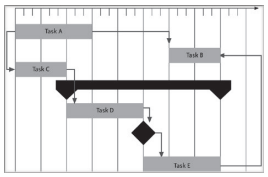
The last process, Control Schedule, is in the Monitoring and Controlling process group.

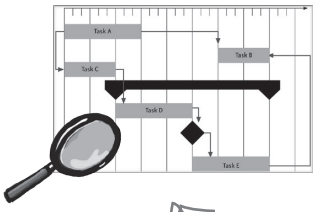
5 Develop Schedule



Then you build a schedule from all of the estimates and the resource and activity information you've created.

The schedule pulls all of the information together to predict the project end date.

6 Control Schedule



Finally, you monitor and control changes to the schedule to make sure that it is kept up to date.

Keeping track of the issues that require schedule changes and dealing with them is as important in Schedule Management as it was in Scope Management.

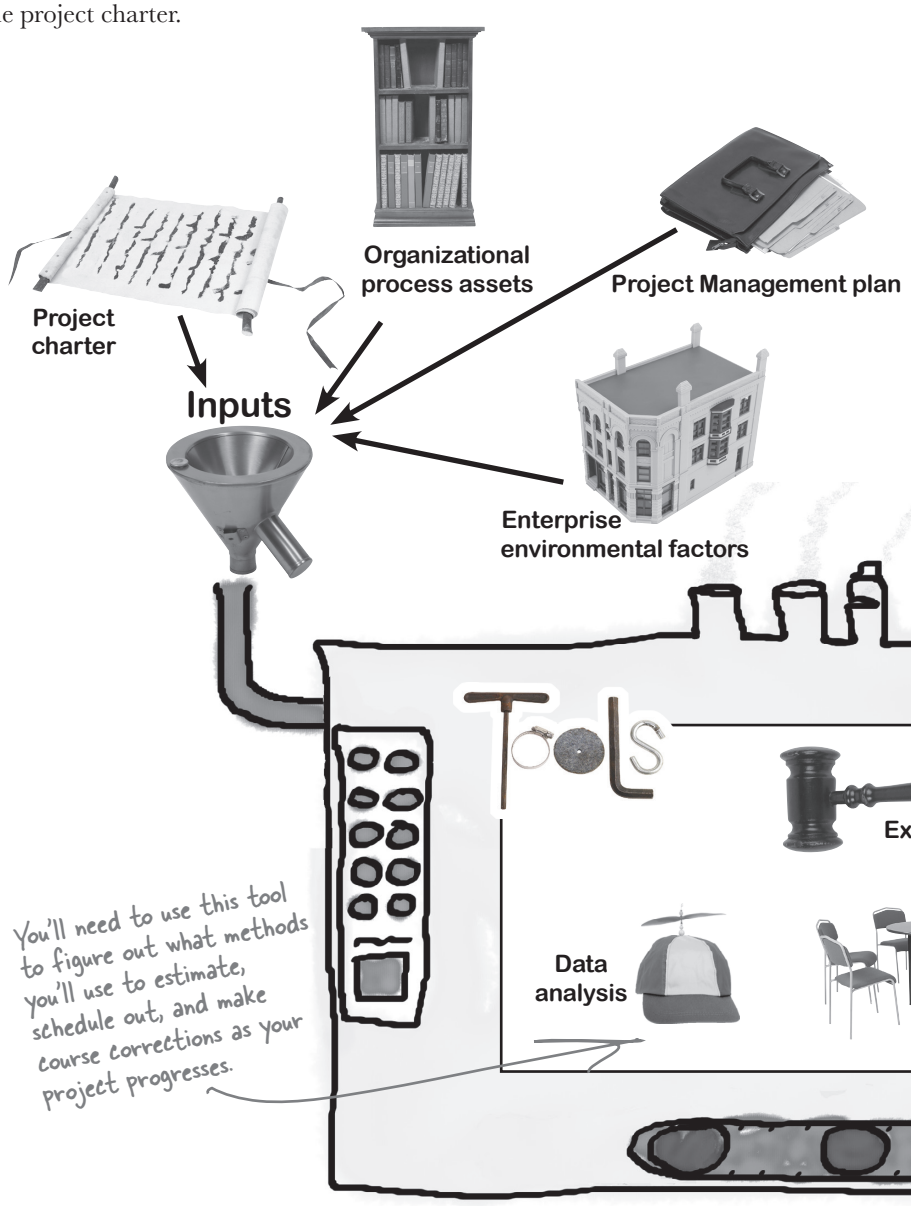
The first five Project Schedule Management processes are in the Planning process group because they're all about coming up with the schedule—and you need that before you can start executing your project.

Project Schedule Management is all about breaking the work down into activities, so you can put them in order and come up with estimates for each of them.

What do you need to know before you can figure out what activities are needed for a project?

Plan your scheduling processes

The **Plan Schedule Management** process is just like all of the other planning processes you've seen so far. In fact, you've already seen all of the inputs and tools that are used to create it in previous processes. Just like with the Plan Scope Management process from Chapter 5, your goal is to build a Schedule Management plan from the other project management plans, your company's culture and existing documents, and the project charter.



Now you know how you'll track your schedule

The only output of the Plan Schedule Management process is the Schedule Management plan. It describes the way you'll estimate your work, track your progress, and report on it.

Outputs

Rob and Rebecca's Wedding
Schedule Management Plan

Project Schedule Model Development: Kathleen will create a schedule model for the wedding using Microsoft Project. It will be stored in an open document repository and updated on a weekly basis. The initial schedule will be based on high-level estimates that will be refined at set intervals as requirements are defined for the project. The schedule will be baselined whenever a change request is approved, and also at the following milestones:

Scope Statement Complete
Venue Booked
Invitations Sent
RSVPs Received
Bridesmaids

Level of Accuracy: The initial schedule model is expected to be accurate by +/– 10%. As each week passes, the schedule update increases the level of accuracy because the team knows more and more about the project. At the time of RSVPs received, the schedule model will be +/– 3% accurate. This possible 15% overage will be included in the team's overall estimate as a contingency to assist in risk mitigation.

Units of Measure: All estimates will be provided in calendar days.

Organizational Procedures Links: The project schedule model will follow the organizational outline provided by the WBS. All schedule status reports will follow the format provided in the WBS as well.

Project Schedule Model Maintenance: On a weekly basis, Kathleen will update the project schedule model with individual % complete numbers on tasks to keep the schedule up to date.

Reporting Formats: Every Thursday, Kathleen will host a weekly status meeting to discuss how the project is tracking to its estimates with Rob and Rebecca. The status report for this meeting will follow the standard wedding planning status report template.

Use the Define Activities process to break down the work

Define Activities uses everything we already know about the project to divide the work into activities that can be estimated. The inputs for this process all come from the processes in the Integration Management knowledge areas. The first step in Project Schedule Management is figuring out how the project work breaks down into activities—and that's what the **Define Activities** process is for.

The Schedule Management plan was the output of the last process. It tells you the methods to use when you define the activities in your schedule.

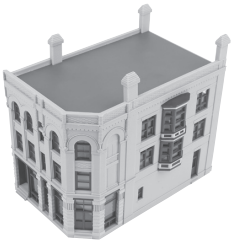
Project Management plan

The Project Management plan includes the scope baseline that we covered in Chapter 5. The WBS and WBS dictionary are important considerations when you're defining the activities you'll do in your project

You might want to look at all of the lessons from similar projects your company has done to get a good idea of what you need to do on the current one.

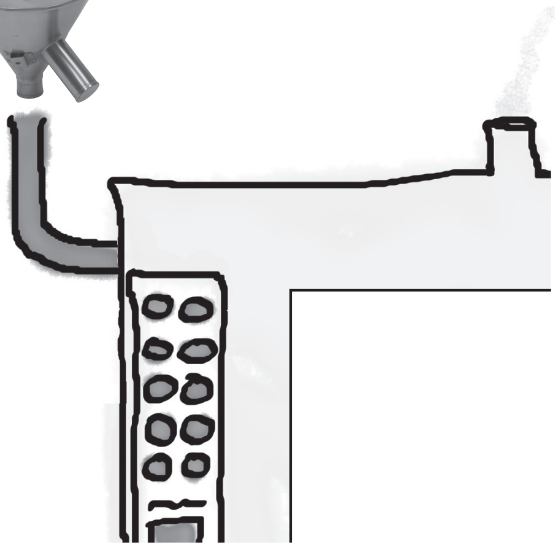
Organizational process assets

Inputs



Enterprise environmental factors

You'll need the project management information system (PMIS), because that's where you store information about your activities. But that's not the only thing you need to know about your working environment. Can you think of other environmental factors that influence the way you break down the work?



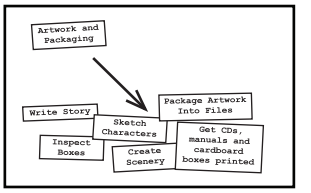
Tools and techniques for Define Activities

Kathleen wrote down everything she knew about the project. She used the activity list from her last wedding as a guide and then thought about the things that Rob and Rebecca wanted that were different from her past projects. She broke those things down into activities and pulled everything together into an activity list.

This "Tools" icon means we're showing you the tools and techniques for the process. Get the picture?

Decomposition

This means taking the work packages you defined in the Scope Management processes and breaking them down even further into activities that can be estimated.



Expert judgment

Ask somebody who has done this before to give an opinion on what activities will be needed to get the job done.

Rolling wave planning

When you plan this way, you decompose only the activities that you need to plan for because they're coming up soon. You leave everything else planned at the milestone level until it gets closer to the time when you'll do it.

Flip the page for an example of this tool!

Meetings

You'll need to talk to the team to figure out what they think they need to do to achieve your project's goals. Getting the team together to discuss the plan will be a useful tool when you're defining the activities in your schedule.

Rolling wave planning lets you plan as you go

Sometimes you start a project without knowing a lot about the work that you'll be doing later. **Rolling wave planning** lets you plan and schedule only the stuff that you know enough about to plan well.

If Kathleen were using rolling wave planning, she might write a schedule for only the tasks it takes to do the invitations, and leave the planning for the menu and the seating up in the air until she knows who will RSVP.

Rob and Rebecca probably wouldn't be happy hearing that Kathleen was only going to plan for the invitations to be sent, though. They want to know that their wedding is going to happen on time. That's why rolling wave planning should be used only in cases where it's not possible to plan any other way.

Think back to the definition of a project in Chapter 2. Remember how projects are **progressively elaborated**? Rolling wave planning takes advantage of the fact that you know more about the project as you go to make plans more accurate.

there are no Dumb Questions

Q: How would you use experts to help you define tasks?

A: A wedding is something that a lot of people have experience with, but some projects are not as easy to get a handle on. If you were asked to manage a project in a new domain, you might want to ask an expert in that field to help you understand what activities were going to be involved.

Even in Kathleen's case, access to a catering expert might help her think of some activities that she wouldn't have planned for on her own.

It could be that you create an activity list and then have the expert review it and suggest changes. Or, you could involve the expert from the very beginning and ask to have a Define Activities conversation with him before even making your first draft of the activity list.

Q: I still don't get rolling wave planning.

A: One way to develop a project is to divide it up into phases of work, and gather requirements for each phase as the previous one is completed. Sometimes projects are done iteratively, where you divide the work up into phases and then plan out each phase before you execute on it. Rolling wave planning is all about committing to planning out one portion of the work that you'll do, executing it, and then moving on to the next portion.

Software projects using **agile methodologies** use a form of rolling wave planning to make sure that everything they sign on to do gets done. They might do user stories for a release of the software up front, build it, and deliver it, and then gather more requirements based on the users' ideas after working with the released version.

Activity Magnets

Here is part of a WBS. Arrange the activities underneath the WBS to show how the work items decompose into activities.

This is one work package from the wedding WBS. How does it decompose into activities?

This is part of the WBS that Kathleen made for the wedding project.

1. .....
2. .....
3. .....

1. .....
2. .....
3. .....
4. .....

1. .....
2. .....
3. .....
4. .....

Shop for shoes

Shop for dress

Mail the invitations

Finalize the menu

Create the guest list

Find caterer

Print the invitations

Arrange tailoring and fitting

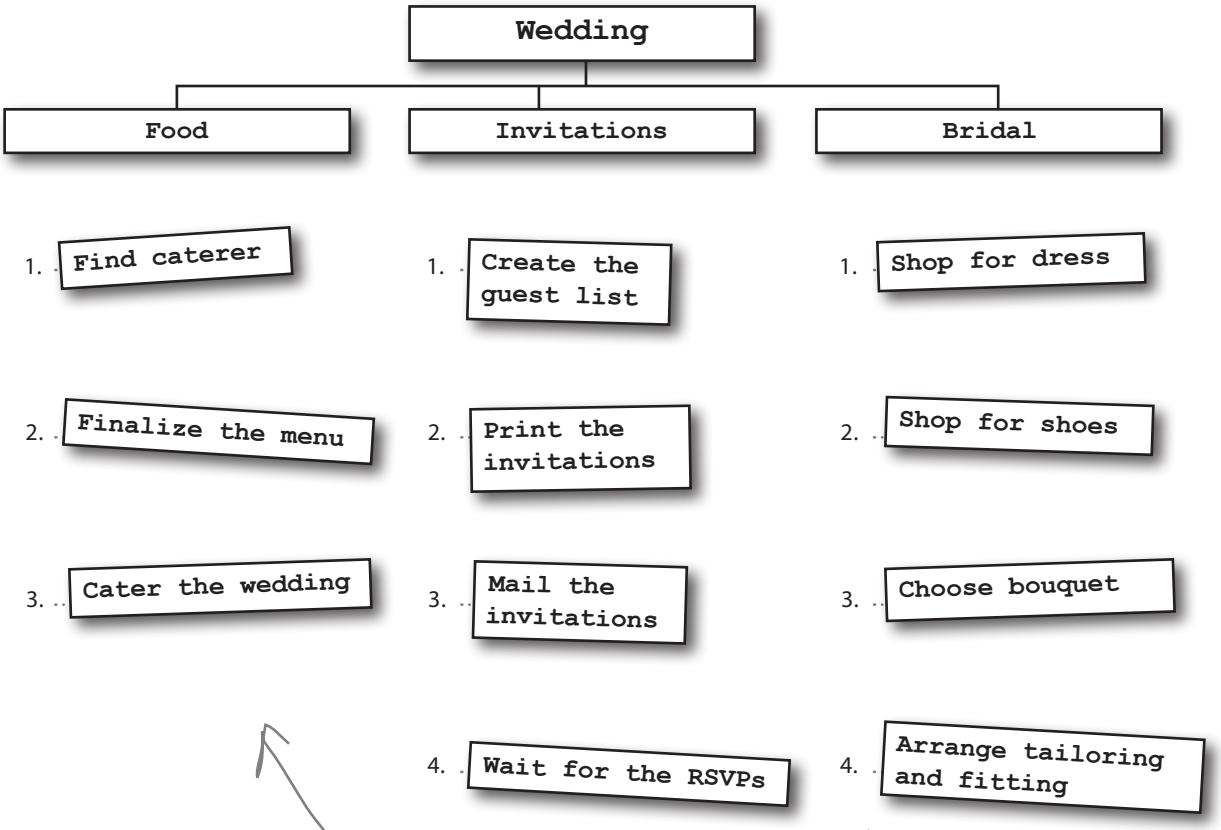
Cater the wedding

Choose bouquet

Wait for the RSVPs

Activity Magnets Solution

Here is part of a WBS. Arrange the activities underneath the WBS to show how the work items decompose into activities.



There are lots of other activities that could be defined for the three work packages in Kathleen's WBS.

The important thing to remember about activities, though, is that they are broken down to the level at which they can be estimated accurately.

Define activities outputs

The main output of this process is the **activity list**. It's the basis for all of the estimation and scheduling tasks you will do next. But there are a few other outputs that go along with it, and help to make the estimates more detailed and accurate.

Outputs

Activity list

This is a list of everything that needs to be done to complete your project. This list is lower-level than the WBS. It's all the activities that must be accomplished to deliver the work packages.

Activity list

Activity attributes

Here's where the description of each activity is kept. All of the information you need to figure out the order of the work should be here, too. So any predecessor activities, successor activities, or constraints should be listed in the attributes, along with descriptions and any other information about resources or time that you need for planning.

Activity attributes

Milestone list

Some milestones for the wedding:

* Invitations sent
* Menu finalized
* Church booked
* Bridesmaids' dresses fitted

All of the important checkpoints of your project are tracked as milestones. Some of them could be listed in your contract as requirements of successful completion; some could just be significant points in the project that you want to keep track of. The milestone list needs to let everybody know which are required and which are not.

