowns is unavailable, the potential need for additional time or funds should be addressed with reserves within the risk management process. Through risk management, uncertainties are turned into identifiable opportunities and threats. Uncertainties then do not remain hidden.

Remember it is a PMI-ism that proper project management has been done unless an exam question indicates otherwise. There is no need for padding when the following is in place 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.
- Three-point estimates can be used, which by averaging the worst-case scenario, the most likely scenario, and the best-case scenario, builds uncertainty into the estimate.
- The estimators know there will be time and cost reserves on the project determined through the risk management process to address identified risks.

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How Estimating Is Done

The part of the team doing the estimating may use one or many techniques as identified earlier in the schedule management plan.

First, let's look at the project manager's role in estimating. The project manager's role here 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 in the "Risks and Issues" 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. We have organized the following two sections into predictive and adaptive estimating techniques. These methods are generally used with these approaches and are likely to appear on the exam in these contexts. However, any variety of these techniques may be used, especially with a hybrid approach.

Methods for Predictive Estimating

Traditional projects use the following methods for estimating. Analogous estimating is an example of an estimating practice applicable to both predictive and adaptive approaches.

Analogous Estimating (top-down) Analogous estimating uses expert judgment and historical information to estimate. It can be applicable to time, cost, and resources. It is usually not considered definitive. For example, management or the sponsor might use analogous estimating for high-level estimation while establishing a business case and for project selection. 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 estimates are refined later during planning.

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 accuracy. For example, "This company has created many thousands of programming modules and they have taken an average of X hours so we will use that as a starting point."

On the other hand, analogous estimates are used when there are little supporting data. For example, "The last two times this activity was done each took three days. Since we have no other data to go on, we will estimate three days and review estimates as we learn more details."

For the exam, know analogous estimating can be done at various times. It is usually not thought to be definitive but the level of accuracy can also depend on how much analogous data are available and how closely the project or activity matches the historical record.

Bottom-up Estimating

This method involves creating detailed estimates for each activity or work package, using an accurate WBS. The individual estimates are then rolled up into control accounts and finally into an overall project estimate. You will see how these estimates roll up into a budget in the "Budget and Resources" chapter.

Parametric Estimating

Parametric estimating involves a mathematical equation using data from historical records or other sources, such as industry requirements or standard metrics. 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.

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An estimator might create parametric estimates using the following:

Regression Analysis (Scatter Diagram) This diagram tracks two variables to see if they are related; the diagram is then used to create a mathematical formula for future parametric estimating. Figure 8.5 shows an example of a scatter diagram.

Learning Curve (by example): The 100th room painted will take less time than the first room because of improved efficiency.

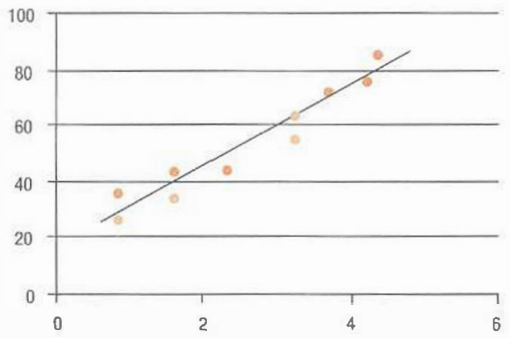

FIGURE 8.5 *Regression analysis (scatter diagram)*

Single-point Estimating (One-point Estimating)

This type is based on a single estimate; however, it can be problematic. For example, the person doing the estimate may say that an activity will take five weeks. This may be based on expert judgment or historical information, or it could be just a guess.

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 since it doesn't include best- and worst-case scenarios.
- When a person's one-point estimates turn out flawed—for example an activity takes 15 days instead of an estimated 20, it can make the project estimates and estimators seem unreliable.
- One-point estimating can result in a schedule that no one believes in, thus decreasing buy-in to the project management process.

We can come together to use single numbers for project activity estimates, for example, using a more realistic estimating method like three-point estimating, covered next. For each activity, it is easier to use a single number (of days, for example) to draw a network diagram and find the project's critical path. On the exam, one-point estimates allow for quick calculation (if a question supports that) and demonstrates that you understand concepts such as the critical path.

Three-Point Estimating (a version of multi-point estimating)

Estimates are best given in a range since there is a very small probability of completing a project on exactly any one date. Three-point estimates are the best known of multi-point estimating techniques.

Three-point estimates better account for uncertainty: What could go right (opportunities) and what could go wrong (threats), to help estimators determine an expected range. This way the project manager can better understand the potential variation of the activity estimates.

There are two ways of calculating three-point estimates for the exam, as follows. Memorize these formulas and remember they can be used for both time and cost estimates:

Triangular Distribution (Simple Average) A triangular distribution 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 (or the uncertainties, which are the **P** and **O** estimates) are considered equally along with the most likely (**M**) estimate.

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Beta Distribution (Weighted Average) The beta distribution (a weighted average) gives more consideration to the most likely (M) estimate. This method uses the formula (P + 4M + O)/6, a weighted average. 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.

Think About It. For the exam, know these formulas and how they are applied to estimating.

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 8.6 *Three-point estimating formulas*

If you are asked to calculate the activity duration or cost, 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 a calculation or just analyze information to determine which formula is best for the scenario. Use triangular distribution if the scenario indicates that the project manager doesn't have a lot of experience or historical information; it provides a straight average. Use beta distribution when there are historical data or samples to work with. Most of exam questions relating to this are relatively simple and may require assessment but not calculations. But the calculations are not difficult and the following exercises can help you prepare for them. First, review the three-point estimating formulas in figure 8.6.

8.1 Exercise (Triangular Distribution)

Calculate the expected activity duration using triangular distribution. You may write the answer here or use your Exercise Notebook. All estimates are in hours.

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

Answer (Triangular Distribution)

Activity	Expected Duration
A	29.33
B	63.33
C	43.66
D	36

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8.2 Exercise (Beta Distribution)

Calculate the expected activity duration using beta distribution. You may write the answer here or use your Exercise Notebook. All estimates are in hours.

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

Answer (Beta Distribution)

Activity	Expected Duration
A	28.17
B	61.67
C	43.83
D	36.50

Compare the answers using triangular distribution to the answers for the beta distribution. It may seem that the results are not significantly different, but think about it in terms of a cumulative effect with many activities.

Activity Standard Deviation This concept describes a possible range for an estimate.

Example An activity estimate of 30 hours with a standard deviation of +/– 2 is expected to take between 28 hours and 32 hours.

Think About It. You won't be asked to calculate "beta activity standard deviation," or (P – O)/6 but interpreting it in a situational question is important. Think through the following so you understand it.

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). The SD is likely to be given. 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 Duration	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

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Additional points to know:

- Understand that estimates of time (or cost) should be in a range.
- 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.
- The formulas we've been discussing relate to activities. The exam concentrates on three-point estimates to find ranges for activity duration and cost estimates. Be prepared to do simple calculations using these formulas
- You may also see beta total project duration used in questions that require you to evaluate the situation rather than do a calculation (Example: The project duration is 35 months plus or minus 3 months). As with an activity, the greater the range for the project, the greater the risk.
- You can use these concepts to better monitor and control projects. The expected durations help you know the potential variances on your project and determine appropriate courses of action.
- You can use estimated ranges and standard deviation to assess risk. Looking back at the table presenting beta standard deviation, 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.