Milestone list

Change requests

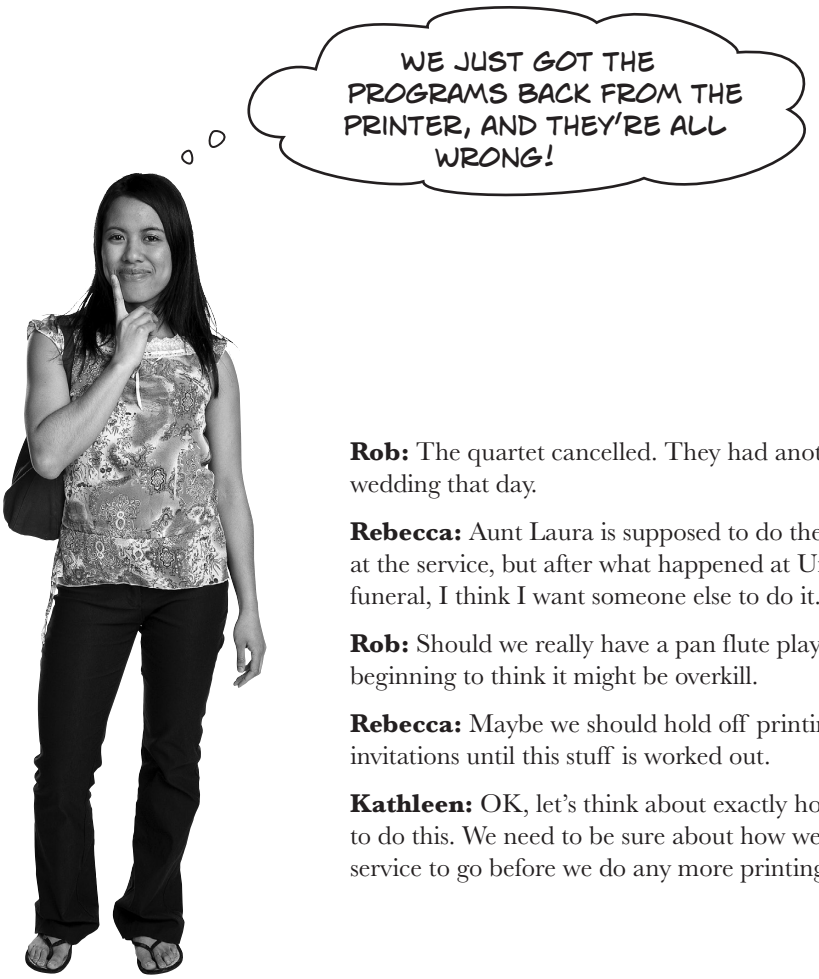
As the team is working through the work they'll do, they sometimes find new information about the scope or requirements of the project. When that happens, they'll need to create a change request to update the scope of the project.

Change requests

Project Management plan updates

When the team identifies new activities there will likely be changes to both the **schedule baseline** and the **cost baseline**. You'll need to put those changes through change control and then update the Project Management plan to include the new activities.

Project Management plan updates



Rob: The quartet cancelled. They had another wedding that day.

Rebecca: Aunt Laura is supposed to do the reading at the service, but after what happened at Uncle Stu's funeral, I think I want someone else to do it.

Rob: Should we really have a pan flute player? I'm beginning to think it might be overkill.

Rebecca: Maybe we should hold off printing the invitations until this stuff is worked out.

Kathleen: OK, let's think about exactly how we want to do this. We need to be sure about how we want the service to go before we do any more printing.

The Sequence Activities process puts everything in order

Now that we know what we have to do to make the wedding a success, we need to focus on the order of the work. Kathleen sat down with all of the activities she had defined for the wedding and decided to figure out exactly how they needed to happen. That's where she used the **Sequence Activities** process.

The **activity attributes** and the **activity list** she had created had most of the predecessors and successors written in them. Her **milestone list** had major pieces of work written down, and there were a couple of changes to the scope she had discovered along the way that were approved and ready to go.

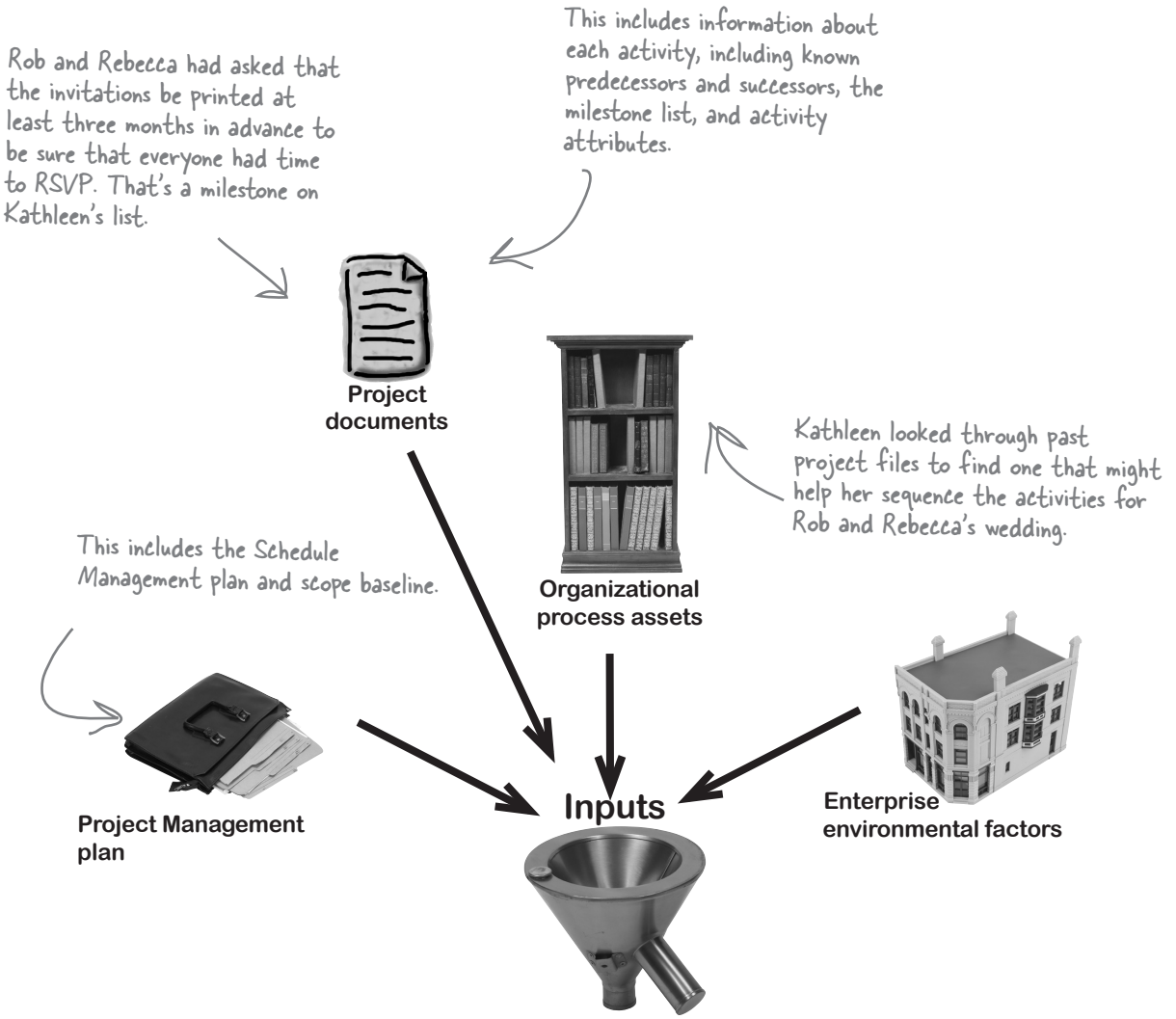
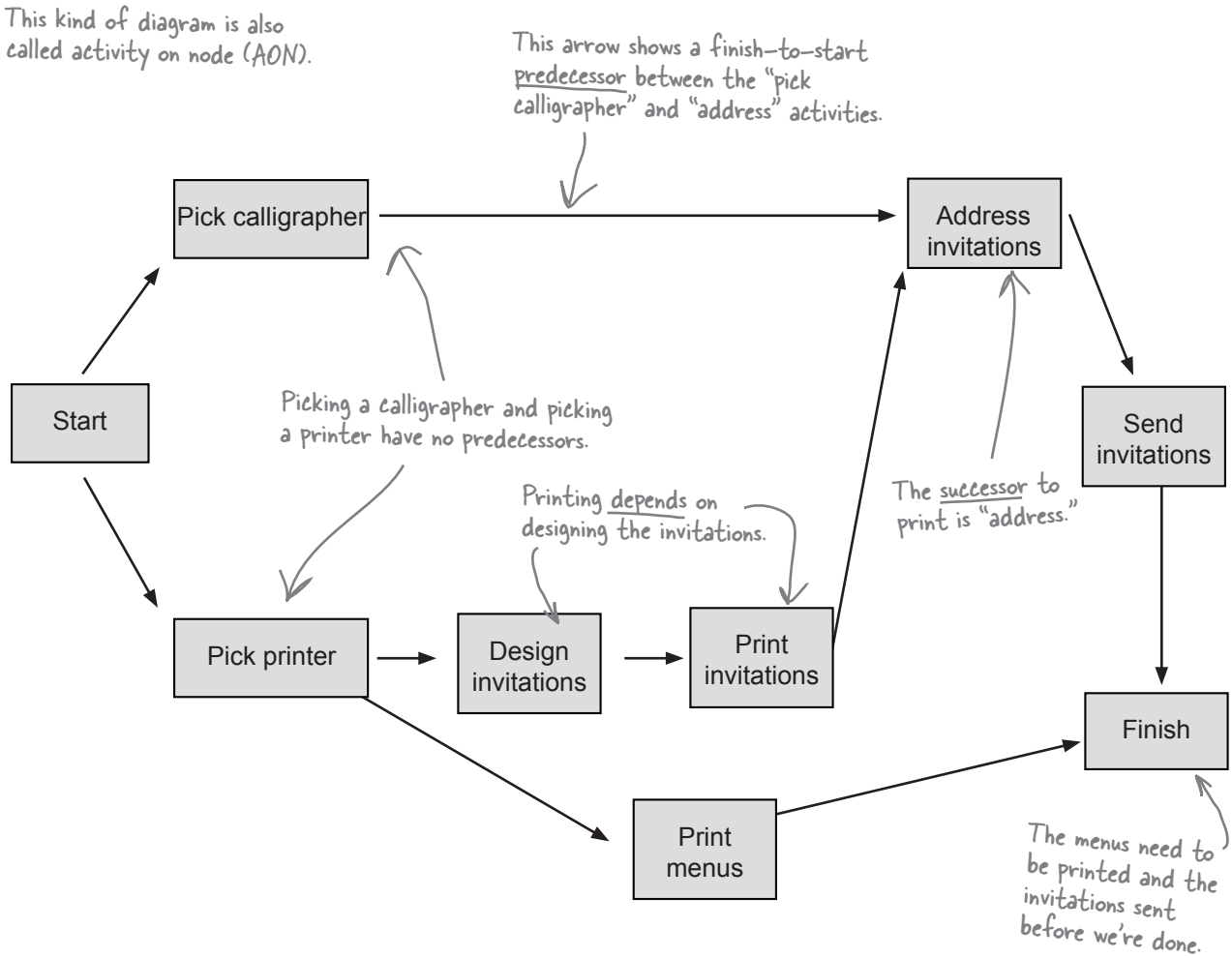


Diagram the relationship between activities

One way to visualize the way activities relate is to create a **network diagram**. Kathleen created this one to show how the activities involved in producing the invitations depend on one another.

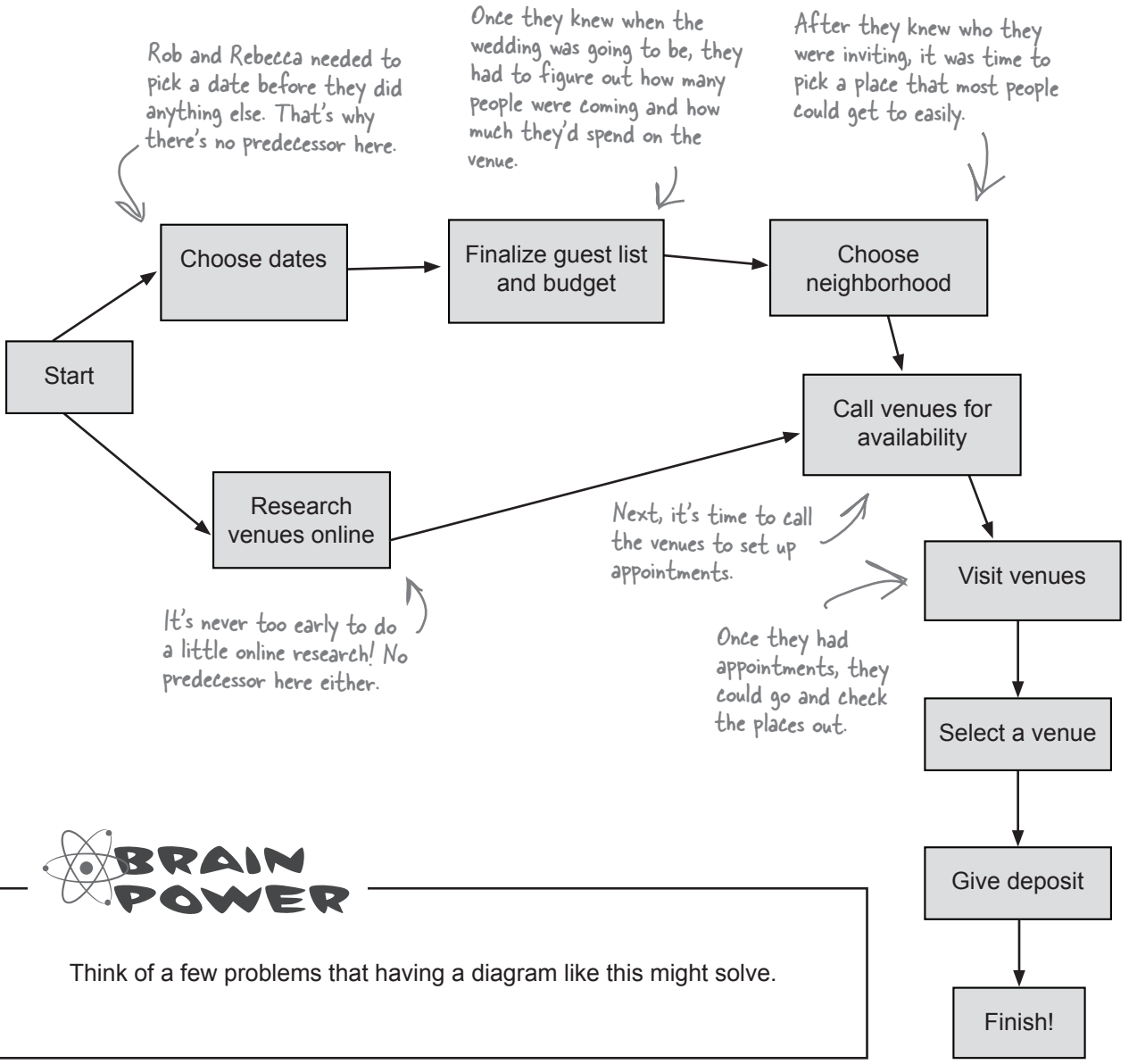
For example, the calligrapher is the person who's hired to write the addresses on the invitations, so Rob and Rebecca need to pick one before the invitations can be addressed. But the invitations also need to be printed before they can be addressed, because otherwise the calligrapher won't have anything to write on! See how predecessors can get all complicated? Luckily, a diagram makes sense of them!

Showing the activities in rectangles and their relationships as arrows is called a **precedence diagramming method** (**PDM**).



Network diagrams put your tasks in perspective

Just looking at the way all of these tasks relate to one another can help you figure out what's important at any time in the project. Once Rob and Rebecca looked at the network diagram below, they realized they needed to get online and start looking for a venue for their wedding right away, even before they'd figured out their budget and guest list.



Think of a few problems that having a diagram like this might solve.

Sharpen your pencil

You'll need to know how to turn a table of nodes into a network diagram, so here's your chance to get some practice! Here's a list of nodes for a PDM network diagram. Try drawing the diagram based on it:

Name	Predecessor
Start	—
A	Start
B	A
C	B
D	Start
E	D
F	B
G	C
H	D
I	E, H
Finish	F, G, I

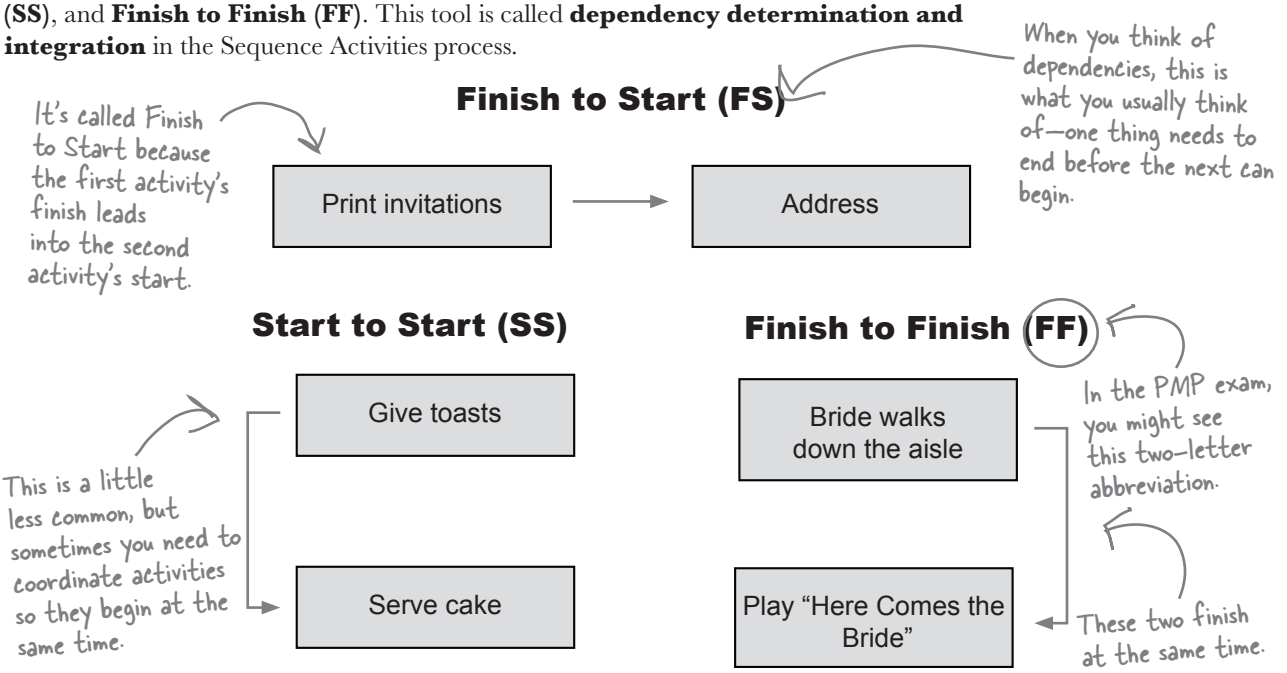
Now try another one!

Name	Predecessor
Start	—
1	Start
2	1
3	2
4	Start
5	3
6	Start
7	6
Finish	7, 4, 5

Answers on page 336.

Dependencies help you sequence your activities

The most common kind of dependency is the Finish to Start. It means that one task needs to be completed before another one can start. There are a few other kinds of dependencies, though. They can all be used in network diagrams to show the order of activities. The three main kinds of dependency are **Finish to Start** (**FS**), **Start to Start** (**SS**), and **Finish to Finish** (**FF**). This tool is called **dependency determination and integration** in the Sequence Activities process.



External dependencies

Sometimes your project will depend on things outside the work you are doing. For the wedding, we are depending on the wedding party before us to be out of the reception hall in time for us to decorate. The decoration of the reception hall then depends on that as an external dependency.

Discretionary dependencies

Rob and Rebecca really want the bridesmaids to arrive at the reception before the couple. There's no necessity there—it's just a matter of preference. For the exam, know that you should set discretionary dependencies based on your knowledge of the best practices for getting the job done.

Mandatory dependencies

You can't address an invitation that hasn't been printed yet. So, printing invitations is a mandatory dependency for addressing them. Mandatory dependencies are the kind that have to exist just because of the nature of the work.

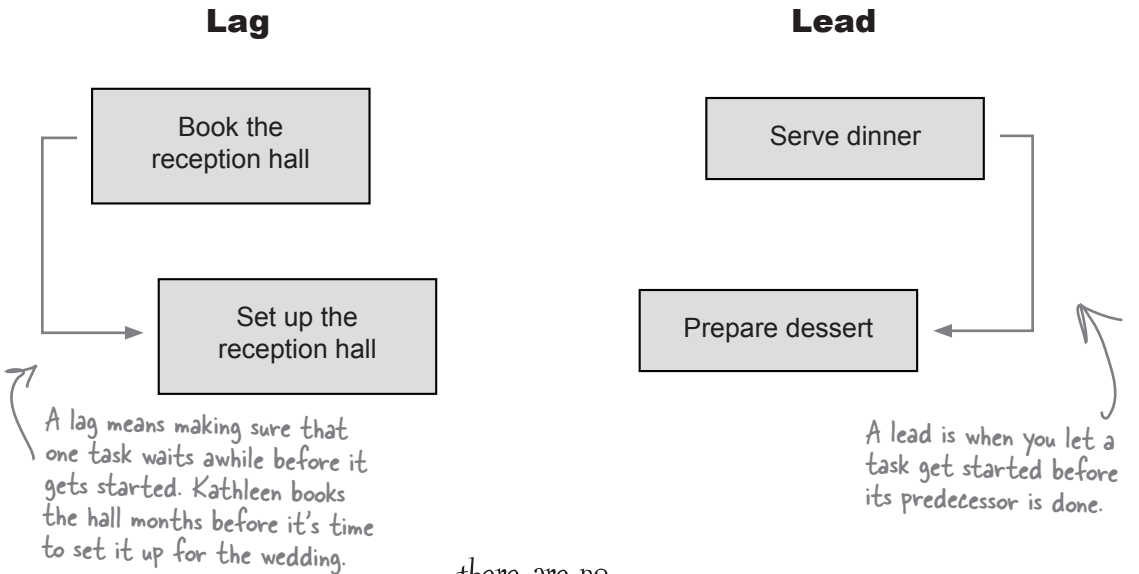
Internal dependencies

The rehearsal dinner can't begin until the happy couple leaves the church. Some dependencies are completely within the team's control.

Leads and lags add time between activities

Sometimes you need to give some extra time between activities. **Lag time** is when you purposefully put a delay between the predecessor task and the successor. For example, when the bride and her father dance, the guests wait awhile before they join them.

Lead time is when you give a successor task some time to get started before the predecessor finishes. So you might want the caterer preparing dessert an hour before everybody is eating dinner.



there are no Dumb Questions

Q: Where do you get the dependency information to figure out your network diagram?

A: Your **activity attributes** should list the predecessors and successors for each activity. As you build the network diagram, you might discover new dependencies as well. Your project team will determine the dependencies necessary for each of the activities.

Q: What about Start to Finish dependencies?

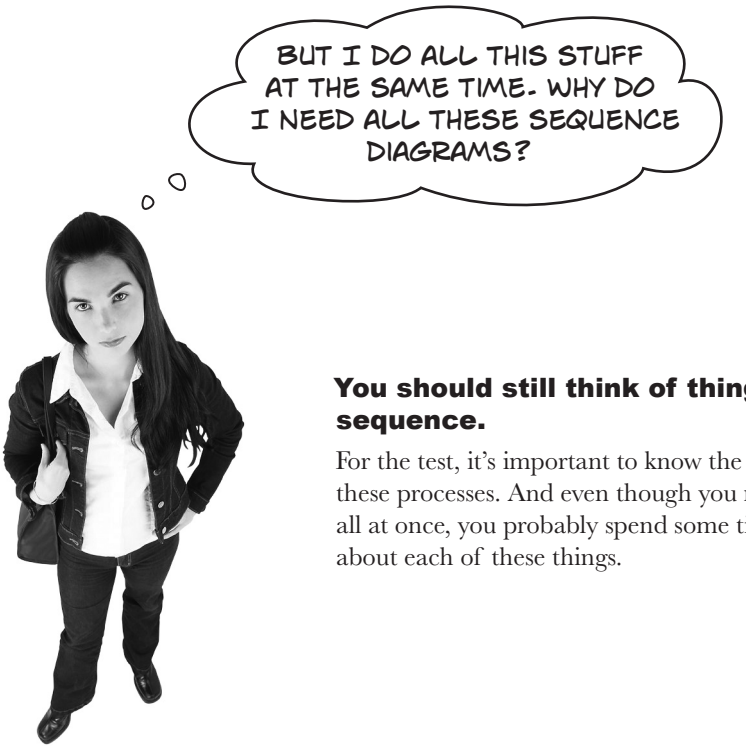
A: It's possible for activities to require that a task has been started before it can finish. An example might be that singing couldn't start until after the music had started. But tasks like that are pretty rare and almost never show up in network diagrams.

Q: My scheduling software makes network diagrams for me. Why do I need to know this?

A: Most scheduling software does create one of these diagrams automatically. But spending the time to think through your dependencies and examine them visually can really help you find places where you might need to give some tasks more priority if you want to get your project done on time. So you should know how to make them too.

Scheduling software can help you see the sequence of activities

Many people use applications like Microsoft Project to visualize their activity list and organize their dependencies. Taking the time to really understand the best sequence of activities can have a real impact on your project's deadlines, so using software like that as part of your company's **project management information system** is a good way to get a handle on just the right sequence for your project to run efficiently.



You should still think of things in sequence.

For the test, it's important to know the order of these processes. And even though you might do it all at once, you probably spend some time thinking about each of these things.

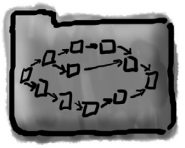
What's the advantage of thinking about Define Activities and Sequence Activities separately?

Create the network diagram

As you sequence the activities, you will find new activities that need to be added and new attributes for activities that you didn't know about. So, while the main product of this process is the network diagram, you also produce updates to some of the Define Activities documents and outputs of other processes, too.

Outputs

For the test, you won't need to know exactly which documents change as an output to this process. All you need to know is that project document updates are an output.



Project schedule network diagrams

Here's where you work out how all of the tasks fit together based on their predecessors and determine the critical path through the project.

Project documents updates

When you've sequenced your activities, you might find that some of the documents you've created as part of other processes need to be updated. The *PMBOK® Guide* calls documents like these "project document updates." The pictures to the right are some examples, but there could be other documents that require updates as well.

Activity attributes updates

Sometimes sequencing will show that two tasks rely on each other. If you find new predecessors or successors, their attributes will need to be changed.

Assumption log

When you sequence your activities, you might find that the assumptions you made when you initiated the project have proven incorrect. That's why you would want to update the assumption log once you've made a decision about the order of activities.

Activity list updates

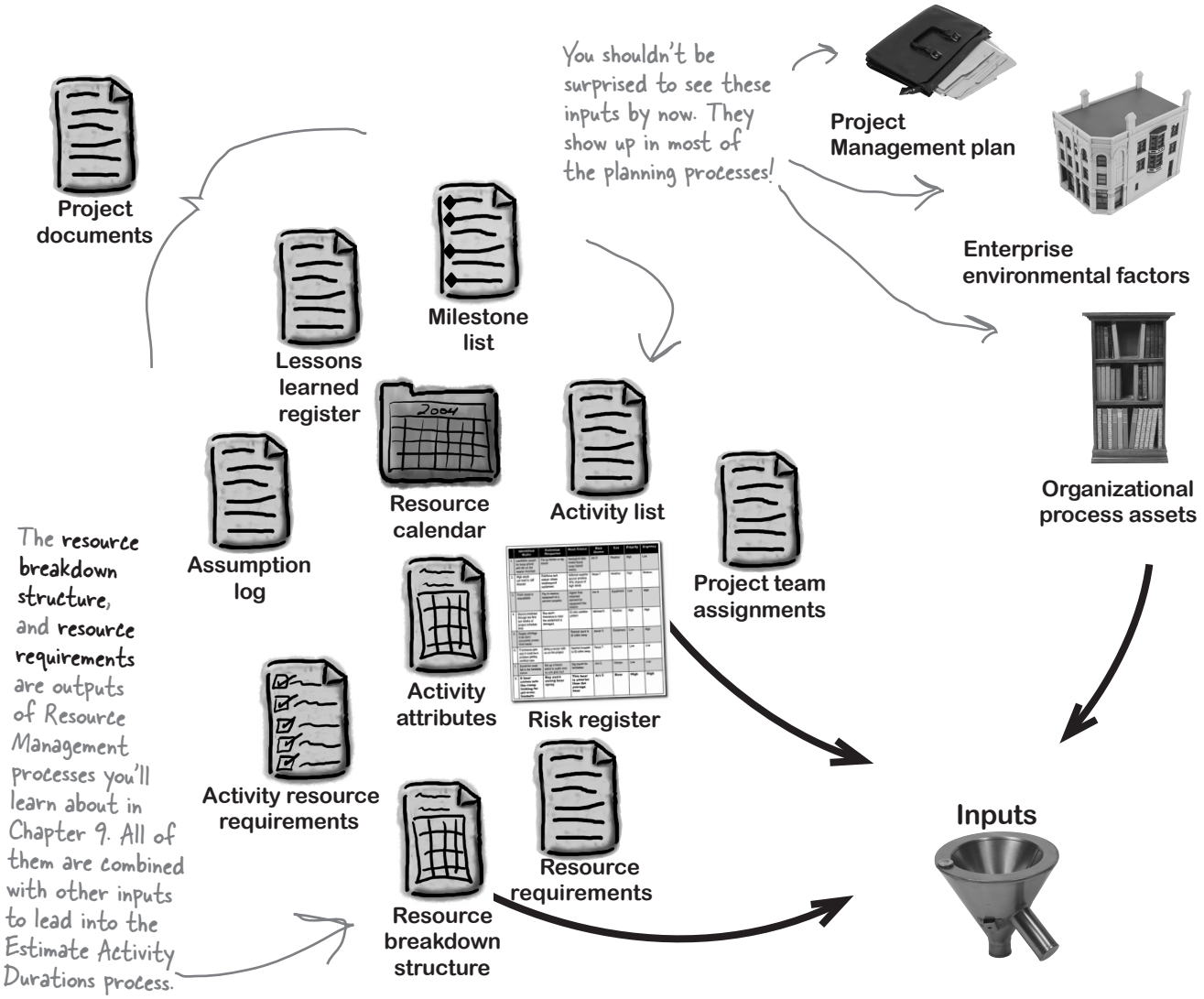
If you find a new activity while sequencing, updates need to be made to the activity list.

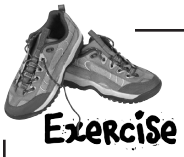
Milestone list

When you sequence your activities, you can find new milestones that you can use to measure interim progress.

Figuring out how long the project will take

Once you're done with Sequence Activities, you've got everything you need to figure out how long each activity will take. That's done in a process called **Estimate Activity Durations**. This is where you look at each activity in the activity list, consider the scope and the resources, and estimate how long it will take to perform.





You'll need to understand the various inputs and outputs for each process for the exam. Here's a list of some of the project documents and other inputs for Estimate Activity Durations. Write down what you think each of them will be used for when you actually sit down and estimate how long each activity will take.

1. Activity list and activity attributes

2. Activity resource requirements

3. Project scope statement

4. Enterprise environmental factors

5. Organizational process assets

You'll need to understand the various inputs and outputs for each process for the exam. Here's a list of some of the inputs for Estimate Activity Durations. Write down what you think each of them will be used for when you actually sit down and estimate how long each activity will take.

1. Activity list and activity attributes

Contains information about the activities that are being estimated

You need these because the goal of this process is to estimate the duration of each activity.

2. Activity resource requirements

Shows which resources are assigned to each activity

The more resources you add to an activity, the less time it takes.

But sometimes adding people won't get the job done any faster! Remember, nine women can't have a baby in one month.

3. Project scope statement

Lists constraints and assumptions for each activity

You're probably not the first person in your company to do this sort of project. Information from people around you will be very valuable when you're creating estimates.

This input is always about looking elsewhere in your organization for information.

4. Enterprise environmental factors

Other people or databases in my company can help with estimation

Any time you see this, think about historical information and project records!

The more you know about how past projects went, the more accurate your estimates will be.

5. Organizational process assets

Contains historical information and records from past projects

Estimation tools and techniques

Estimating the duration of an activity means starting with the information you have about that activity and the resources that are assigned to it, and then working with the project team to come up with an estimate. Most of the time you'll start with a rough estimate and then refine it (maybe a few times!) to make it more accurate. You'll use these tools and techniques to create the most accurate estimates.

Expert judgment will come from your project team members who are familiar with the work that has to be done. If you don't get their opinion, then there's a huge risk that your estimates will be wrong!

Parametric estimating means plugging data about your project into a formula, spreadsheet, database, or computer program that comes up with an estimate. The software or formula that you use for parametric estimating is built on a database of actual durations from past projects.

Bottom-up estimating means building your estimates up based on individual estimates from the people who will do the work.

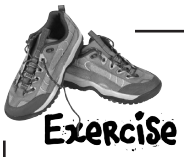
Data analysis means using **reserve analysis** to add extra time to the schedule (called a *contingency reserve* or a *buffer*) to account for extra risk. It can also mean using **alternatives analysis** to think through all of the possible options to find the most efficient path for delivery.

Analogous estimating is when you look at activities from previous projects that were similar to this one and see how long it took to do similar work for them. But this only works if the activities and the project team are similar!

Three-point estimates are when you come up with three numbers: a **most likely** estimate that probably will happen, an **optimistic** one that represents the best-case scenario, and a **pessimistic** one that represents the worst-case scenario. The final estimate is the average.

Decision-making techniques help the team decide on the best estimates for the activities they've defined.

Meetings help teams to work together when they estimate the work.



Each of these scenarios describes a different tool or technique from Estimate Activity Durations. Write down which tool or technique is being described.

1. Kathleen comes up with three estimates (one where everything goes wrong, one where some things go wrong, and one where nothing goes wrong) for printing invitations, and averages them together to come up with a final number. .....

2. There will be two different catering companies at the wedding. Kathleen asks the head chef at each of them to give her an estimate of how long it will take to do the job. .....

3. There's a spreadsheet Kathleen always uses to figure out how long it takes guests to RSVP. She enters the number of guests and their zip codes, and it calculates an estimate for her. .....

4. Kathleen's done four weddings that are very similar to Rob and Rebecca's, and in all four of them it took exactly the same amount of time for the caterers to set up the reception hall. .....

Answers on page 333.

Three-Point Estimates Up Close

PERT (Program Evaluation Review Technique) is the most common form of three-point estimation. It's a technique that was developed in the 1960s by consulting firms working with the US government as a way of getting more accurate project duration predictions up front. To do a PERT estimate, you start with three estimates—pessimistic, most likely, and optimistic estimates. (The formula used for PERT estimates is called *beta distribution*.) Since the pessimistic and optimistic estimates are less likely to happen than the normal estimate, the normal estimate is weighted (multiplied by 4) and added to the optimistic and pessimistic estimates, and then the whole thing is divided by 6 to give an expected duration. The formula looks like this:

$$\left(\text{Optimistic duration} + 4\,\text{Most likely duration} + \text{Pessimistic duration}\right) \div 6 = \text{Expected duration}$$

Kathleen used a PERT estimate for all of the wedding planning activities to make sure that she could get it all done in time for Rob and Rebecca's big day. They only have six months until the wedding, so all of the planning needs to be done within the month to leave enough time to actually finish everything. She wrote down the **assumptions** she made for each estimate, coming up with all of the reasons she could think of that she took into account when coming up with her estimates.

When Kathleen assumed the best-case scenario, these assumptions led her to her 9-day estimate.

$$(9 + 4(15) + 30) \div 6 = 16.5$$

An assumption is a decision that you make to account for things you don't know when you make an estimate.

Optimistic = 9 days	Most likely = 15 days	Pessimistic = 30 days
All guests RSVP early.	Half of the guests won't RSVP until the very last week; a few won't RSVP at all but will still show up.	Nobody RSVPs and many bring guests unannounced.
The couple settles on the first venue they visit.	They'll visit four or five and spend weeks negotiating with venue operators.	They'll comb the neighborhood and visit every possible place for weeks.
The printer can get the invitations done in two weeks.	They'll want to talk to a few printers and most of them will ask for at least a month.	All the printers will be booked, so we'll have to use somebody from out of town and it'll take six work weeks (30 business days).