Methods for Adaptive Estimating

It is worth repeating that while we have organized these sections into predictive and adaptive estimating techniques, any variety of these techniques may be used with approaches from predictive to hybrid to adaptive. For example, although it is common to think about "affinity estimating" in an agile context, categorizing activities on predictive projects into those taking more or less than 40 hours to complete is also a form of affinity estimating.

Adaptive estimating is done in stages, using progressive elaboration. Story collection estimating typically begins with "t-shirt sizing" for the initial plan, which is refined during release and iteration planning, and throughout the project.

Affinity Estimating

This is a technique where groups of similar items are grouped into collections—i.e., "affinities." For example, placing user stories into size categories makes it easier to see whether stories with similar estimates are, in fact, comparable in size.

T-shirt Sizing

A form of affinity estimating, or grouping like items together, t-shirt sizing is an approach to estimating product features and user stories early in the project. The team is not yet trying to generate thorough estimates. They are aiming for high-level (course-grained) estimates, sufficient to map out the overall project effort.

Here is an example from a project for an online movie service. The team has identified six features:

ES	S	M	L	XL	XXL
Sort movies by year	Rate movies	Browse movies	Rent movies	Sell movies	
		Review movies			

FIGURE 8.7 *Features by t-shirt size*

The results of the sizing effort are shown in figure 8.7. As you can see, it's been decided that:

- "Sort movies by year" will require the least effort to build; this is Extra Small.
- Two features that we think will take Medium effort are "Browse movies"; "Review movies."
- An online shopping cart for "Sell Movies" will require the most effort; this is Extra Large.
- None of these features will require an Extra-Extra-Large effort.

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Once the team has identified the features, they will decompose them into user stories. In figure 8.8, the user story cards are stacked under each column. These user story cards represent the work estimated by the team to be done to build the product.

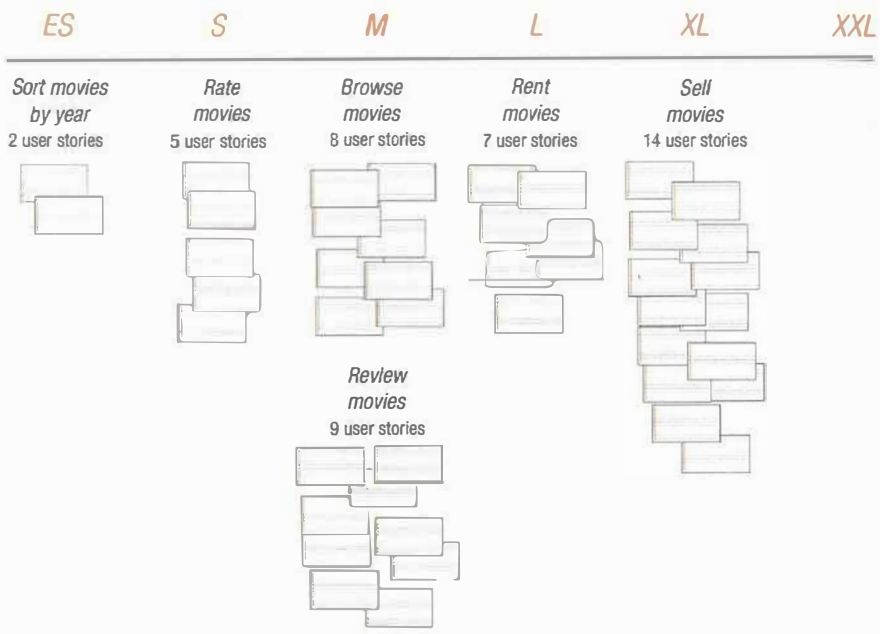

FIGURE 8.8 *Features and user stories*

You can see at a glance what will take the most effort to build ("Sell movies" with 14 user stories) and what will take the least ("Sort movies by year" with 2 user stories).

It also appears that "Rent movies," which was sized Large, might actually be smaller than "Browse movies" and "Review movies," which were sized Medium.

However, the team has not yet determined the relative size of the stories. Some of the stories may be very small, and others may be very large. The team has to estimate all the user stories in t-shirt sizes, like they did for the features.

After that, they can also use affinity estimating to ensure the stories in each category are comparable in size. The stories based on t-shirt sizes might look something like figure 8.9.

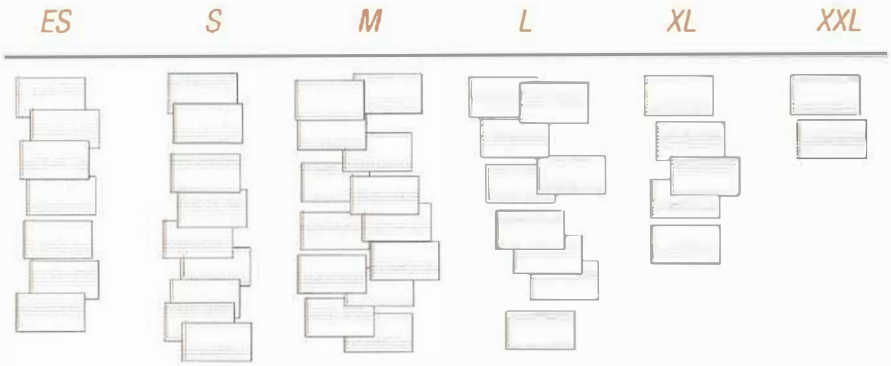

FIGURE 8.9 *User stories by t-shirt size*

Now that all the stories have been sized, the team can use the relative sizes of the stories in each feature to refine their t-shirt estimates for each one. For example, let's say they find out that, on average, the stories in "Rent movies" are larger than the stories in "Browse movies" or "Review movies." Then "Rent movies" will require more effort than the two Medium features, as originally thought.

Planning Poker®

Planning Poker® is a common and collaborative game using relative sizing. The goal is not to create precise estimates. It aims to help the team quickly and efficiently reach consensus on reasonable estimates. The project can keep moving forward.

Here's how to play. An agile team gathers to estimate the stories that need to be built. Each player gets a set of cards with the numbers as shown in figure 8.10. Someone reads a story and each player evaluates it for the work effort they think it requires. The estimating process continues as follows.

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Remember these stories are in a backlog that the product owner has prioritized.

1. All at once (to avoid group think), each team member throws down a card (representing a number of story points).
2. The group discusses differences. As they do this, they are discussing the work involved in each story.
3. As needed, they play another estimating round or two before coming to consensus on the number of points assigned to the story.
4. They repeat this for all stories needing estimates.
5. For the project's first iteration the team estimates how many stories they think they can complete.
6. Once the first iteration is complete, they compare estimated to actual story points completed.
7. The actual number of completed story points is used to select stories for the next iteration.
8. After a few iterations they can average their story points for a working average, or velocity, of story points completed per iteration. They can adjust velocity as appropriate throughout the project.