Here are some examples of three-point estimates. Use the formula to figure out the expected time for each of these.

1. A software team gathered estimates for all of the work they'd have to do to build the next major release of their flagship product. Last time it took them around 45 days, but they're hoping that the lessons learned from the past release could bring the time down to 30 days. However, the infrastructure team needs to upgrade their servers, and they are concerned that procurement delays could potentially extend the project out to 90 days.

Expected duration = _____ Optimistic duration = _____ Most likely duration = _____
Pessimistic duration = _____

2. A construction team gathered estimates for all of the work they'd have to do to build a garage. In general, they can build a garage in 20 days, but rain or cooler temperatures could stretch the project out to 30 days. If, however, the forecast is correct, warm, sunny weather might bring the duration down to just 12 days.

Expected duration = _____ Optimistic duration = _____ Most likely duration = _____
Pessimistic duration = _____

3. A project manager used data from past projects to come up with an estimate for an upcoming software system replacement project. She felt confident about a 25-day duration, but also noted that adding an extra resource could bring the schedule down to 10 days. The test team felt that the complexity of some completely new features would add additional test cases, adding a few weeks for a 40-day estimate.

Expected duration = _____ Optimistic duration = _____ Most likely duration = _____
Pessimistic duration = _____

4. A project manager in charge of a big civil engineering project came up with an estimate for a highway repaving project. The worst-case scenario was 82 days, but the team felt more certain based on past experience that they could get it done in 49 days. If all went well with their equipment and materials, it might be done in 33 days instead.

Expected duration = _____ Optimistic duration = _____ Most likely duration = _____
Pessimistic duration = _____

Answers on page 333

Create the duration estimate

You've got a list of activities, you know what resources are needed to actually do each activity, and you've got your estimation tools and techniques…now you have enough to create the estimates! That's the whole point of the **Estimate Activity Durations** process, and it's also the main output.

You don't always know exactly how long an activity will take, so you might end up using a range (like 3 weeks +/– 2 days).

Outputs

The activity **duration estimates** are estimates of how long each activity in the activity list will take. The estimate can be in hours, days, weeks…any work period is fine, and you'll use different work periods for different jobs. A small job (like booking a DJ) may just take a few hours; a bigger job (like catering—including deciding on a menu, ordering ingredients, cooking food, and serving guests on the big day) could take days. You'll also a produce a **basis of estimates** document that describes your approach, the assumptions you made, and factors you considered.

The activity duration estimate consists of estimates for each activity. It's the main output of the Estimate Activity Durations process.

You'll also learn more about the specific activities while you're estimating them. That's something that always happens—you have to really think through all of the aspects of a task in order to estimate it. So the other output of Estimate Activity Durations is **updates to the project documents**.

You may have guessed from the name that the activity duration estimates are always **duration estimates**, not effort estimates, so they show you calendar time and not just person-hours.

Duration estimates

Project document updates

Basis of estimates

there are no Dumb Questions

Q: When you use parametric estimation, how does the program or formula know how much to estimate?

A: When people design a system for parametric estimation, they collect a lot of data from past projects and condense it into a table or a database. And then they come up with a **heuristic** (like a rule of thumb) that lets you boil your estimation down into just a few parameters that you need to enter. Most successful parametric estimation systems need a lot of time to develop.

Q: Since reserve analysis lets me use buffers, why can't I just put everything I don't know about into the reserve?

A: The idea behind reserve analysis is that there are always unknowns on any project, but you can account for these unknowns by taking your best guess at what's going to go wrong and inserting a buffer. But you can't just make an enormous reserve, because then there's no reason to ever do any estimation! The entire project becomes one big unknown, and that's not particularly useful to anyone.

Q: Wait a minute! I don't quite get the difference between a duration estimate and an effort estimate. Can you explain?

A: Duration is the amount of time that an activity takes, while effort is the total number of person-hours expended. If it takes two people six hours to carve the ice sculpture for the centerpiece of a wedding, the duration is six hours. But since two people worked on it for the whole time, it took 12 person-hours of effort to create!

Back to the wedding

Kathleen's really got a handle on how long things are going to take, but that's not enough to get the job done. She's still got some work to do before she's got the whole project under control.

Rob and Rebecca know where they want to get married, and they've got the place booked now.

But what about the caterer? They have no idea who's going to be providing the food.

And what about the band that they want? Will the timing with their schedule work out?

BRAIN POWER

It's not easy to plan for a lot of resources when they have tight time restrictions and overlapping constraints. How would you figure out a schedule that makes everything fit together?

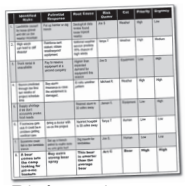
Bringing it all together

The **Develop Schedule process** is the core of Project Schedule Management. It's the process where you put it all together—where you take everything you've done so far and combine it into one final schedule for the whole project. A lot of project managers consider this the most important part of their job. The schedule is your most important tool for managing a project.

There are some assets that you'll need for your schedule, like a calendar of shifts or holidays.

Resource calendar


Project schedule network diagram


Risk register


Organizational process assets


Project Management plan


Enterprise environmental factors


Activity list


Activity attributes


Activity duration estimates


Project team assignments


Basis of estimates


Resource requirements


Resource breakdown structure


Agreements

Look in here for important constraints. They'll include drop-dead dates you absolutely have to meet, and other important milestones.

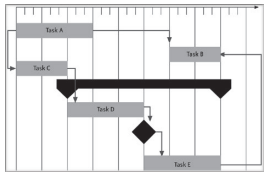
Inputs


Assumption log


Lesson learned


Project Documents

All of the documents you need to understand the best way to organize the work are inputs to this process.



Develop Schedule

Develop Schedule brings everything you've done so far together into one final schedule. All of the outputs from the other Project Schedule Management processes are inputs to Develop Schedule.

HOLD ON! I DON'T REALLY WORK LIKE THAT ALL THE TIME WHEN I'M MANAGING PROJECTS! I FIGURE SOME THINGS OUT, THEN GO BACK AND MAKE CHANGES. LIKE WHAT IF I'M WORKING ON THE SCHEDULE AND I REALIZE I NEED TO CHANGE MY RESOURCES? THIS SAYS I SHOULD HAVE FIGURED THAT ALL OUT BY NOW, RIGHT?

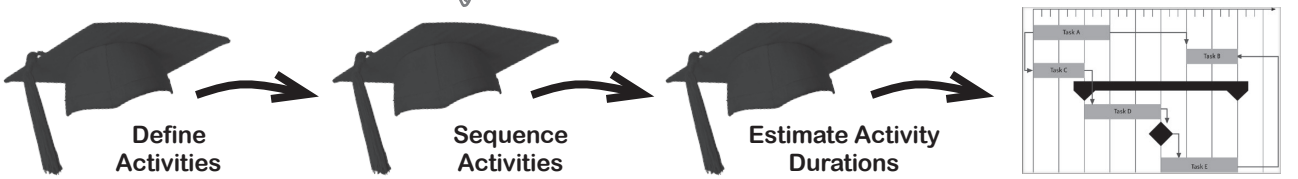
Don't worry, even though you're done with the Estimate Activity Durations process, you're not done with the resources.

You're never going to have the complete resource picture until you're done building the schedule. And the same goes for your activity list and duration estimates, too! It's only when you lay out the schedule that you'll figure out that some of your activities and durations didn't quite work. We'll go in depth about resources when we talk about Project Resource Management in Chapter 9.

Each of the processes allows updates to an output from a previous one, so when you discover changes, you can include them in the schedule.

You're not done with activity attributes yet. When you estimate resources, you'll learn more about some activities and update their attributes.

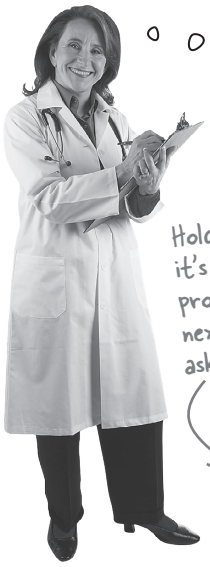
That's why the processes have the word "Estimating" in their names! Because you're taking an educated guess, but you won't know for sure until you've actually developed the schedule.



You created this in Define Activities, but you learned more about it in Sequence Activities. Since the activity list is updated, it's also an output to the process!

You won't know everything about the resources until you actually develop the schedule, so you'll have to keep updating the resource requirements.

Question Clinic: The which-comes-next question



IF YOU WANT TO PASS THE PMP EXAM, YOU'LL NEED TO HAVE A GOOD FEEL FOR THE ORDER THAT THE PROCESSES ARE PERFORMED IN, BECAUSE YOU'LL BE ASKED A LOT OF WHICH-COMES-NEXT QUESTIONS! THESE ARE QUESTIONS THAT QUIZ YOU ON HOW THE PROCESSES FIT TOGETHER INTO ONE BIG FRAMEWORK. THESE QUESTIONS AREN'T HARD, BUT THEY CAN BE A LITTLE MISLEADING.

Hold on—this question doesn't look like it's asking about the order of the processes! But a lot of which-comes-next questions describe a situation and ask you what you'd do.

Don't be thrown if the question asks about an industry you don't know much about. All projects follow the same processes.

In other words, you've used decomposition and created an activity list. These are part of the Define Activities process.

27. You're the project manager for a highway construction project. You've analyzed the work that has to be done and come up with a list of activities. You consulted with the project sponsor in order to find out any important milestones that you need to meet. What's the next thing that you do?

A. Create the project schedule.

B. Perform the Define Activities process.

C. Consult your Project Management plan to figure out how to handle any schedule changes.

D. Figure out the dependencies between activities and create a diagram of the activity network.

The milestone list is an input that you've seen before.

The Develop Schedule process needs more than an activity list and resource availability.

You only do this during Control Schedule, but since there's no schedule yet, there's nothing to control.

The question described the Define Activities process, so you've already performed it.

Did you notice the question said "diagram of the activity network" and not "project network diagram"? The exam might not use the exact same phrasing as the PMBOK® Guide. That's why you're learning how these things are used, not just memorizing their names.

This answer describes Sequence Activities, which happens after Define Activities and takes the activity list and milestone list as inputs. That's the right answer.

THE WHICH-COMES-NEXT QUESTION DOESN'T ALWAYS LOOK LIKE IT'S ASKING ABOUT THE ORDER OF THE PROCESSES! KEEP AN EYE OUT FOR QUESTIONS THAT DESCRIBE INPUTS, OUTPUTS, TOOLS, OR TECHNIQUES AND ASK YOU WHAT YOU'RE SUPPOSED TO DO NEXT.

HEAD  LIBS

Fill in the blanks to come up with your own which-comes-next question! Start by thinking of a process to be the correct answer, and then figure out which process came right before it—that's the one you'll describe in the question!

You are managing a _____ (an industry or the name of a project). You've finished creating the _____ (an output from the previous process), you've come up with _____ (another output from the previous process), and you've just finished _____ (a tool or technique from the previous process). What's the next thing you do?

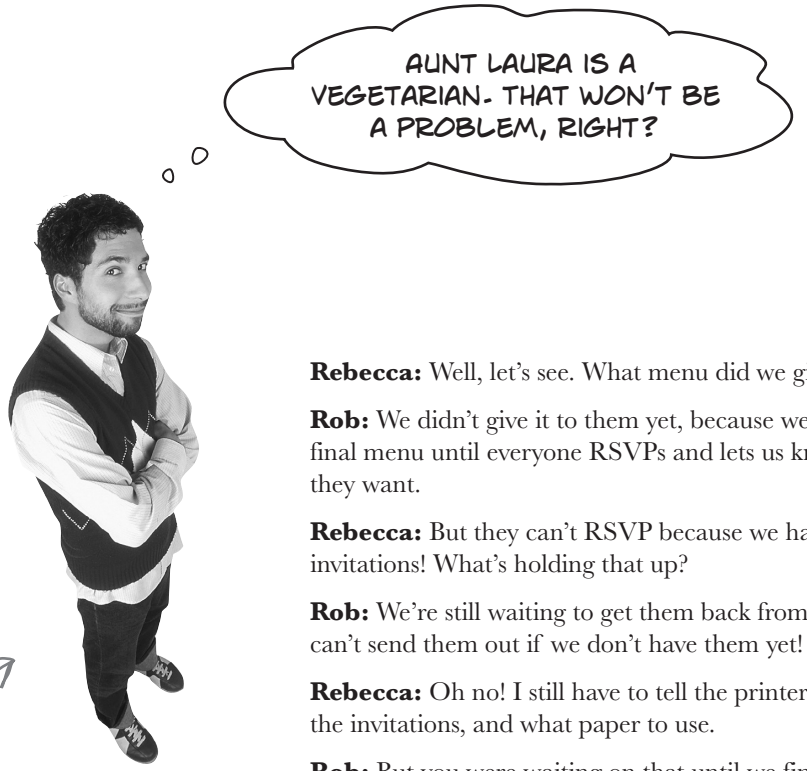
A. _____ (the correct answer—a brief description of what happens during the process)

B. _____ (a description of a different process)

C. _____ (the name of a tool or technique that's part of a totally different process)

D. _____ (the name of an irrelevant process)

One thing leads to another



Rebecca: Well, let's see. What menu did we give to the caterers?

Rob: We didn't give it to them yet, because we won't have the final menu until everyone RSVPs and lets us know which entrée they want.

Rebecca: But they can't RSVP because we haven't sent out the invitations! What's holding that up?

Rob: We're still waiting to get them back from the printer. We can't send them out if we don't have them yet!

Rebecca: Oh no! I still have to tell the printer what to print on the invitations, and what paper to use.

Rob: But you were waiting on that until we finished the guest list.

Rebecca: What a mess!

...but it turns out to be a lot bigger than either Rob or Rebecca realized at first! How'd a question about one guest's meal lead to such a huge mess?

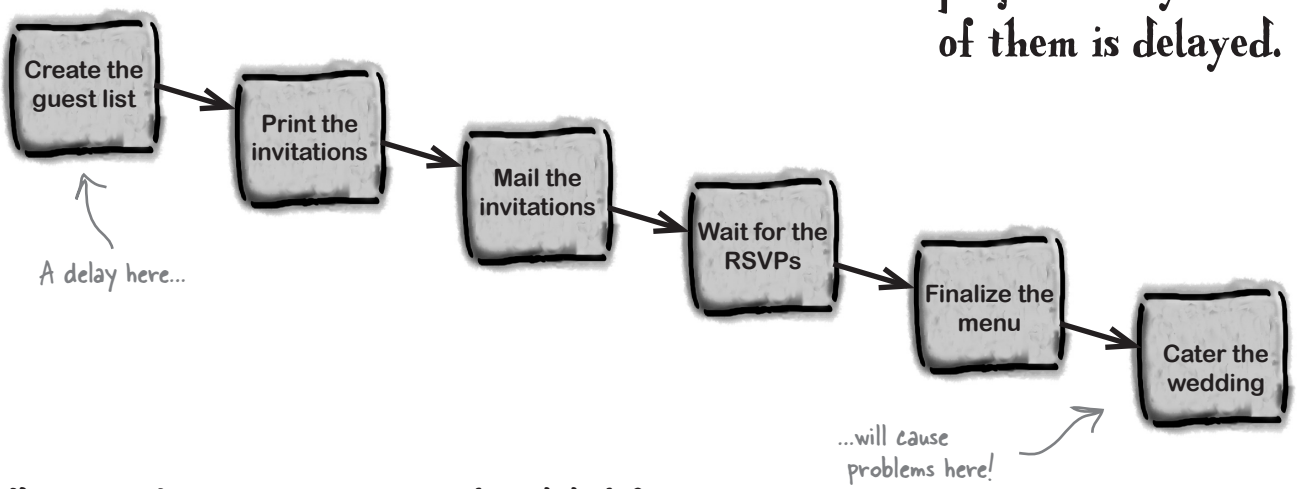
Can you think of a situation where a delay in an activity early on in a project can lead to a problem in a later activity, which leads to another problem in another activity, leading to a cascade of problems that makes the project late?

Use the critical path method to avoid big problems

The **critical path method** is an important tool for keeping your projects on track. Every network diagram has something called the **critical path**. It's the string of activities that, if you add up all of the durations, is longer than any other path through the network. It usually starts with the first activity in the network and usually ends with the last one.

The reason that the critical path is, well, *critical*, is that every single activity on the path must finish on time in order for the project to come in on time. A ***delay in any one of the critical path activities*** will cause the **entire project to be delayed**.

The critical path is the string of activities that will delay the whole project if any one of them is delayed.



How does knowing your critical path help?

Knowing where your critical path is can give you a lot of freedom. If you know an activity is *not* on the critical path, then you know a delay in that activity may not *necessarily* delay the project.

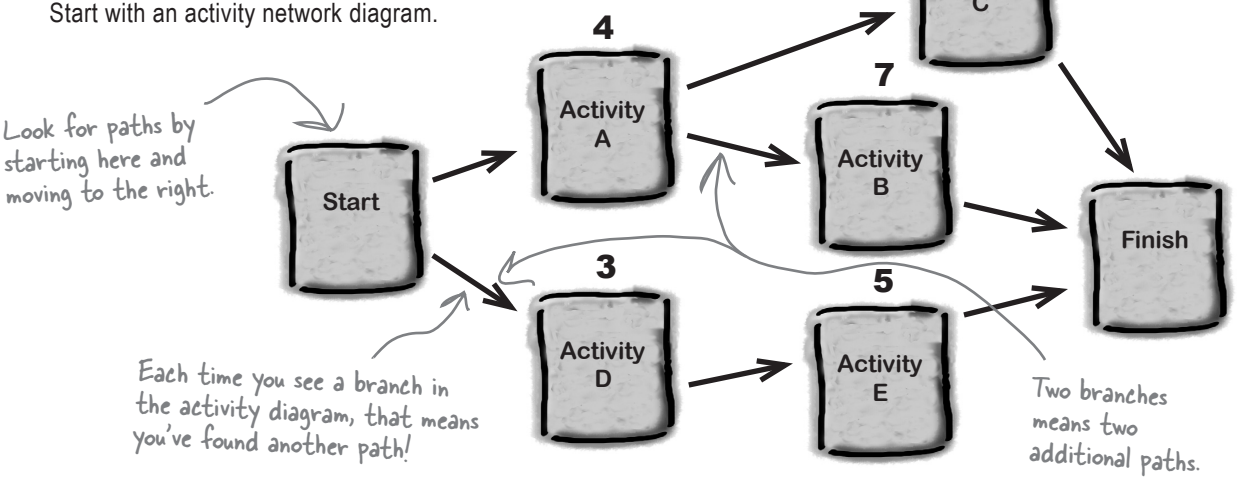
This can really help you handle emergency situations. Even better, it means that if you need to bring your project in earlier, you know that adding resources to the critical path will be much more effective than adding them elsewhere.