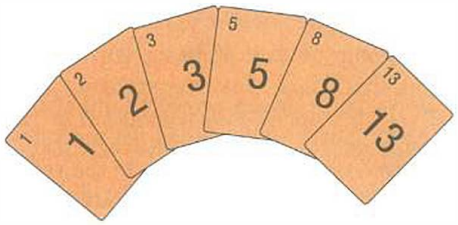

FIGURE 8.10 *Planning Poker® estimating "game" cards*

It is important to note that story points have no value except as measured against other stories in the same project. Be careful if an exam question talks about comparing two team velocities (speed at which they can build stories). Comparing two teams' velocities on two different projects is not relevant or useful.

Methods for Data Analysis

The process 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.

Example Comparing options such as outsourcing work versus completing it internally to meet a schedule constraint. Alternatives analysis involves evaluating the impact of each option on project constraints, including cost versus time saved and level of risk. This process will result in the determination of the best approach to complete project work within the constraints.

Reserve Analysis

This connects the topics of estimating and risk management. Estimating helps to identify more risks. Risk management reduces 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!

As described in the "Risks and Issues" chapter, two types of reserves can be added to the project schedule (and budget): contingency reserves and management reserves.

Contingency Reserves Contingency reserves are allocated in the schedule baseline for identified risks after the Plan Risk Responses process. Significant risks to critical path activities may be managed by allocating a specific amount of schedule reserve. Employing contingency plans using contingency reserves helps keep the project within the schedule baseline.

Management Reserves These are additional funds and time to cover unforeseen risks (or "unknown unknowns") that may impact the ability to meet the schedule. Management reserves are not part of the schedule baseline. They may not be applied at the project manager's discretion. They require approval through the change control system.

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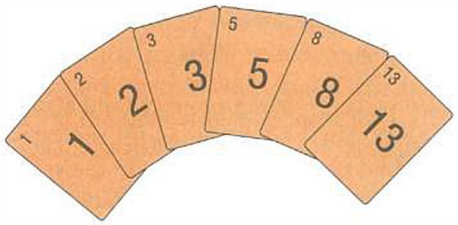

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Methods for Decision Making

We've said that involving team members in estimating is beneficial because those most familiar with the work have the best understanding of the time required to complete each effort. This and the team's inclusion in decision making increases their buy-in to the resulting schedule. Here are some group decision-making methods that are useful in project estimating – and in many types of decision making. Each are a variation on using voting in decision making.

Plurality, Majority, or Unanimity

On plan-driven projects, the project manager may take a simple vote to reach one of these, depending on the circumstances. Take the example of a scheduling decision regarding a small activity that is far into the future of the project and not on the critical path. The project manager may reach this decision with a simple plurality agreement, while one regarding an activity on the critical path in the near future may require a majority or unanimous agreement.

Roman Voting

Here people phyiscally show their level of support for a decision with a simple "thumbs up, thumbs down" voting style. "Thumbs sideways" can also be used for those who are not sure of their vote or have misgivings.

Fist of Five

This voting technique is commonly used on change-driven projects (and also called "fist to five"). In this variation, a closed fist indicates a zero (no support) and an open fist indicates five (full support). Team members who are not supportive (who showed two or fewer fingers in the vote) 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.

Artifacts of Schedule Estimating

When the Estimate Activity Durations process is complete—including risk management processes—the project manager will have estimates, including reserves. Here are summaries of outputs from this process related to both predictive and adaptive projects. These may be already-existing artifacts that are being updated.

Predictive Project Outputs	Adaptive Project Outputs
– Activity attributes	– Prioritized backlog of user stories
– Assumption log updates	– Coarse-grained estimates of user stories
– Lessons learned register updates	– Release goal focused on customer value
	– Target release date or release number

Basis of Estimates Another artifact of estimating activity durations, the basis of estimates, explains how estimates were derived, including assumptions, constraints, what risks were taken into consideration. Basis of estimates also includes the confidence level for the estimates, expressed as a range, such as plus or minus 20% within which the actual project results are expected to fall.

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Develop Schedule

Once the network diagram and activity duration estimates are completed—or for agile a release plan, feature and story prioritization in a backlog, and estimates—it is time to create a schedule model. This can be done using a variety of software tools within a PMIS.

For traditional projects, the schedule model is the first schedule rendition and may be updated throughout the project based on approved changes. During the original project planning it is iterated until ready for approval. It is created using project data gathered thus far, including:

- Activities
- Start dates (for activities without dependencies)
- Duration estimates
- Dependencies
- Leads and lags

Process Groups Model
PG: Planning
Process: Develop Schedule

ECO
Domain II
Task 6 Plan and manage schedule

PMBOK® Guide
Domain 2.4 Planning

Think About It. Representations of the schedule include milestone charts and bar charts (as often shown through Gantt chart view in project management software). Once approved, the schedule becomes part of the project's baseline (which is part of the project management plan). It is calendar-based, comprehensive, and realistic. Inherent in it are contingency reserves to manage risk. Consider what creating a schedule model involves.

Let's start at the beginning. What do you need before you can develop a schedule for your project? To develop a schedule, you need to have:

- Historical records of previous, similar projects including lessons learned
- 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
- Activity duration estimates
- Resource requirements estimates
- Resource calendars
- The required resources by category (resource breakdown structure)
- A company calendar identifying working and nonworking days
- Already existing project team assignments list
- Risk register

8.3 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? Write the answer in your Exercise Notebook.

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Answer

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 and on operations.
- Take into consideration the skill levels and availability of known resources assigned to the team.
- 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

Schedule network analysis is used to analyze and iterate the schedule model until the project schedule is approved. This analysis may use one or more of the following techniques:

- Critical path method
- Schedule compression
- What-if analysis (e.g. Monte Carlo analysis)
- Resource optimization
- Agile release planning

Critical Path Method

The critical path method involves determining the earliest and latest times each activity can start, and the earliest and latest times each can be completed. In software this can be done by entering activity start dates and durations. Where activities have dependent activities following (or succeeding) them, the software can calculate succeeding start and finish dates using duration data. Understanding this method requires you to understand the following basic concepts.

Using the Critical Path As the longest duration path through a network diagram, the critical path determines the shortest possible duration for the project. It is along this path that there is the least schedule flexibility. The easiest way to find the critical path is to identify all paths through the network diagram and add the activity durations along each path. The path with the longest duration is the critical path. Be sure you do the exercises that follow and practice doing this work for the exam.

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Near-Critical Path This path is closest in duration to the critical path and should also be watched closely. The closer in length the critical and near-critical paths are, the more risk the project has. Close monitoring and controlling activities on both the critical and near-critical paths (yes, there can be more than one) is needed to ensure the project can finish on time.

Using Float For the exam, you should understand float and be able to calculate it. Note that the terms "float" and "slack" mean the same thing. Slack is an older term and is rarely used anymore. It is unlikely that you will see it on the exam but know it just in case it is used. Here are the three types of float to know for the exam.

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

Other things to know about float are:

- Activities on the **critical path** have **zero** float.
- **Total** and **free** float are related to **activities**.
- **Project** float is specific to the **entire project**.
- **Negative** float results when externally imposed completion dates are not feasible. These issues must be addressed in planning to ensure the approved schedule is achievable.
- If critical path activities are delayed, negative float analysis helps in looking for corrective actions to bring the schedule back within the schedule baseline.

When you know the critical path(s) and near-critical path(s), you can use float as a way to achieve better allocation of resources.

Example If you have a resource who has the needed skill set but is not very experienced, you can assign them to work on activities with float. Even if their activities take longer, the project is less likely to be delayed.

Knowing float also helps team members juggle their work on multiple projects. The amount of float tells them how much time flexibility they may have for each activity they are assigned to. Collaborating with the project manager, they may flex the exact start time of some activities with float.

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

Either formula gets you the same answer. Here is a trick for remembering the formulas:

"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	Finish Formula
Float = LS – ES	Float = LF – EF

You determine whether to use the start or finish formula based on the information available.

Example An exam question says: "You have a late start of 30, an early start of 18, and a late finish of 34." How do you find the float? You know to subtract the two starts or the two finishes (using the previous trick). You have not been given two finishes, so you use the equation 30 – 18, which equals 12.

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Practice with the Critical Path Method

Think About It. 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 8.11 as an example. The letters in the boxes indicate the activities, and the numbers above the boxes indicate the duration of each activity. The critical path is identified by the bold arrows.

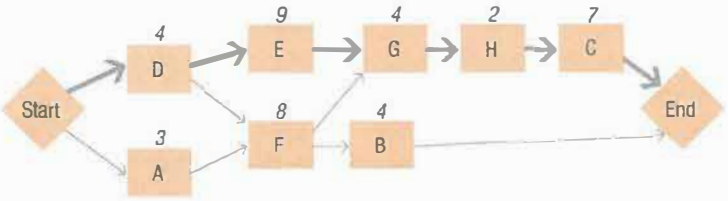

FIGURE 8.11 *Critical path method*

- To determine the earliest and latest each activity can start, and the earliest and latest each activity can end, perform a forward and backward pass through the network diagram.
- **Forward pass** The "early" figures are found by calculating from **<Start>** to **<End>** of the project, following the dependencies in the network diagram.
- **Backward pass** The "late" figures are found by calculating from **<End>** to **<Start>** of the project, following the dependencies in the network diagram.

Let's start with the forward pass. You need to calculate through the activities from **<Start>** to **<End>**, determining early starts and early finishes for all activities. This example uses zero as the early start for the first activity. Use figure 8.12 to walk through this.

Note: Some people, use 1 as the early start of the first activity; others use zero. Either method will get you the right answer. Pick one method and use it consistently. We use zero as the first activity's early start because people consistently find it easier when learning this concept.

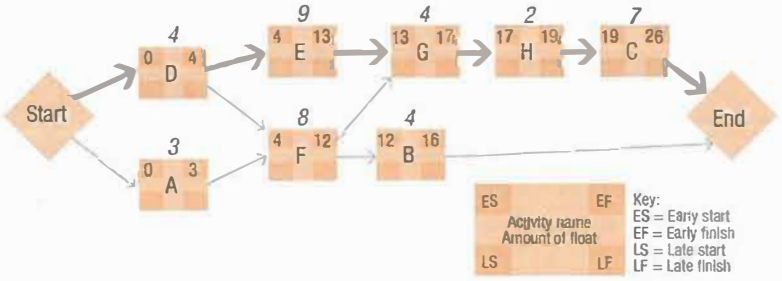

FIGURE 8.12 *Forward pass through network diagram*

- It is important to look at path convergence (where paths meet). To calculate the early start and the early finish in a forward pass, you must account for all the paths that lead into that activity (notice activities F and G in figure 8.12).
- The same concept applies to the backward pass. To calculate the late finish and late start you need to consider all paths that flow backward into an activity (activities D and F in figure 8.12).

To make it easier to follow, we will step you through a forward pass here (EF and ES in parenthesis are early finish and early start, respectively):

1. In figure 8.12, paths converge at activities F and G.
2. Therefore, you must do the forward pass on both paths leading up to activity F. So:
   ✓ Calculate the early finishes for activities D (**EF** = 4) and A (EF = 3).

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✓ Select the latest early finish between activities D and A. Use it as the early start for activity F (since F cannot start until both D and A are complete).

✓ Therefore, the early start of activity F is 4.

3. 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 diagram.

See figure 8.13 for the late start and late finish data.

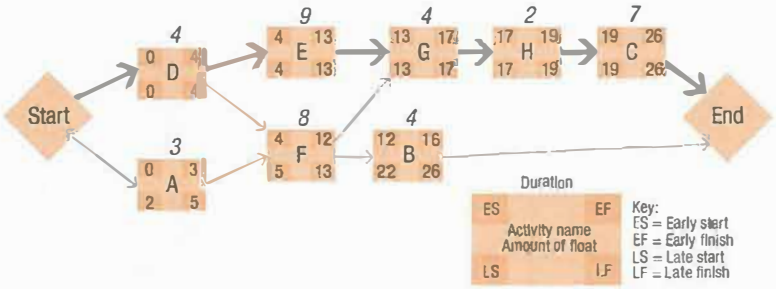

FIGURE 8.13 *Backward pass through network diagram*

1. Be careful at points where paths converge as you move through the network diagram.
2. Paths converge at activity F and at activity G.
3. Work from <End> backwards. First compute the late start of activities B (LS = 22) and G (LS = 13).
4. Select the earlier late start for the late finish of activity F (since activity F must be finished before either activity B or G can start).
5. The late finish of activity F is 13.
6. 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.

TRICKS OF THE TRADE What was that trick again? "There is a start formula and a finish formula, and we always begin late." The formulas are:

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

The activities with zero float are on the critical path (see the bold arrows). See figure 8.14 for the float of each activity.

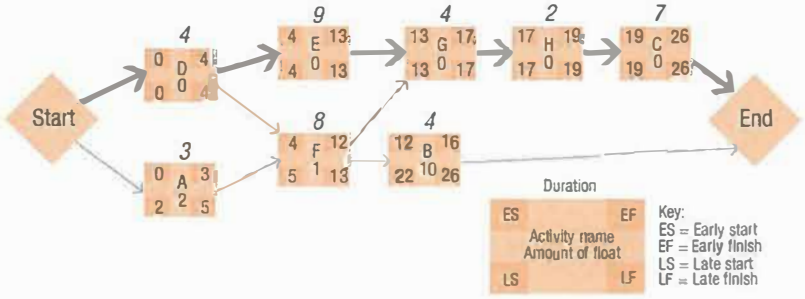

FIGURE 8.14 *Float of activities on network diagram*

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Think About It. Practice will help you understand these concepts better. As you do the following exercise, think about how knowing float helps you manage your projects. On the exam there are not many questions requiring you to do these calculations, and you may not be asked to draw a network diagram. But understanding this entire process will help you get more questions right.

8.4 Exercise

Test yourself. In your Exercise Notebook, draw a network diagram based on the following information, and then answer questions 1-7 below.

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.