How to find the critical path

It's easy to find the critical path in any project! With a little practice, you'll get the hang of it. Of course, on a large project with dozens or hundreds of tasks, you'll probably use software like Microsoft Project to find the critical path for you. But when it does, it's following the same exact steps that you'll follow here.

You'll usually write the duration above each node in the diagram.

1 Start with an activity network diagram.



2 Find all of the paths in the diagram. A path is any string of activities that goes from the start of the project to the end.

Start → Activity A → Activity B →
→ Activity A → Activity C →
→ Activity D → Activity E → Finish

3 Find the duration of each path by adding up the durations of each of the activities on the path.

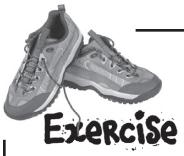
Start → Activity A → Activity B → **11**

Start → Activity A → Activity C → Finish = 4 + 2 = **6**

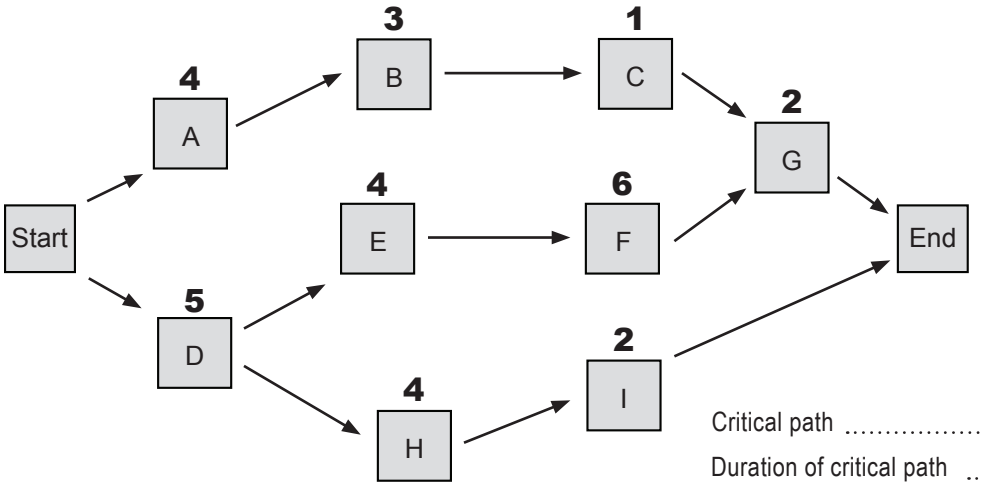
Start → Activity D → Activity E → Finish = 3 + 5 = **8**

This path has a duration of 11, which is longer than the other two (6 and 8). So it's the critical path!

The critical path is the one with the longest duration!



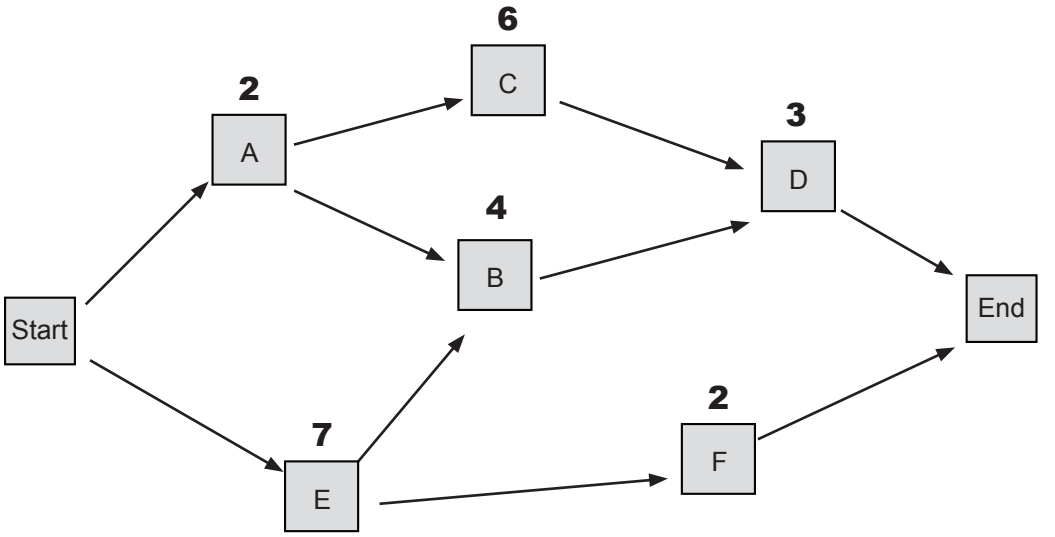
You may get questions on the exam asking you to identify the critical path in a network diagram. Here's some practice for doing that! Find the critical path and duration for these PDMs.



Critical path .....

Duration of critical path .....

Total number of paths .....



Critical path .....

Duration of critical path .....

Total number of paths .....

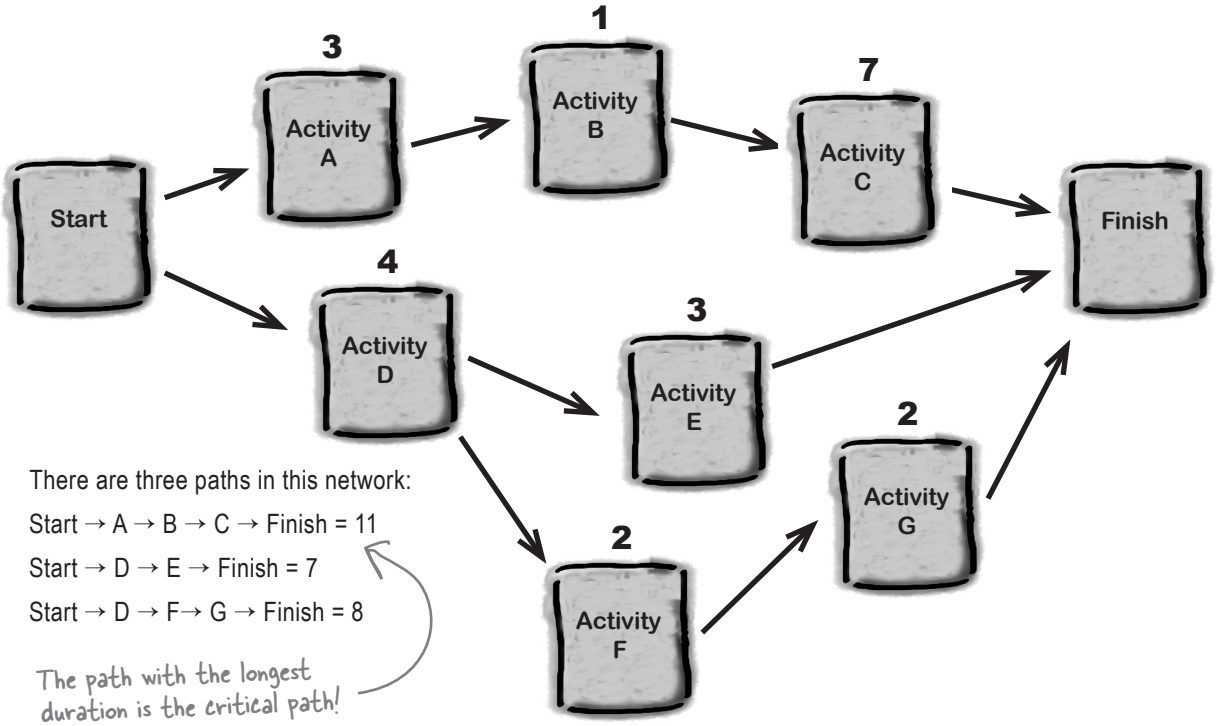
Answers on page 334.

Finding the float for any activity

The goal is to find the float for each activity. We're not really concerned with finding a total float for each path—we're looking at the activities independently.

Once you've figured out the critical path, there's all sorts of useful stuff you can do with it. One of the most useful things you can do is calculate the **float**. The float for any activity is the amount of time that it can slip before it causes your project to be delayed. You might also see the word *slack*—it's the same thing.

Luckily, it's not hard to figure out the float for any activity in a network diagram. First you write down the list of all of the paths in the diagram, and you identify the critical path. The float for every activity in the critical path is zero.



1. There are three paths in this network:

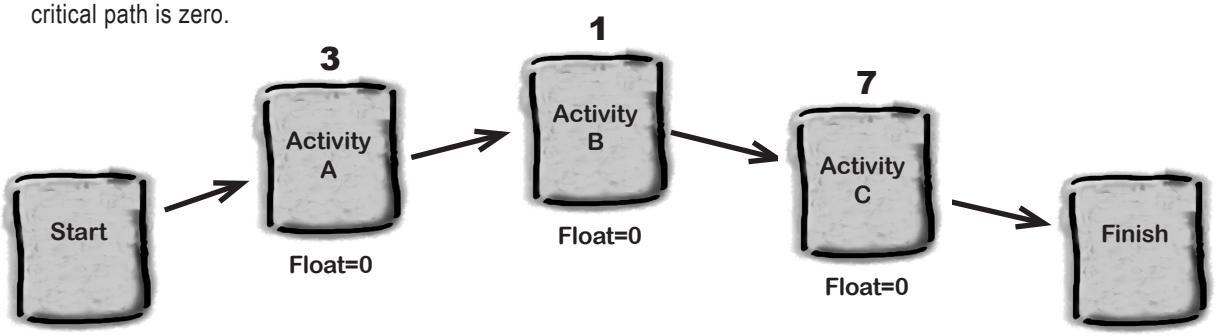
   Start → A → B → C → Finish = 11

   Start → D → E → Finish = 7

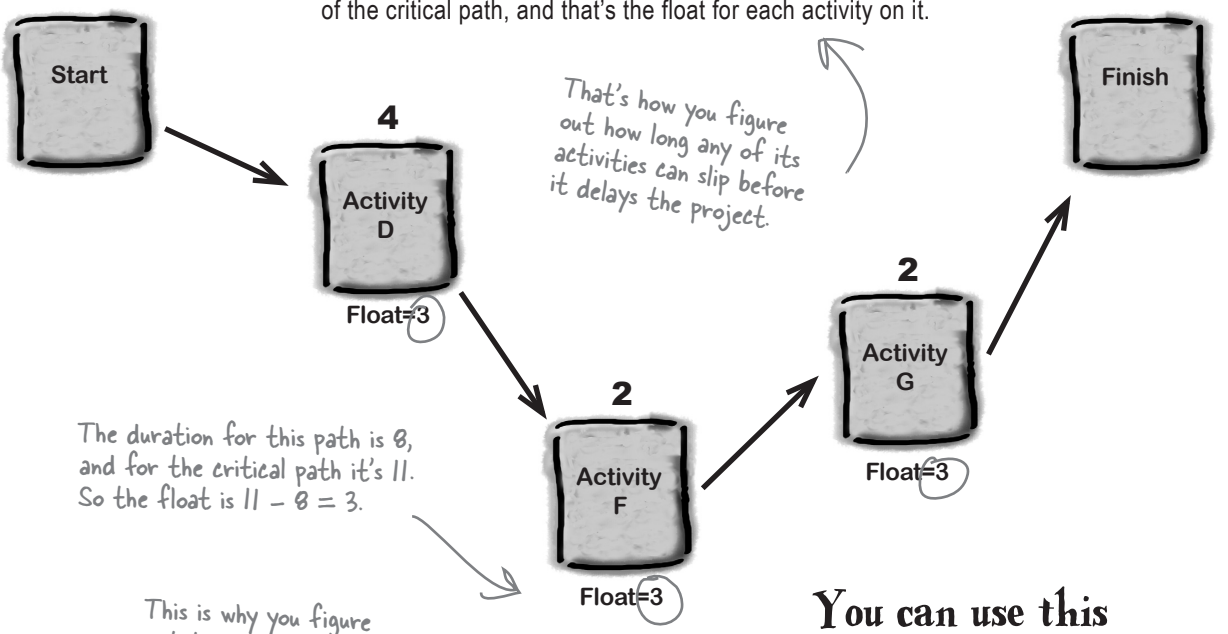
   Start → D → F→ G → Finish = 8

   The path with the longest duration is the critical path!

2. The float for each of the activities on the critical path is zero.



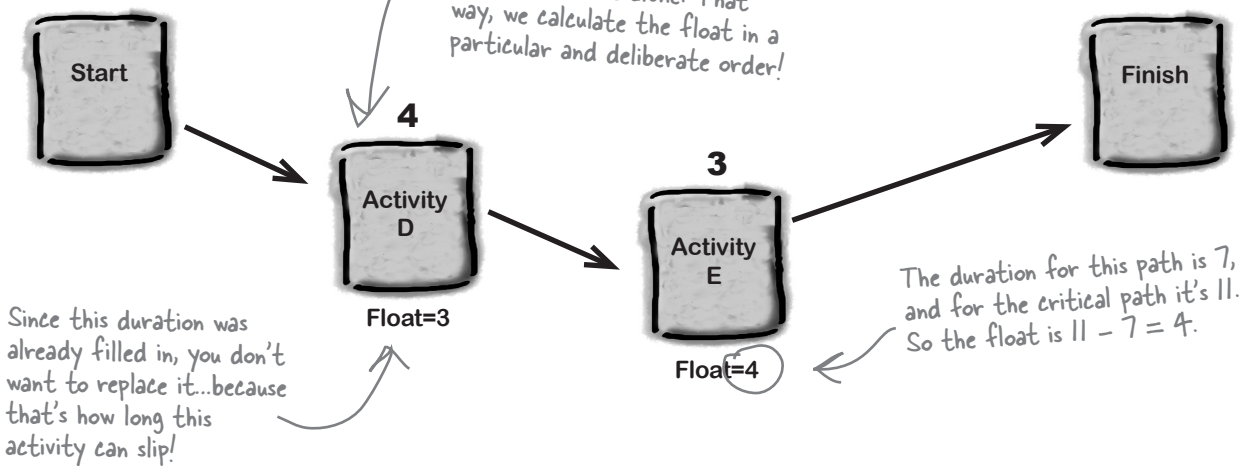
3 Find the **next longest path.** Subtract its duration from the duration of the critical path, and that's the float for each activity on it.



This is why you figure out the length of each path before you start.

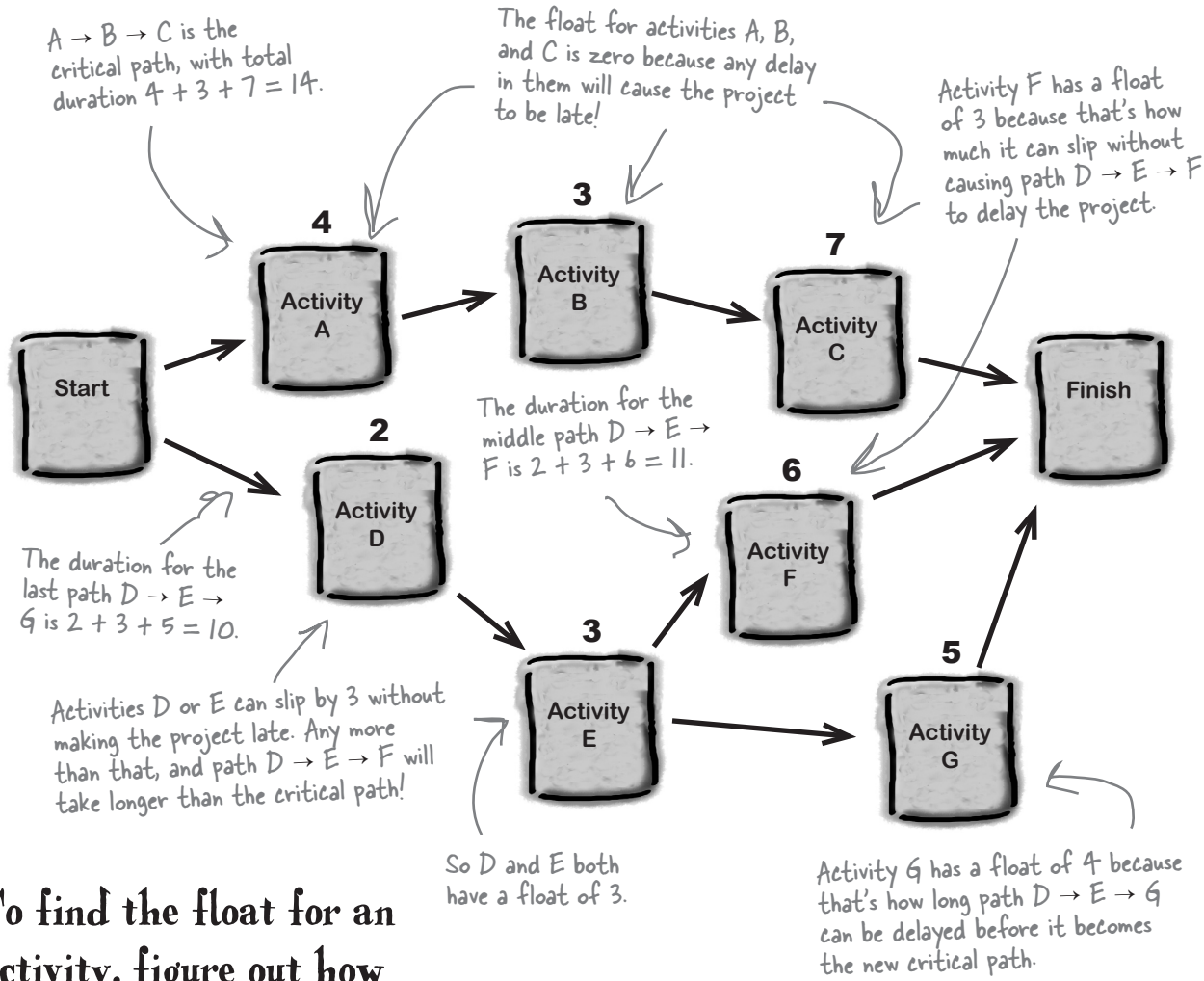
4 Do the same for the **next longest path,** and so on through the rest of the network diagram. Pretty soon, you'll fill in the float for every activity!

You can use this method to find the float for every activity in a network diagram. Another word for float is slack.

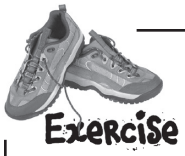


Float tells you how much extra time you have

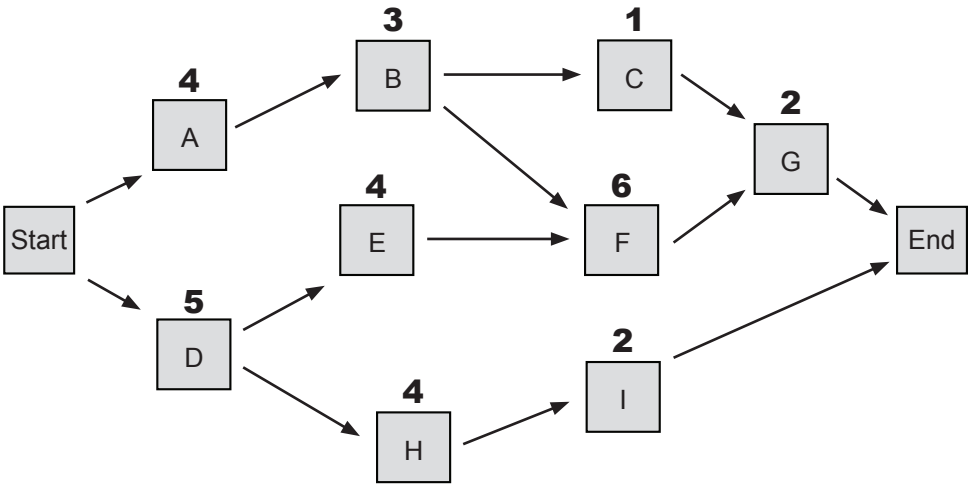
Once you know the float, you know how much play you have in your schedule. If an activity has a float of 2 days, it can slip by that much without affecting the end date.



To find the float for an activity, figure out how much it can slip before it makes the project late. The float for any activity on the critical path is ZERO!



You'll need to be able to calculate the float of an activity in a network diagram for the exam. Take another look at this PDM from the last exercise. Can you calculate the float for each activity?



1. What is the float for each activity on the critical path? ……..

2. What is the total duration for path A → B → C → G? …….

3. What is the total duration for path A → B → F → G? ……..

4. What is the total duration for path D → E → F → G? ……..

5. What is the total duration for path D → H → I? ……..

6. Which path is the critical path? ……..→……..→……..→……..

7. Write down the float for each activity:

A …….. B …….. C …….. D …….. E ……..

F …….. G …….. H …….. I ……..

Hint: First fill in the float for the critical path activities. Then move on to the next longest path, and then the next longest one, filling in any float that hasn't been filled in yet.

Answers on page 335.

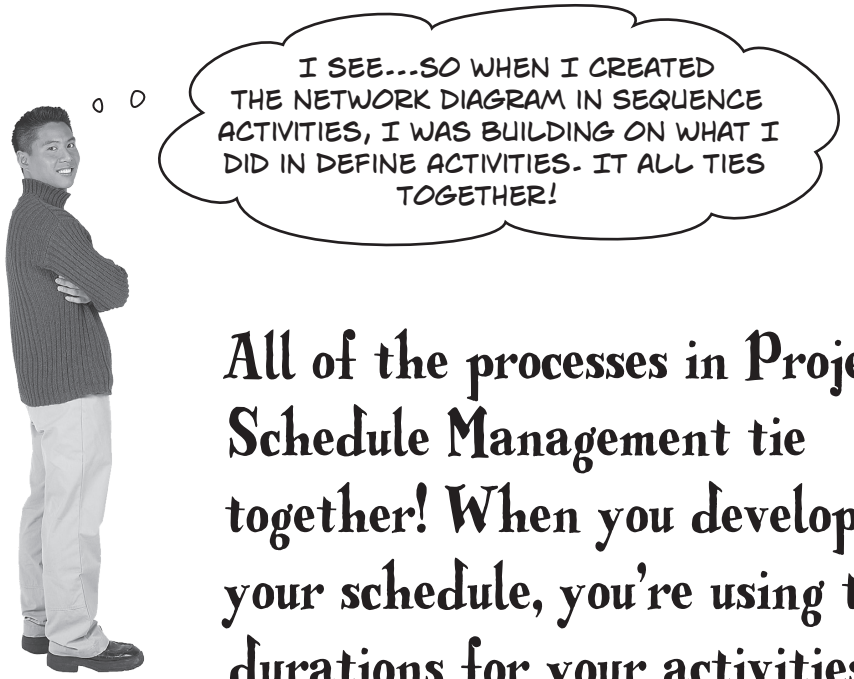
there are no Dumb Questions

Q: Where do the duration numbers come from on each activity?

A: A lot of people ask that question. It's easy to forget that everything you do in Sequence Activities builds on the stuff you did in the other Project Schedule Management processes. Remember the estimates that you came up with during Estimate Activity Durations? You used techniques like three-point estimates, analogous estimating, and parametric estimating to come up with an estimate for each activity. Those are the estimates that you use on your network diagrams!

Q: What if there's a path that's not critical, but where even a small slip in one activity would delay the project?

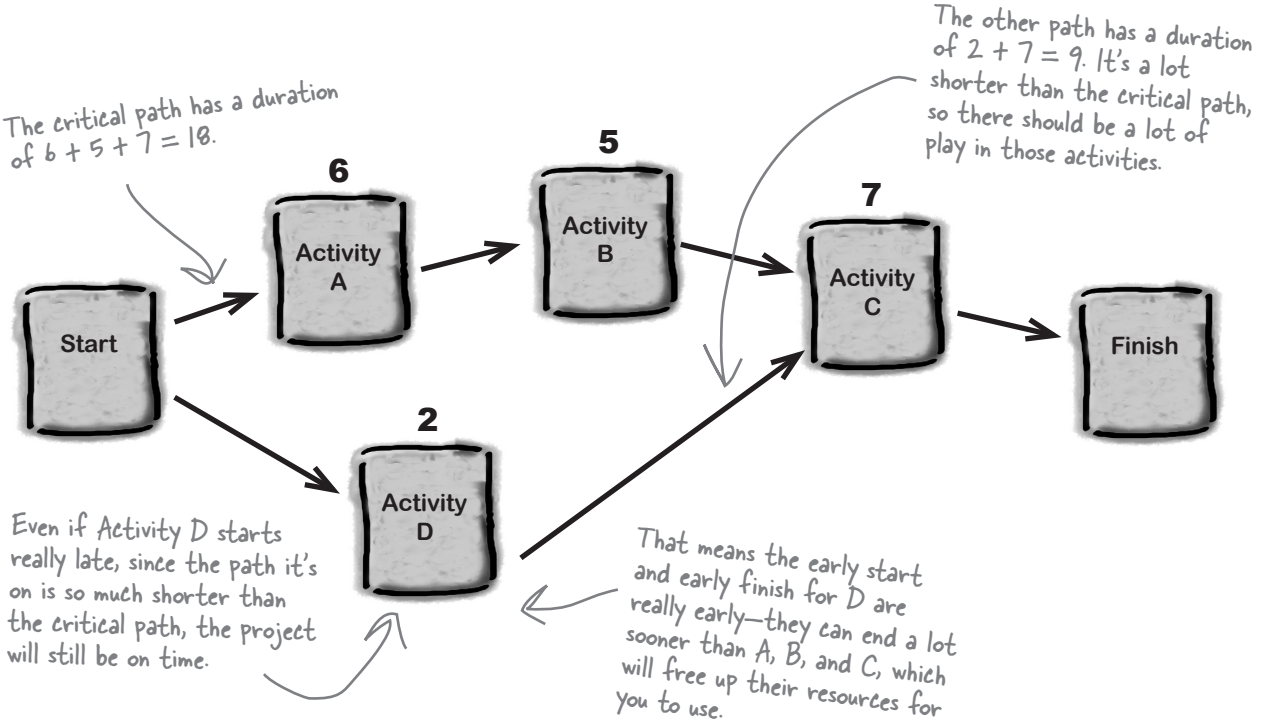
A: This is exactly why it's important to know the float for each of your activities. When you're managing your project, it's not enough to just pay attention to the activities on the critical path. You need to look for any activity with a low float. And don't forget that there may be some activities that aren't on the critical path but still have a float of zero! These are the ones where you really want to pay attention and watch out for potential resource problems.



All of the processes in Project Schedule Management tie together! When you develop your schedule, you're using the durations for your activities that you came up with in Estimate Activity Durations.

Figure out the early start and early finish

Coming up with the float for each activity is useful, but you can actually do better! When you have a long critical path, but the other paths in your network diagram are short, then you have a lot of freedom in when you can start and finish each of the activities that are not on the critical path. You can use **early start** and **early finish** to get a handle on exactly how much freedom you have in your schedule.



Early start

Is the earliest time that an activity can start. An activity near the end of the path will only start early if all of the previous activities in the path also started early. If one of the previous activities in the path slips, that will push it out.

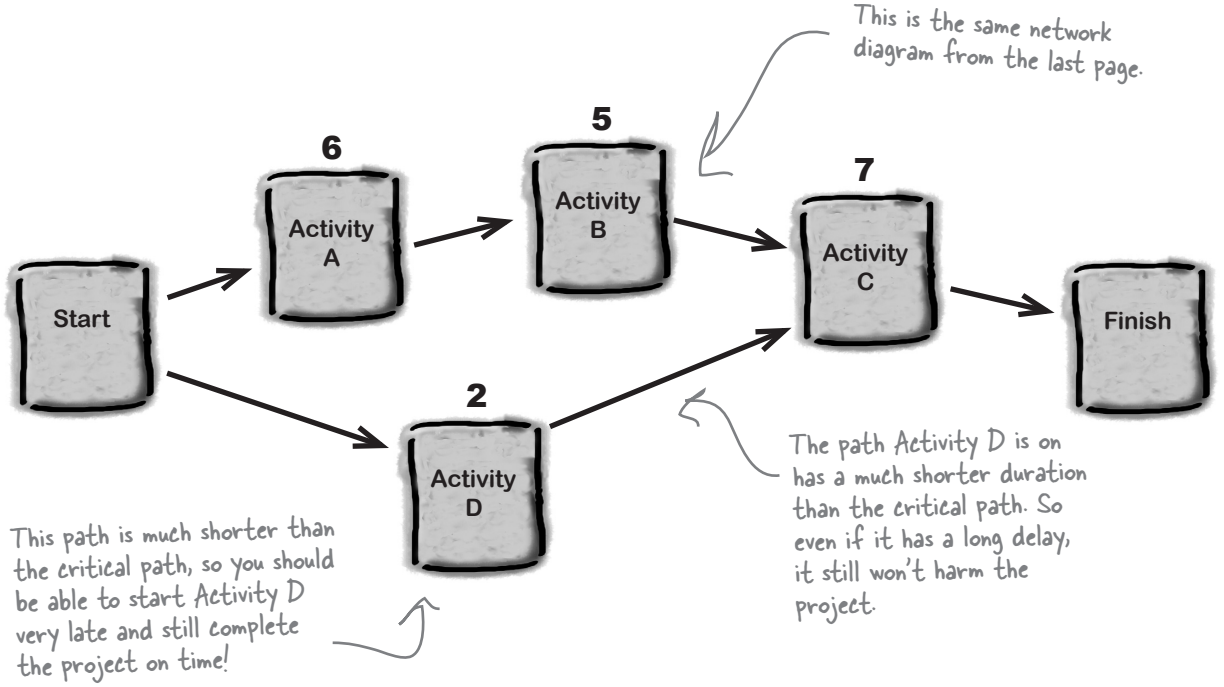
Early finish

Is the earliest time that an activity can finish. It's the date that an activity will finish if all of the previous activities started early and none of them slipped.

When you find the early start and early finish for each task, you know exactly how much freedom you have to move the start dates for those activities around without causing problems.

Figure out the latest possible start and finish

It's also important to know how late any activity can run before it delays the project. That's what **late start** and **late finish** are for! They let you figure out how late you can start a certain task and how much it can slip before it delays your project.



Late start

Is the latest time that an activity can start. If an activity is on a path that's much shorter than the critical path, then it can start very late without delaying the project—but those delays will add up quickly if other activities on its path also slip!

Late finish

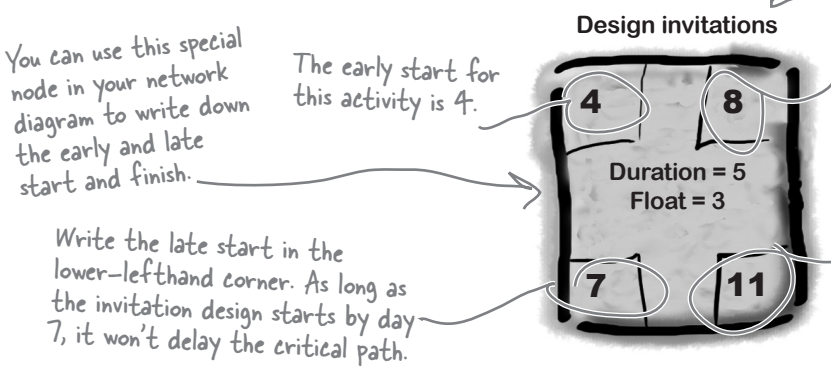
Is the latest time that an activity can finish. If an activity is on a short path and all of the other activities on that path start and finish early, then it can finish very late without causing the project to be late.

Figuring out the late start and late finish will help you see how much "play" you have in your schedule. An activity with a large late start or late finish means you have more options.

Add early and late durations to your diagrams

You can use a method called **forward pass** to add the early start and finish to each path in your network diagram. Once you've done that, you can use **backward pass** to add the late start and finish. It makes your network diagrams look a little more complicated, but it gives you a lot of valuable information.

Early start and finish go in the upper corners. Write the name of the activity above it, and the duration and float inside the box.



You can use this special node in your network diagram to write down the early and late start and finish.

The early start for this activity is 4.

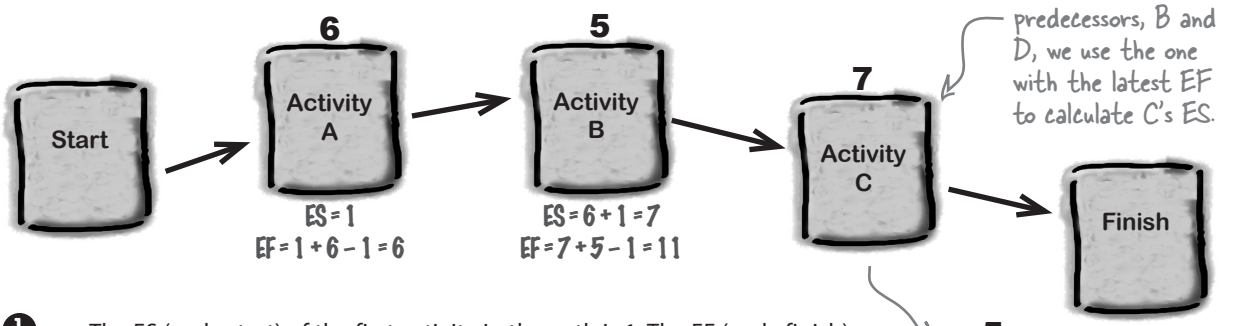
The early finish for this activity is 8. There's no way it can end before day 8.

Write the late start in the lower-lefthand corner. As long as the invitation design starts by day 7, it won't delay the critical path.

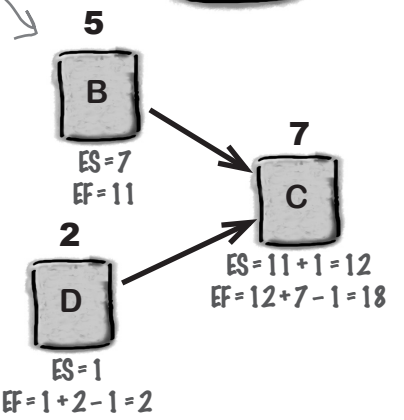
The late finish for the Design Invitations activity is 11, which means the latest it can finish without delaying the schedule is on day #11. If it hasn't finished by then, Kathleen should worry!

Take a forward pass through the network diagram.

Start at the beginning of the critical path and move forward through each activity. Follow these three steps to figure out the early start and early finish!



Since C has two predecessors, B and D, we use the one with the latest EF to calculate C's ES.



1. The ES (early start) of the first activity in the path is 1. The EF (early finish) of any task is its ES plus its duration minus 1. So start with Activity A. It's the first in the path, so ES = 1, and EF = 1 + 6 – 1 = 6.