Questions:

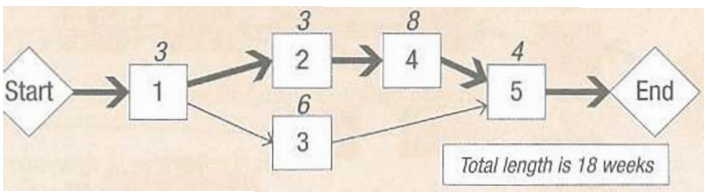
1. What is the duration of the critical path?
2. What is the float of activity 3?
3. What is the float of activity 2?
4. What is the float of the path with the most float?
5. The resource working on activity 3 is replaced with another resource who is less experienced. The activity will now take 10 weeks. How will this affect the project schedule?
6. 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 the previous question, how much longer will the project take?

Answer

There are many ways to answer these questions. If you learned another way in other 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, 2, 4, 5, End is the longest duration path and is therefore the critical path at 18 weeks.

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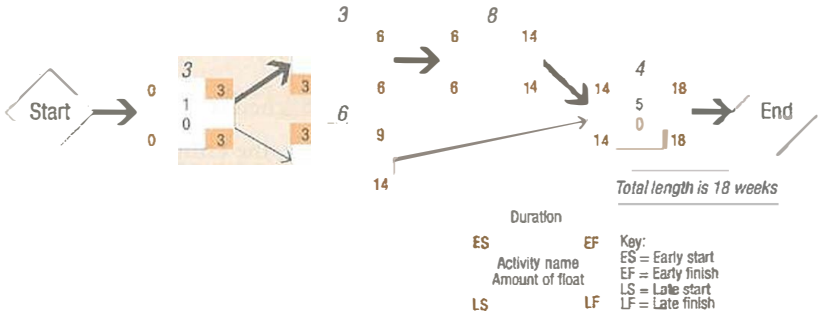
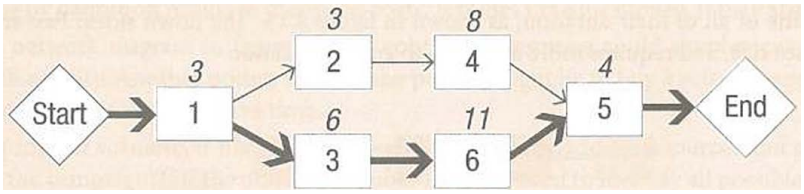
2. The float of activity 3 is 5 weeks, per the following diagram, which shows how to calculate float using the forward and backward pass.



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:
   a. Start, 1, 2, 4, 5, End and Start, 1, 3, 5, End.
   b. Only the non-critical path (Start, 1, 3, 5, End) will have float.
   c. You can calculate the float for this path by adding the float for each activity: 0 + 5 + 0 = 5.
   d. Therefore, the total float of the path with the longest float is 5.
5. The resource change on activity 3 will have no effect.
   a. The length of path activities 1, 3, and 5 is 13.
   b. Adding 4 more weeks to the length of activity 3 will make that path 17.
   c. Since that path is still shorter than the critical path, the critical path does not change.
   d. The length of the critical path is still 18 weeks because activity 3 is not on the critical path.
6. The stakeholder who says the time added to the project will be less than 11 weeks is correct.
   a. The new activity will be added to a non-critical path that has a float of 5 weeks.
   b. Therefore, adding 11 weeks will make this path the new critical path.
   c. The effect of adding an activity that takes 11 weeks is 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.



Note: If you want more practice, there is an extra float and critical path exercise on the RMC Resources page (rmcls.com/rmc-resources).

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The following are good questions to practice concepts related to the critical path, 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 schedule.
- 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 schedule baseline.
- Does the network diagram change when the end date changes? Not automatically, but the project manager should investigate schedule compression options such as fast tracking and crashing, to meet the new date. Then, with approved changes, the project manager should change the network diagram. See Schedule compression in the next section of this chapter.
- 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.

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If 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 in a network diagram. When attempting to identify a critical path, carefully look at each path to ensure you calculate them all before determining which is critical.

Methods for Schedule Compression

One of the most common problems on projects is a difficult or unrealistic timeframe. This problem can arise during planning when management or the customer requires a completion date that cannot be met, or during executing when the project needs to be brought back in line with the schedule baseline due to delays or changes. It is the project manager's responsibility to present options and to make sure the project is achievable. Schedule network analysis techniques such as schedule compression can help.

Schedule compression describes using methods such as fast tracking and crashing to decrease project length. Schedule compression can be used during planning. Beyond the initial planning period, schedule compression may be used during Perform Integrated Change Control and Control Schedule to evaluate options and manage the impacts of change. In this case the objective would be to control the schedule without changing the schedule baseline.

Fast Tracking

This technique involves taking critical path activities that were originally planned to be completed sequentially and doing them in parallel for some or all of their duration, as shown in figure 8.15. The down sides: Fast tracking often results in rework, usually increases risk, and requires more attention to communication.

FIGURE 8.15 *Fast tracking*

Think About It. Which activity in figure 8.16 would you fast track to shorten the project?

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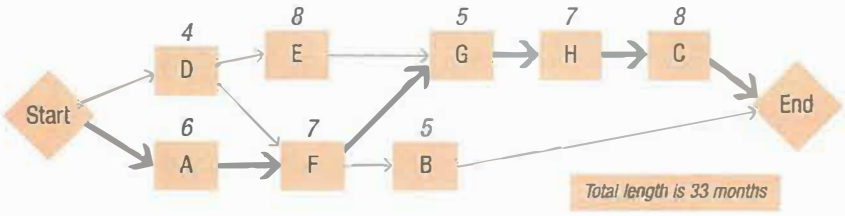

FIGURE 8.16 *Which activity would you fast track?*

Assuming the dependencies are discretionary:

- Activity H could be fast tracked by making it occur at the same time as (in parallel with) Activity G.
- Activities C and H could be fast tracked by doing part of Activity C in parallel with Activity H.
- Any other pair of activities on the critical path could possibly be fast tracked.

Think About It. Let's look at an example scenario to help you further think about fast tracking and creating options. This example may or may not have made use of a network diagram.

Example A cable TV provider was using a hybrid approach to implement web analytics tools. The team was asked to fast track the product launch to coincide with a large marketing push in response to competition from streaming channels.

- The product owner met with management to review the release map and product backlog.
- They identified scope that could be deferred until after initial launch, allowing most functionality to be delivered on time and accommodate the new promotion.
- The customer could at first create some reports in spreadsheets rather than relying on the tool, and some metrics could be eliminated from scope or deferred.
- The core data and decision-making frameworks would be delivered on time.
- Management approved the reduced functionality and workarounds.
- The team proceeded and delivered most of the business value in time for the campaign.
- The team prepared instructions and training for early buyers to mitigate the effects of a reduced reporting functionality.
- A future release of the project completed the functionality and retired the spreadsheets.

Here, scope was compromised temporarily to fast track the schedule. This added some risk and reduced initial functionality. Yet it was an effective way to meet a decreased schedule requirement.

Crashing

The schedule compression method called "crashing" involves adding or adjusting resources while maintaining the original project scope. Crashing by definition results in increased costs. It trades time for money. It may also increase risk.

Example In the network diagram in figure 8.16, a contracted resource could supplement the internal resource's efforts on a critical path activity. Another option to crash the project might be to buy a software application. This assumes either option adds cost but helps the team save time.