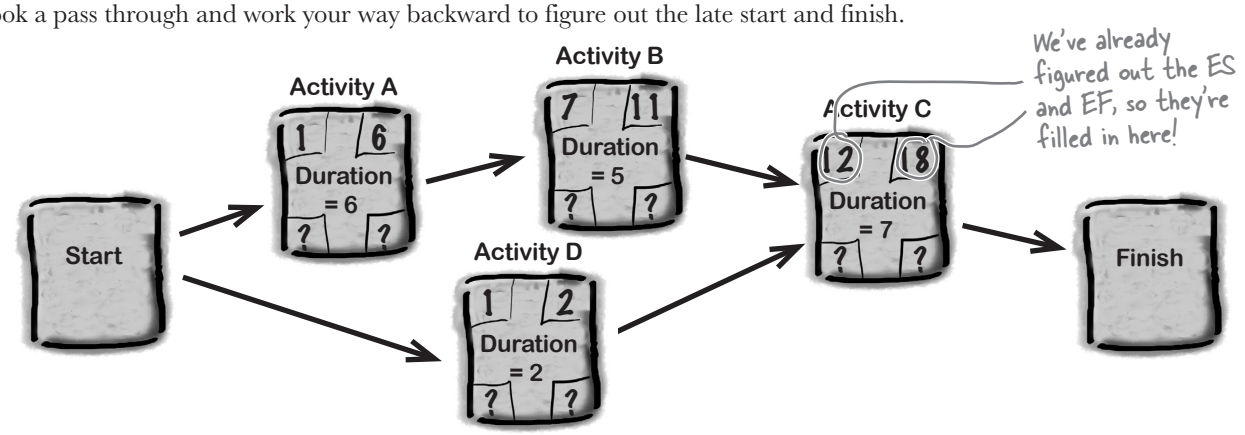
2. Now move forward to the next activity in the path, which is Activity B in this diagram. To figure out ES, take the EF of the previous task and add 1. So for Activity B, you can calculate ES = 6 + 1 = 7, and EF = 7 + 5 – 1 = 11.

3. **Uh-oh! Activity C has two predecessors.** Which one do you use to calculate EF? Since C can't start until both B and D are done, use **the one with the latest EF**. That means you need to figure out the EF of Activity D (its ES is 1, so its EF is 1 + 2 – 1 = 2). Now you can move forward to Activity C and calculate its EF. The EF of Activity D is 2, which is smaller than B's EF of 11, so for Activity C the ES = 11 + 1 = 12, and EF = 12 + 7 – 1 = 18.

Take a backward pass to find late start and finish

You can use a **backward pass** through the same network diagram to figure out the late finish and start for each activity.

The backward pass is just as easy as the forward pass. Start at the end of the path you just took a pass through and work your way backward to figure out the late start and finish.



Start with the critical path.

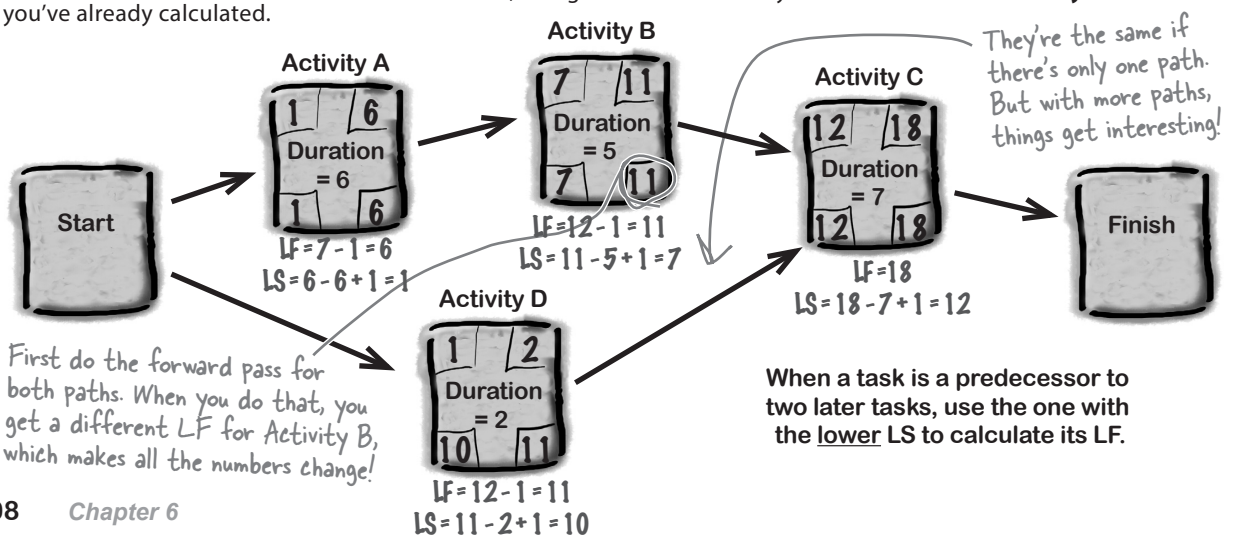
You're calculating the latest any activity can start and finish, so it makes sense that you need to start at the end of the project and work backward—and the last activity on the critical path is always the last one in the project. Then do these three steps, working backward to the next longest path, then the next longest, and so on, until you've filled in the LS and LF for all of the activities. Fill in the LF and LS for the activities on each path, but **don't replace** any LF or LS you've already calculated.

1. Start at the end of the path, with Activity C. The LF (late finish) of the last activity is the same as the EF. Calculate its LS (late start) by subtracting its duration from the LF and adding 1. LS = 18 – 7 + 1 = 12.

2. Now move backward to the previous activity in the path—in this case, Activity B. Its LF is the LS of Activity C minus 1, so LF = 12 – 1 = 11. Calculate its LS in the same way as step 1: LS = 11 – 5 + 1 = 7.

3. Now do the same for Activity A. LF is the LS for Activity B minus 1, so LF = 7 – 1 = 6. And LS is LF minus duration plus 1, so LF = 6 – 6 + 1 = 1.

4. Now you can move onto the next longest path, Start-D-C-Finish. If there were more paths, you'd then move on to the next longest one, and so on, filling in LF and LS for any nodes that **haven't already been filled in**.



When a task is a predecessor to two later tasks, use the one with the lower LS to calculate its LF.

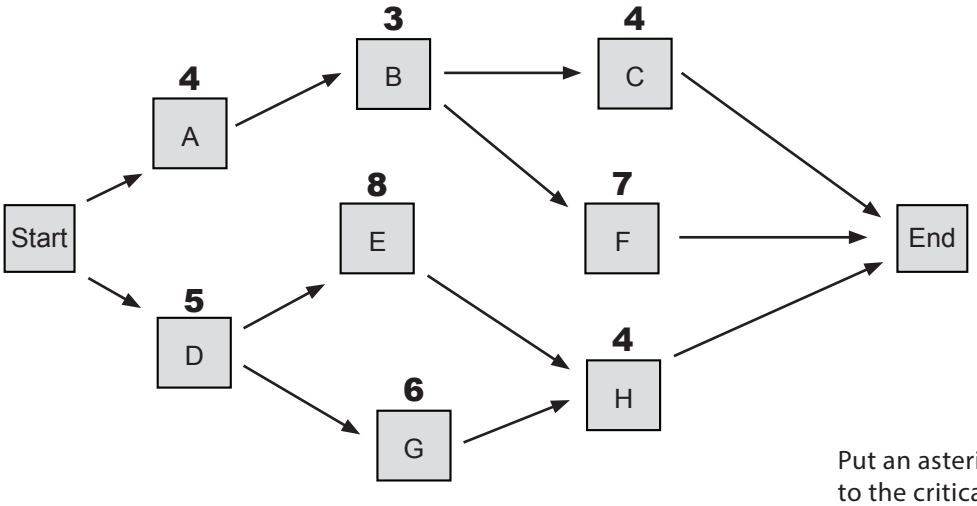
Let's take some time out to walk through this!

All of this critical path stuff seems pretty serious, right? It seems like one of the toughest concepts on the exam...at first! But don't sweat it, because it's actually not hard—it just takes a little practice. Once you do it yourself, you'll see that there's really nothing to worry about.

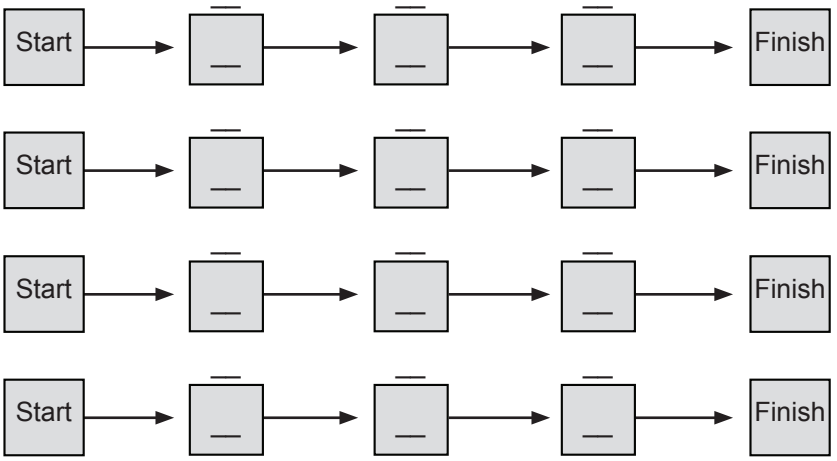
Calculating the ES, EF, LS, and LF may seem complicated, but it only takes a little practice to get the hang of it. Once you walk through it step by step, you'll see that it's actually pretty easy!

Sharpen your pencil

There are four paths in this network diagram. Fill in the activity names and durations for each of the paths.



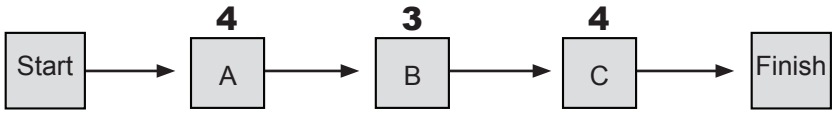
Put an asterisk (*) next to the critical path.



We're not done yet! There's more on the next page...

Sharpen your pencil

Take a forward pass through each of the four paths in the diagram and fill in the early starts and early finishes for each activity. Start with the first one.



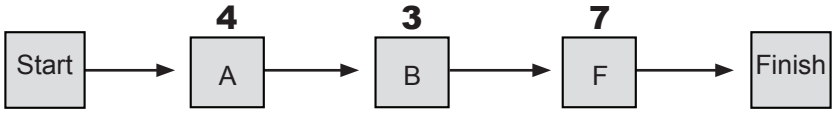
Remember, the early start of the first activity in a path is 1.

ES=__ EF=__ | ES=__ EF=__ | ES=__ EF=__

The early finish of an activity is its ES plus its duration minus 1.

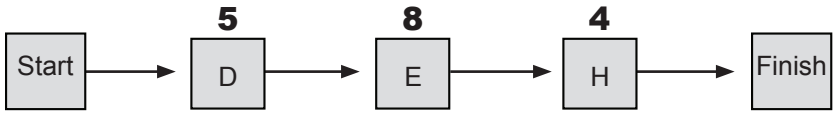
The early start of an activity is the early finish of the previous activity plus 1.

Let's move on to the second path.



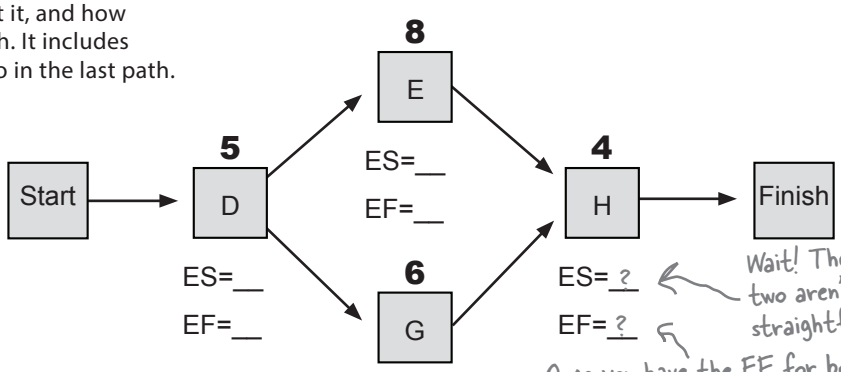
ES=__ EF=__ | ES=__ EF=__ | ES=__ EF=__

The next path isn't as straightforward as it looks. Start by filling in its values.



ES=__ EF=__ | ES=__ EF=__ | ES=__ EF=__

Now take another look at it, and how it mixes with the last path. It includes Activity H, which was also in the last path. H will have a different ES depending on which path you use! So which predecessor do you use: E or G? The idea here is that you **use the predecessor with the larger EF value** when you calculate the ES for activity H (because you want the ***latest possible*** start date).



ES=__ EF=__

ES=__ EF=__

ES=__ EF=__

ES=__ EF=__

ES=__ EF=__

ES= ? EF= ?

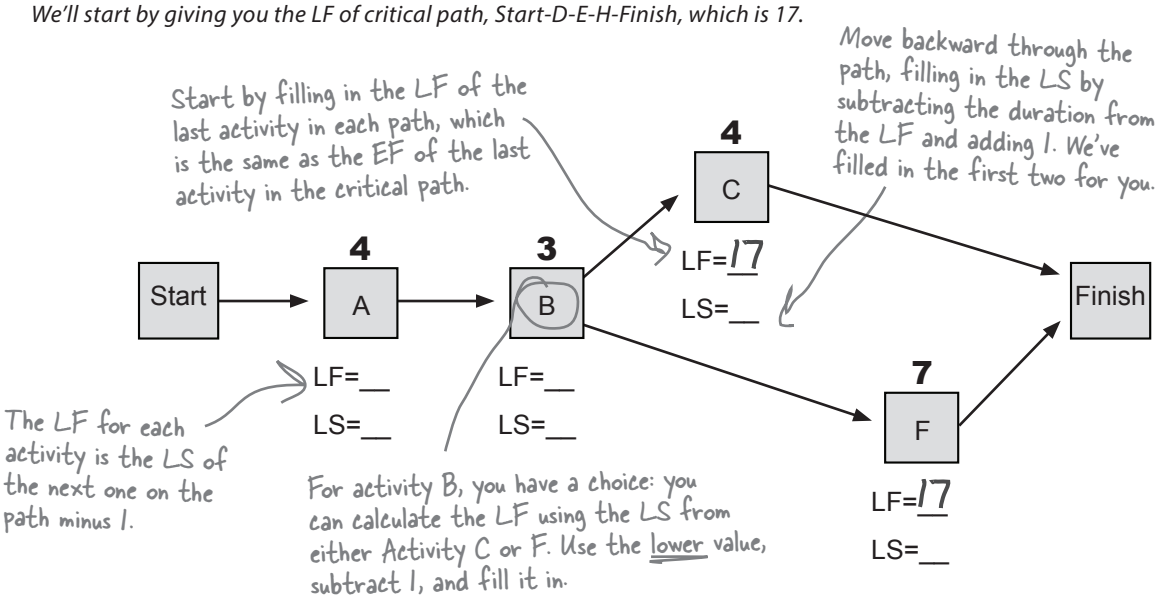
Wait! These two aren't so straightforward.

Once you have the EF for both activities E and G, you can use the bigger one to come up with the ES for Activity H.

You've calculated the ES for each activity. Use that information and take a backward pass through the paths, starting with the first two paths.

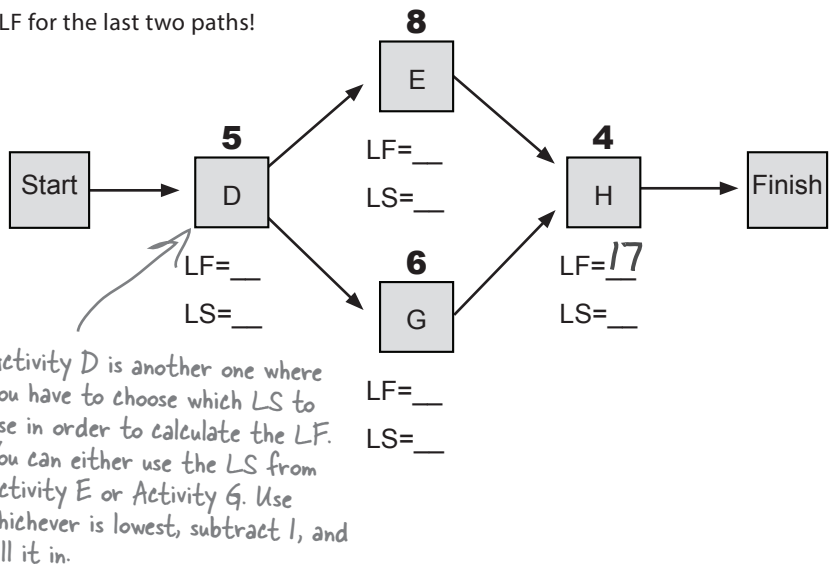
First start with the critical path. Take the EF of the last activity in the critical path and use it as the LF for the last activity in ***every*** path. If you take a minute to think about it, it makes sense to do that. The point of LF is to figure out the absolute latest that the activity can end without making the project late. And as long as every non-critical-path activity ends before the last activity in the critical path, then it won't be late.

We'll start by giving you the LF of critical path, Start-D-E-H-Finish, which is 17.



Finish up by calculating the LS and LF for the last two paths!