In the cable TV provider scenario, it may also be possible to crash by adding resources and get all the functionality completed in time for the campaign. For the exam, remember that you need to identify all possible options and, if given a choice between crashing or fast tracking, select the choice or combination of choices with the least negative impact on the project, and adds the least risk.

Think About It. 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 carefully consider all potential choices and then select the option or options that have the least negative impact on the project and/or adds the least additional risk.

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Many project managers have gaps in their knowledge in this area. Let's review another scenario. Figure 8.16 shows that a project duration is estimated to be 33 months. But what if you're given a constraint of 30 months? Options are listed in the following table to illustrate how the project duration may be shortened by three months.

Option	How to Achieve It (or what it is called)	Explanation (including assumptions made)
Reestimate.	Reduce risks.	Look at the estimates and see which contain hidden risks. By reducing risks, estimates can often be lowered. This way, the project finishes faster.
Execute Activities H and C in parallel.	Fast track (compress schedule).	Will work if the dependency between activities H and C is discretionary. Or may add risk.
Add resources to Activity G from the within the organization (adds cost).	Crash (compress schedule).	Would work if adding resources to activity G is practical and there are resources available.
Cut Activity H.	Reduce scope.	Not the first choice as it may affect the customer; still, reducing scope should be considered an option.
Hire consultants to assist on Activity G, H, or C (adds cost).	Crash (compress schedule).	Would work if adding external resources to these activities is practical and resources are available.
Move more experienced people to critical path activities (activities G, H, or C).	Compress schedule.	Would work if some of the critical path activities are being done by less experienced people, and more experienced people are available.
Cut time by cutting quality. (Do not get excited! Read on.)	Lower quality standards.	Quality is a project constraint; lowering quality standards is an option. If it is feasible, it would probably be faster to complete the project with lowered quality standards. Might add risk.
Get more work done with the same number of resources.	Work overtime.	Not an option during project planning. There are many other ways to compress a schedule that do not have the negative effects of overtime. Save it for a last resort.
Say no; the project must have 33 months.	Say it can't be done.	A viable option only after other alternatives are exhausted. Always endeavor to provide options.

Think About It. Now consider the following questions in thinking about which of the options listed are best. There is no way to know since the scenario is limited. The goal here is, as always, to consider the impacts 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 also adds cost.
- Why not work overtime? Overtime is not free. Most organizations are working at close to 100 percent capacity. The project team working overtime runs the risk of burnout. Also, the possibilities for responding to emergencies for other projects are narrowed, putting other projects at risk. For the exam, don't consider overtime a viable option until all other options are exhausted.
- Generally, it's best to look at risks and then reestimate. Once you know that the schedule (or budget) must be reduced, investigate activity estimates that contain the most unknowns. Reduce or eliminate these risks, thus decreasing the schedule. Eliminate more risks; everyone wins! If this offers only a partial solution, you could continue looking to shorten the schedule with other methods.

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Schedule Compression Summary

Look at the schedule compression options again, and review the impacts of each option. Note that these methods can apply to a project using any life cycle and development approach.

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
Cut quality	• May save cost, resources, and time • May increase risk • Requires good metrics on current and desired quality levels to be effective • May negatively impact customer satisfaction

There is an additional schedule compression exercise on the RMC Resources page (rmcls.com/rmc-resources).

8.5 Exercise

Consider the following question and write the answer. You may choose to do so in your Exercise Notebook.

Management has said to get the project completed two weeks early. What is the best thing 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. This is the best choice because you will have to assess the impact of the change and inform management of that no matter what else you do. There is no data to back up the other possible answers.

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" 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."

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.

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Data Analysis and Simulation

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. One example is Monte Carlo analysis.

Monte Carlo Analysis

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. It is more accurate than other methods because it simulates the actual details of the project and calculates probability.

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 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 figure 8.17). Monte Carlo analysis is also used as a risk management tool to quantitatively analyze risks (see the "Risk" chapter).

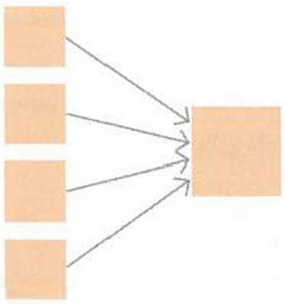

FIGURE 8.17 *Path convergence*

Resource Optimization

Resource optimization refers to finding ways to adjust the use of resources. There are two techniques that can achieve this outcome.

Resource Leveling

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

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.

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Agile Schedule Development

Agile teams attempt to keep schedule and cost stable while negotiating scope to make that happen. The concept of float certainly applies to agile although agile practitioners do not always use the project schedule network diagram. Instead, based upon the estimated story sizes and prioritization, an agile team will gather stories for each iteration and estimate how much can be completed in a given iteration, adjusting estimates until an average velocity is established.

Agile Release Planning

Agile projects are often divided into releases and iterations. An iteration is a short, timeboxed development period, typically one to four weeks in duration. A release is a group of iterations that results in the completion of a valuable deliverable on the project. An agile project will have one or more releases, each of which will contain one or more iterations, as illustrated in figure 8.18.

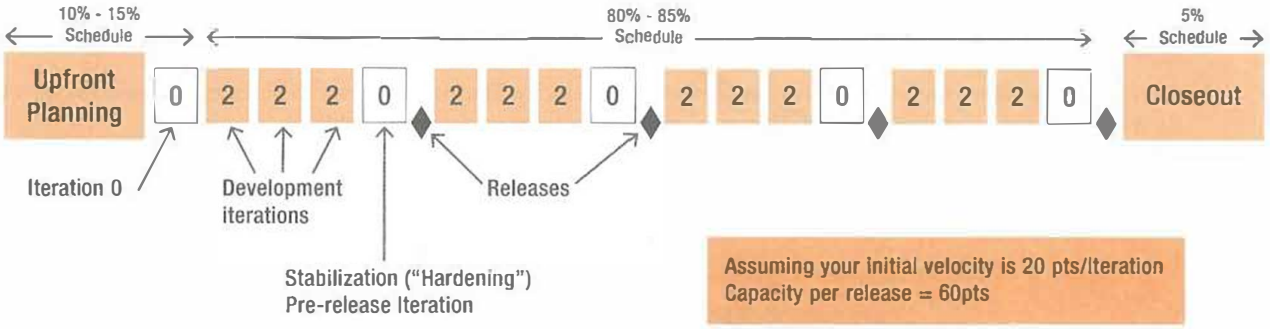

FIGURE 8.18 *Project broken into releases and iterations*

This diagram shows a single project with four planned releases. Agile teams start planning releases and iterations early in the project life cycle and progressively refine the planning effort multiple times as the project progresses.

Do you remember our discussion on the backlog and product roadmap in the "Scope" chapter? While the backlog and the product roadmap help identify and manage project scope, they are also valuable tools that help develop and manage the project schedule.

On agile projects, teams select from the top-priority backlog items to come up with their next iteration goal. Then, they decompose the iteration goal into user stories to get the iteration plan. Planning continues by decomposing those user stories into tasks. While the work is being done, the team discusses the details of the work in the daily standup meetings.

Cumulative Flow Diagrams

Cumulative flow diagrams (CFDs) are valuable tools for tracking and forecasting the delivery of value. They can help the project manager gain insight into project issues, cycle times, and likely completion dates. Basically, CFDs are stacked area graphs that depict the features that are in progress, remaining, and completed over time. An example of a CFD is illustrated in figure 8.19.

This figure shows the features completed versus the features remaining for a fictional project that is still in progress. The orange area represents all the planned features to be built. This number rose from 400 to 450 in June and then to 500 in August as additional features were added to

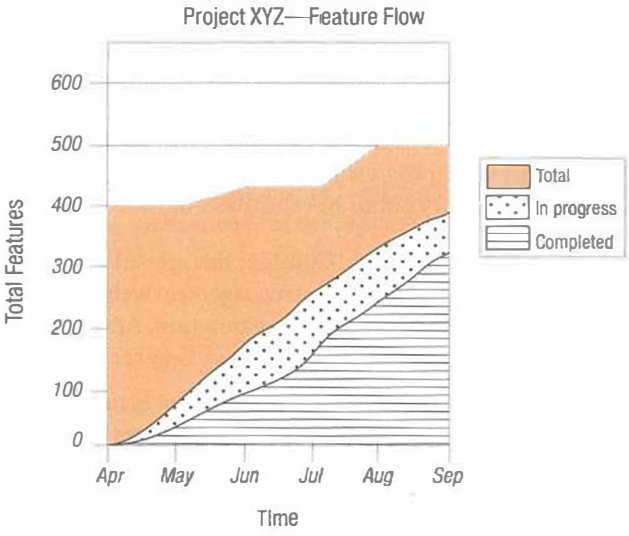

FIGURE 8.19 *Cumulative flow example*

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the project. The dotted section plots the work in progress, and the striped section shows the total number of features completed on the project.

Velocity

As mentioned in an earlier section of this chapter, teams establish an average velocity, which describes how much work (what stories) can be completed in a given iteration. The team iteratively analyzes their actual velocity against the stories in the backlog to be completed, so this practice works as a planning method and as a control method. Velocity works like this:

- Before the first iteration of the project the team establishes a starting velocity. The metric is most often story points. This helps estimate what stories can be completed in the first iteration.
- For the first iteration, the team selects and builds stories from the top of the prioritized backlog based on the starting velocity.
- After the first iteration (not including iteration zero), the estimate is compared to what the team actually completed, and for the second iteration the team will use the actual velocity from the first iteration. They select stories from the top of the prioritized backlog based on this number.
- After several iterations the team has an average or working velocity. They will continue to select stories from the top of the backlog based on average velocity. They recalculate the average velocity as it stabilizes.

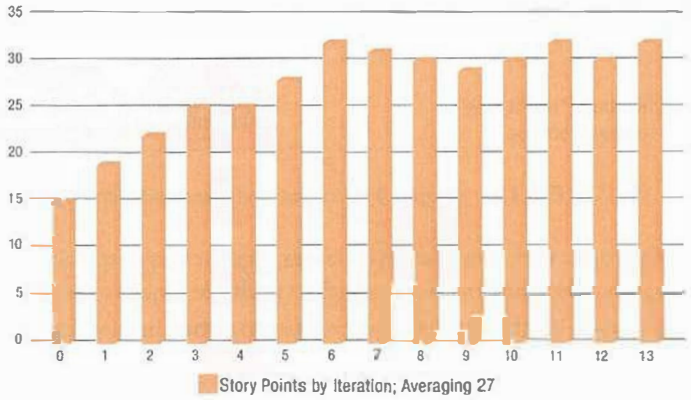

FIGURE 8.20 *Velocity tracking chart*

Cautions on Story Point Estimates and Velocity

The use of story points is a relative estimating method that is very effective. But problems with this method can only be avoided if teams use it properly and good leadership skills and communications ensure that other stakeholders understand it. Story points in estimating and velocity in practice are strictly tailored to every team and every project. For analyzing performance, the progress of no two teams can be compared based on story points or velocity, and no single team can compare their story points or velocities from one project to the next.

Think About It. Consider this scenario. A hybrid team is using story points to track their velocity on a rewrite of a customer account management website. The team is using short iterations and demos to deliver functionality in a largely predictive organization. After the steering committee learned the team was using story points and velocity to track their progress, they focused on the weekly velocity figures.

If the points completed did not increase each week, the team was asked to explain. Consciously or unconsciously, the team started to inflate their story point estimates for work. That way, they would have more points to report as complete each week. A screen that might have been originally estimated as three points became five. However, the points were now meaningless to the team since they could not compare current to past performance. Questions like "are these five new points or five old points?" became common wastes of time.

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To reset the process, the team used affinity estimation to compare and reset new stories with the point value from previous stories of comparable size and complexity. Story point inflation was reversed, and points became useful for the team once more. The project manager explained the situation to the steering committee, who agreed not to focus on weekly velocity but to use velocity only to track actual versus planned project progress across iterations toward a scheduled release. The project manager no longer showed detailed velocity metrics to management but instead used graphics like the following burndown chart. Figure 8.21 shows project progress over 4 iterations. It turns data into information, using velocity but better representing project progress than would focusing on the actual velocity data.

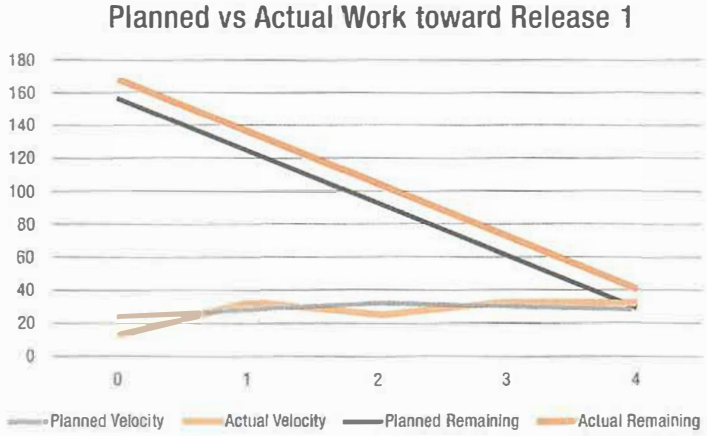

FIGURE 8.21 *Progress tracking burndown chart*

Outputs of Developing the Plan-driven Schedule

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

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Milestone Charts

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 8.22.

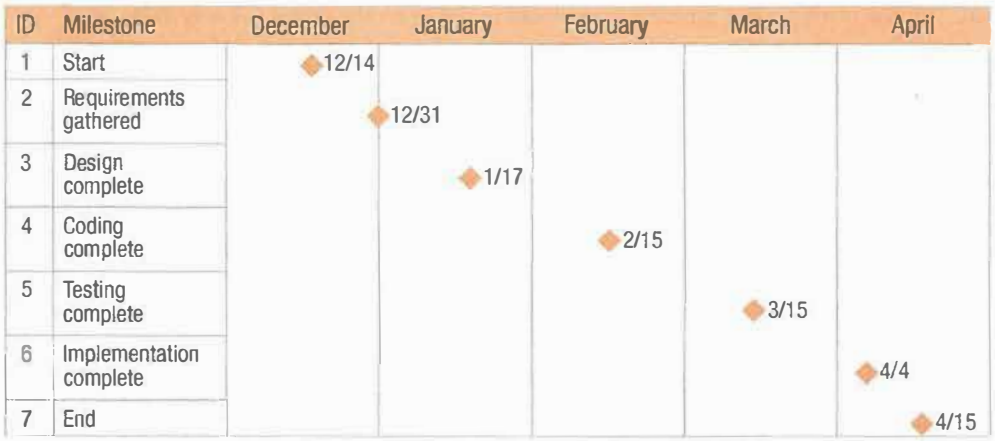

FIGURE 8.22 *Milestone chart*

Bar Charts

Bar charts are weak planning tools, but they are effective for progress reporting and control. They are not project management plans. The velocity tracking chart in figure 8.20 is a bar chart.

Schedule Baseline

The schedule baseline is the approved version of the schedule model used to manage the project; what the project and team performance is measured against. On plan-based projects the baseline can only be changed as a result of formally approved changes. 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. Agile projects tend to have a "moving baseline" for velocity but it is assumed that this will soon stabilize after a few iterations. Agile project schedules are normally baselined since exact scope is negotiable.

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 progresses, 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.

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.

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8.6 Exercise

Test yourself! In your Exercise Notebook, record the answers to the following questions.

1. Under what circumstances would you use a network diagram?
2. Under what circumstances would you use a milestone chart?
3. Under what circumstances would you use a bar chart?

Answer

1. To show interdependencies between activities; to calculate the critical path; to show the length of the project
2. To report to senior management
3. To track progress; to report to the team

Control Schedule

Process Groups Model
PG: Monitoring and Controlling
Process: Control Schedule

ECO
Domain II
Task 6 Plan and manage schedule

PMBOK® Guide
Domain 2.7 Measurement

A major measure of project (and project manager) success is the schedule baseline—the end date agreed to in planning and adjusted for approved changes—being met. Monitoring and controlling efforts and taking preventive and corrective action throughout the project keeps it in line with the plan. This is as important to the project's success as planning it well.

Schedule control includes looking for the things that are causing preventable changes and influencing the sources, or root causes, of the changes.

Example There is one person or one piece of work causing a lot of changes. This is a signal that the project manager and team need to evaluate it and do something about it rather than letting the issues and the high number of changes continue. Using diligence and being proactive is the key to success.

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.

Think of schedule control as 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. The following are some activities that can be used to help 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 Management discussion in the "Budget and Resources" 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 leads and lags, crashing, and fast tracking).
- Consider adjusting 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.

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- 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 "Budget and Resources" 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.

Methods for Control Schedule

Although the project manager did their best to understand the project well enough to estimate it sufficiently in planning, there are always changes that occur during a project that impacts those plans. Measuring performance on a regular basis, using schedule compression methods where necessary, and reestimating as needed are common methods of adjusting for normal changes to time management on projects.

Measurement

The schedule itself has a natural set of metrics with which to measure progress. Traditional EVM is a common practice on plan-driven projects and agile teams use velocity to constantly measure actual progress against planned, and adjust as needed. Agile teams also use burnup and burndown charts to measure overall project progress.

Reestimating

It is standard practice to reestimate the remaining work at planned times and whenever it seems prudent. This is how the project manager makes sure they can still satisfy the project objectives within the schedule, budget, and other project constraints, and adjust the performance measurement baseline if they cannot.

Artifacts of Control Schedule

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" chapter. On agile projects, again, it is most often scope—features and functions—that are renegotiated if, as usual, schedule is to be kept stable and the team is behind when measured against the plan.

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.

Putting It All Together

Were you surprised at the amount of effort it takes to plan and manage a project schedule? It is the project manager's responsibility to create a realistic schedule and to monitor and control it. For the exam, make sure you understand the precedence diagramming method and know how estimating is done in both predictive and adaptive environments. Go through the Quicktest at the beginning of the chapter again to help identify any gaps in your knowledge. Review the concepts you are still unsure about.

Complete the following exercises based on our library case study.

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8.7 Exercise

Review the list of work the project manager needs to do to create the project schedule. Here or in your Exercise Notebook indicate the order in which this work should be completed by placing the letter assigned to each item into the order table below. Also indicate which process this work describes.

A. Each of the stakeholders or team members who are responsible for an activity will be responsible for determining how long the activity should take.

B. The project manager will bring together the architect, construction team lead, librarian, and the other team members to review the work breakdown structure and determine the activities needed to complete the project.

C. The project manager needs to think about who will be needed to complete the project and how to measure performance

D. All the activities will be plotted onto a calendar based on the availability of the person assigned to complete it.

E. The team will discuss each activity required and identify its predecessors and successors.

Order	Work	Process Groups Model Name
1st		
2nd		
3rd		
4th		
5th		

Answer

Order	Work	Process Groups Model Name
1st	C	Plan Schedule Management
2nd	B	Define Activities
3rd	A	Sequence Activities
4th	E	Estimate Activity Duration
5th	D	Develop Schedule

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8.8 Exercise

Try this exercise based on a case study using adaptive tools.

The library software application needs to be upgraded. A backlog of requested features has been collected and prioritized in the following backlog. Review this list and with the information provided, draft a Product Roadmap with three releases. Each release should include an extra feature if the team has time (stretch goal). Be sure to consider the dependencies.

Backlog

Feature#	Feature	Priority	Dependencies	Estimate (est.)
1	Map of library	High	None	1 story points
2	Collect patron profile information	Med	None	3 story points
3	Allow patron to set up login id and password	High	2	5 story points
4	"Resume Builder"	High	3	5 story points
5	"Job application cover letter builder"	Med	4	3 story points
6	Connect to popular job boards	Med	None	5 story points each
7	Search by author name	Med	None	3 story points
8	Search by book title	High	None	5 story points
9	Search by magazine article title	Med	None	8 story points
10	Ability to join a book club	Med	11	3 story points
11	Ability to add a new book club	Med	3	5 story points

Product Roadmap

	Release 1		Release 2		Release 3	
	Feature	Est.	Feature	Est.	Feature	Est.
High priorities						
Total						
Stretch goal						
Total with Stretch						

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Answer

Does your product roadmap look like this? In parentheses is the feature number for each story. If you have variations, make sure that you understand the differences and think about why your version is a plausible way to approach the project as well as why ours is a plausible version of completing the project.

	Release 1		Release 2		Release 3	
	Feature	Est.	Feature	Est.	Feature	Est.
High priorities	Map of library (1)	1	Search by book title (8)	5	Connect to first job board (6)	5
	Collect patron profile (2)	3	"Resume Builder" (4)	5	"Job application cover letter builder" (5)	3
	Allow patron to set up login id and password (3)	5	Ability to add a book club (11)	5	Ability to join a book club online (10)	3
Total		9		15		11
Stretch goal	Search by magazine article titles (9)	8	Search by author name (7)	3	Connect to second job board (6)	5
Total with Stretch Goal		17		18		16

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