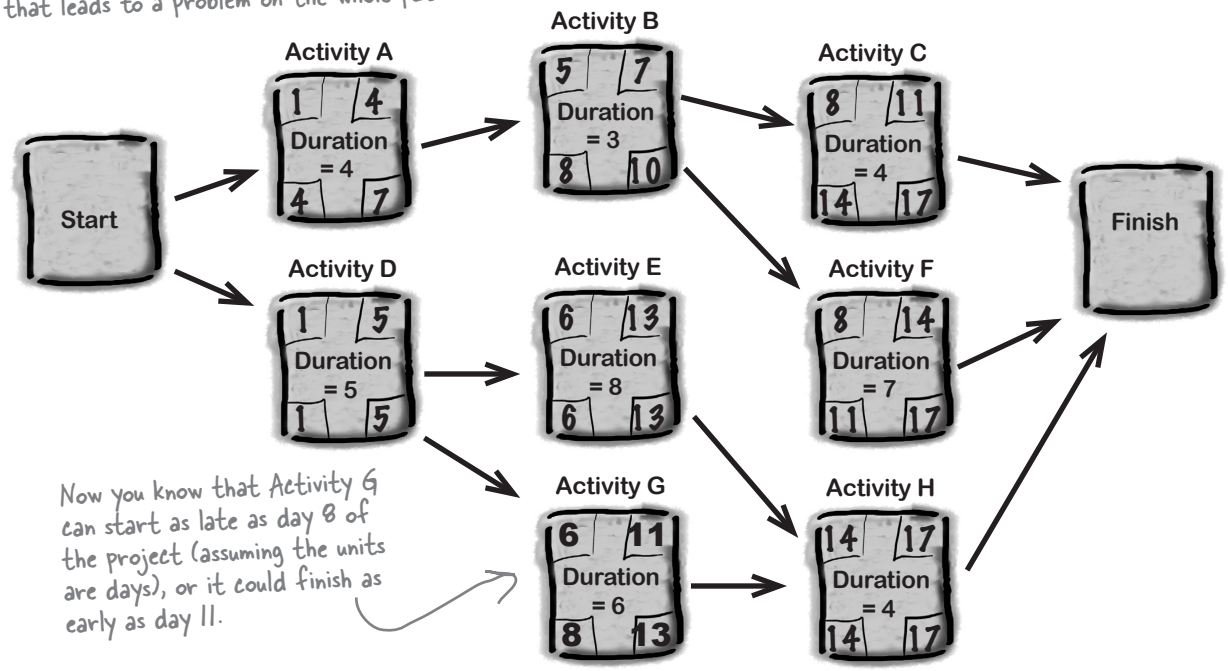
Activities B and D have two possible choices for which LS to use for the calculation. For Activity B, do you use the LS of C or the LS of F? And for Activity D, do you use Activity E or G? The answer is that you always **use the lowest value of LS to calculate the LF**. The reason is that you're trying to find the latest possible start date that *won't make the project late*. If you use an activity with a later LS, and the activity really is delayed by that much, then it'll cause a delay in both following activities. And that will make the one with the lower LS start too late.



Sharpen your pencil Solution

If you got a few of these wrong, don't worry. It's easy to miss one calculation, and that leads to a problem on the whole path.

For the exam, you'll only have to do one or two of these calculations, not a whole string of them like this. You'll definitely be able to handle the exam questions now!



Now you know that Activity G can start as late as day 8 of the project (assuming the units are days), or it could finish as early as day 11.

WAIT A MINUTE...I'VE NEVER HAD TO DO THIS FOR MY PROJECTS AT WORK! I'VE GOT PROJECTS WITH DOZENS OF ACTIVITIES, AND THIS WOULD TAKE ALL DAY!

You won't have to do this kind of thing on the job...that's what computers are for!

Project management software like Microsoft Project will do these calculations for you. But you need to know how to do it yourself, because when the computer is doing critical path analysis, this is exactly how it figures it out!

there are no Dumb Questions

Q: Would I really use this critical path stuff in real life, or is it just something I need to memorize for the PMP exam?

A: Yes, critical path analysis really is important in real life! Sure, for a small project with a dozen or so activities, it's pretty easy to figure out which activities are critical and which can slip by a little bit. But what happens if you've got a project with dozens of team members and hundreds of activities? That's where critical path analysis can come in very handy. For a project like that, you'd probably be using project management software rather than calculating the critical path yourself, and the software will be able to highlight that path for you. Pay special attention to all of the activities that are on the critical path—those are the ones that could potentially delay the project.

Q: What about the other numbers? How do I use float?

A: Float is a very powerful planning tool that you can use to figure out how well your project is going, and to predict where your trouble spots might be. Any activity with a low or zero float absolutely must come in on time, while the people performing an activity with a larger float have more freedom to slip without delaying the project. So you might want to assign your "superstar" resources to the low-float activities, and those people who need a little more mentoring to the ones with higher float.

Q: OK, but what about late start, early finish, and those other numbers? Do those do me any good?

A: Early and late start and finish numbers are also very useful. How many times have you been in a situation where you've been asked, "If we absolutely had to have this in two months, can we do it?" Or, "How late can this project realistically be?" Now you can use these numbers to give you real answers, with actual evidence to back them up.

Here's an example. Let's say you've got an activity in the middle of your project, and one of your team members wants to plan a vacation right at the time that the activity will start. Do you need to find someone to fill in for him? If he'll be back before the late start date, then your project won't be late! But that comes at a cost—you'll have used up the extra slack in the schedule.

Q: I can see how the critical path is useful on its own, but what does it have to do with the rest of Project Schedule Management?

A: If you start putting together your schedule but the activities are in the wrong order, that's really going to cause serious problems…and sometimes doing critical path analysis is the only way you'll really figure out that you've made that particular mistake. That's why you need to pay a lot of attention to the Sequence Activities tools and techniques. If you've come up with an inefficient or inaccurate sequence, with too many or incorrect predecessors and dependencies, then your entire critical path analysis will be useless.

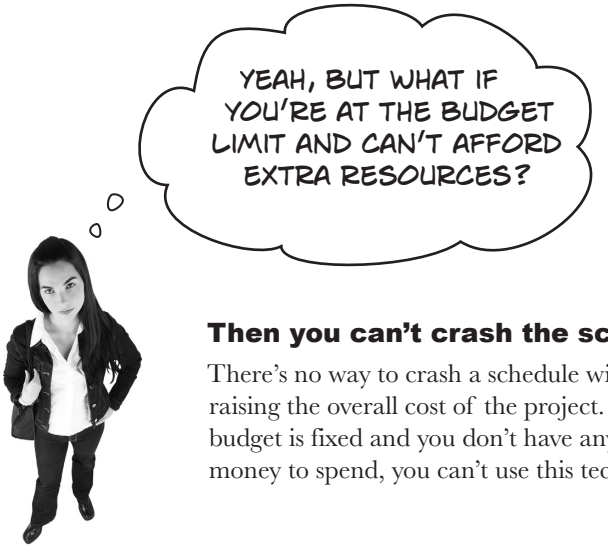
BULLET POINTS: AIMING FOR THE EXAM

- The **critical path** is the path that has the longest duration.
- You should be able to figure out the number of paths in a **project network diagram**, and the duration of each path.
- The **float** for an activity is the amount that its duration can slip without causing the project to be delayed. The float for any activity on the critical path is zero.
- You'll need to know how to calculate the **early start**, **late start**, **early finish**, and **late finish** for an activity in a network diagram using the forward pass and backward pass. This is the core of critical path analysis.
- You may see a **PDM** (or **activity-on-node**) diagram with special nodes that have extra boxes in the corners for the ES, EF, LF, and LS.
- Don't forget that when two paths intersect, you have to decide which ES or LF value to take for the calculation in the next node. For the **forward pass**, use the larger value; for the **backward pass**, use the smaller one.

Crash the schedule

There are two important **schedule compression** techniques that you can use to bring in your project's milestone dates…but each has its own cost. When you absolutely have to meet the date and you are running behind, you can sometimes find ways to do activities more quickly by adding more resources to critical path tasks. That's called **crashing**.

Crashing the schedule means adding resources or moving them around to shorten it. Crashing ALWAYS costs more and doesn't always work!



Then you can't crash the schedule.

There's no way to crash a schedule without raising the overall cost of the project. So, if the budget is fixed and you don't have any extra money to spend, you can't use this technique.

Fast-tracking the project

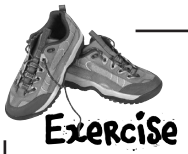
Another schedule compression technique is called **fast-tracking**. Sometimes you've got two activities planned to occur in sequence, but you can actually do them at the same time. On a software project, you might do both your user acceptance testing and your functional testing at the same time, for example. This is pretty risky, though. There's a good chance you will need to redo some of the work you have done concurrently.

On the exam, if you see something about "overlapping activities," it's talking about fast-tracking.

WE CAN SAVE TIME BY HAVING THE FLORIST WORK ON THE RECEPTION HALL FLOWERS WHILE WE FIGURE OUT THE REST OF THE DECORATIONS.

If the decorations don't match the flowers well enough, we'll have to do some rework.

Crashing and fast-tracking are SCHEDULE COMPRESSION tools.



Exercise

Each of these scenarios describes a schedule compression technique. Pick which are examples of fast-tracking and which are crashing.

1. Kathleen guesses that 70% of the invitees will RSVP. Instead of waiting for all of them to come in, she goes ahead and reserves the tables and chairs now.

   ☐ Fast-tracking ☐ Crashing

2. Rebecca is taking a really long time to choose the decorations, so Kathleen brings in a professional decorator to help, even though it will cost more.

   ☐ Fast-tracking ☐ Crashing

3. Kathleen needs to get the invitations out quickly, so she hires two temps to come in and help her stuff envelopes for a few days.

   ☐ Fast-tracking ☐ Crashing

Answers on page 335.

Use data analysis techniques when you build your schedule

Tools

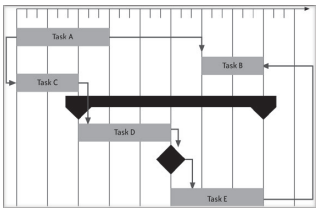
It's always a good idea to think about all of the things that could go wrong on your project in advance. Trying to think through all of the possible problems your project could run into is called **what-if analysis.**

- What if the limo breaks down?
- What if the florist cancels at the last minute?
- What if the dress doesn't fit?
- What if the band gets sick?
- What if the guests get food poisoning?
- What if there's a typo in the church address on the invitation?
- What if the bridesmaids don't show up?
- What if the cake tastes horrible?
- What if we lose the rings?

That way, you can figure out how to deal with any problems that might come your way. Sometimes there's no way to still meet your dates and deal with these scenarios. But it always makes sense to try to understand the impact they will have on your schedule.

Simulation

This is a specific kind of what-if analysis where you model uncertainty using a computer. There are some packages that will help to calculate risk using random numbers and **Monte Carlo analysis** algorithms. While this is not a commonly used technique, there might be a question or two about it on the PMP exam, and you should know what it is.



Scheduling tool

Using a project management software package to create a model of the schedule and adjusting various elements to see what might happen is another technique for analyzing network diagrams.

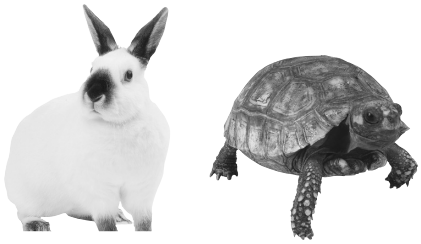
Other Develop Schedule tools and techniques

There are just a few more tools and techniques in the Develop Schedule process that you should know.

Resource optimization techniques

Sometimes only one resource can do a given activity. If that resource is busy doing another activity on the critical path, the path itself needs to change to include that dependency. That's the point of resource leveling. It evaluates all of the resources to see if the critical path needs to change to accommodate resource assignments.

Adjusting leads and lags



If you made any mistakes in your leads and your lags, you might be able to adjust them to change the projected end date.

Data analysis: schedule compression and schedule network analysis

The last two tools and techniques in the Develop Schedule process are the ones you just learned over the last few pages: **schedule compression** and **schedule network analysis** using critical path, float, and the other schedule analysis techniques you just learned.

Agile release planning

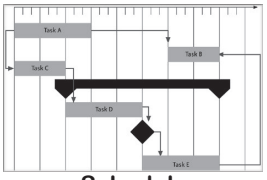
Agile teams typically have a cadence or timebox they use to develop. An Agile release plan takes the list of user stories that have been estimated for a release and uses their estimated size of effort to map them to an upcoming iteration. By presenting the release plan in this way, the team gives the product owner the ability to reprioritize stories and change the order in which stories will be released.

Project management information system

Your company might have scheduling software that they use to generate schedules. You might also use a project management information system to reference existing company calendar information that might impact your schedule.

Outputs of Develop Schedule

Of course, the main product of Develop Schedule is the schedule. But there are a few other supporting documents that help you understand how the work will get done as well.



Schedule

Project schedule

All of that analysis and modeling should produce a schedule that everyone can get behind. After thinking your way through everything that can go wrong and assigning resources, you should have a pretty accurate prediction of the work required to complete the project.

The reason you go through all of that what-if analysis is to make sure everybody agrees that this schedule is achievable!

Change requests

Change requests

These are the same change requests that you've seen in other processes. They should be really familiar by now!

Project calendars

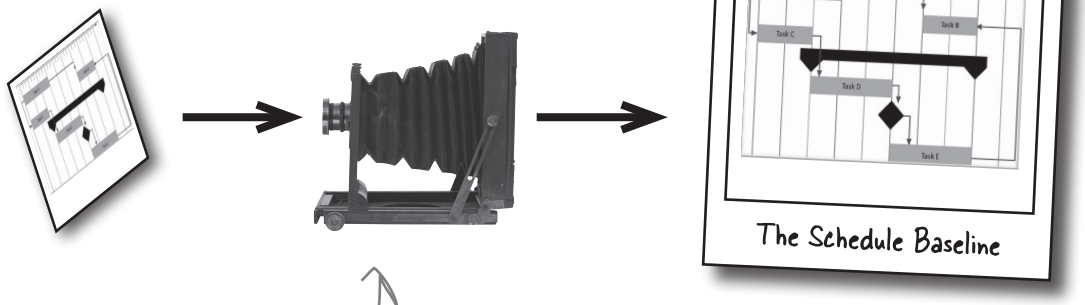
Calendars will help you keep track of the time when team members will be away on vacation or unavailable to work on your project.

Schedule data

Schedule data

The schedule data is a collection of information about your schedule. It will include things that you'll need to analyze your schedule later on in the project: alternative schedules, specific requirements for resources, milestone charts, bar charts, project schedule network diagrams, and other data and metrics about your schedule.

Before you can do change control, you need requested changes. Once the change is approved, you can update the baseline.



This is just like the scope baseline in the last chapter.

Schedule baseline

When the Develop Schedule process is complete, a baseline is created so that actual progress can be compared to the plan.

Project Management plan updates

Since the schedule baseline and Schedule Management plan are both part of the Project Management plan, it makes sense that it would have to be updated.

Project documents updates

While you're creating the schedule, you might find that you need to update calendars, your resource requirements, the attributes of the activities themselves, or even your risk register, to name a few possibilities.

WHAT'S MY PURPOSE

For the exam, you need to know Develop Schedule outputs. Several outputs from the wedding's Develop Schedule process are on the left. Match them to the correct description on the right.

A. Project schedule

B. Schedule data

C. Schedule baseline

D. Project calendars

E. Project document updates

1. Kathleen gives a list of dates to the caterer telling him when he will need to have his menu plans, and when the shopping for the ingredients will need to be complete for the reception and rehearsal dinner.

2. Kathleen realizes that she needs to make a change to how she keeps track of the waiters' time, so she makes a change to the document that describes it.

3. While making the schedule, Kathleen realizes that the catering company can't work from 3 to 4 on the day of the event because they'll be traveling from another event.

4. Kathleen makes a copy of the schedule when it's done so that she can compare how she is doing to the original plan.

5. There's a big poster on the wall where Kathleen keeps track of who does what, and when.

Answers: A–5; B–1; C–4; D–3; E–2

there are no Dumb Questions

Q: Don't we need to go through change control before we update the resource requirements or the activity attributes?

A: No. You need to go through change control if you are requesting changes to, say, your Cost Management plan. But while you are working on creating your schedule, everything you have created as part of the Project Schedule Management knowledge area is fair game.

As you work your way through your network diagram and figure out new dependencies, you will find that you need more resources for some items or that the activity itself has changed. That's why this process gives you the freedom to refine your earlier idea and make all of the Project Schedule Management documents sync with your new understanding.

The Develop Schedule process is about taking all of the information you can think of up front and putting it into a schedule that is realistic. When you are done with this process, you should have a really good idea of what you are going to do, who will do it, and how long it will take.

Q: We always want to do our projects as quickly as we can. Why don't we always fast-track and crash our schedules?

A: Because crashing is expensive and fast-tracking is risky. While it may look good on paper to add a lot of resources to a project that is running late, it often adds so much management overhead and training issues that the project just comes in later.

Even though it might seem like some predecessors are really unnecessary, you usually planned them for a reason. So when you break your dependencies to fast-track your project, you can significantly compromise the quality of the work that gets done. That means you might have to redo it altogether—which would probably take a lot of time.

While fast-tracking and crashing might work sometimes, they always add both risk and cost to your project.

Q: Do people really do Monte Carlo analysis to figure out their schedules? I have never heard of that before.

A: It's true that most people don't use this technique to figure out what might go wrong on their projects, so don't feel bad if you've never heard of it. Some people think that this is just one of those things that is on the PMP exam, so you have to know what it is. But there really are some project managers who use it and get great results!

Updates refine the outputs of previous processes so you don't have to go back and redo them.

Influence the factors that cause change

You might get a question on the PMP exam that asks you about this.

Kathleen doesn't just sit around and wait for schedule changes to happen...

Joe (on phone): Good afternoon, Joe's Catering. Joe speaking. How can I help you?

Kathleen: Hello, Joe. This is Kathleen calling about Rob and Rebecca's wedding.

Joe: Oh, hi! Everything's going fine with that wedding.

Kathleen: Are you sure? What about that big convention across town that's going to be happening at the same time? Won't it be tough to find waiters in June?

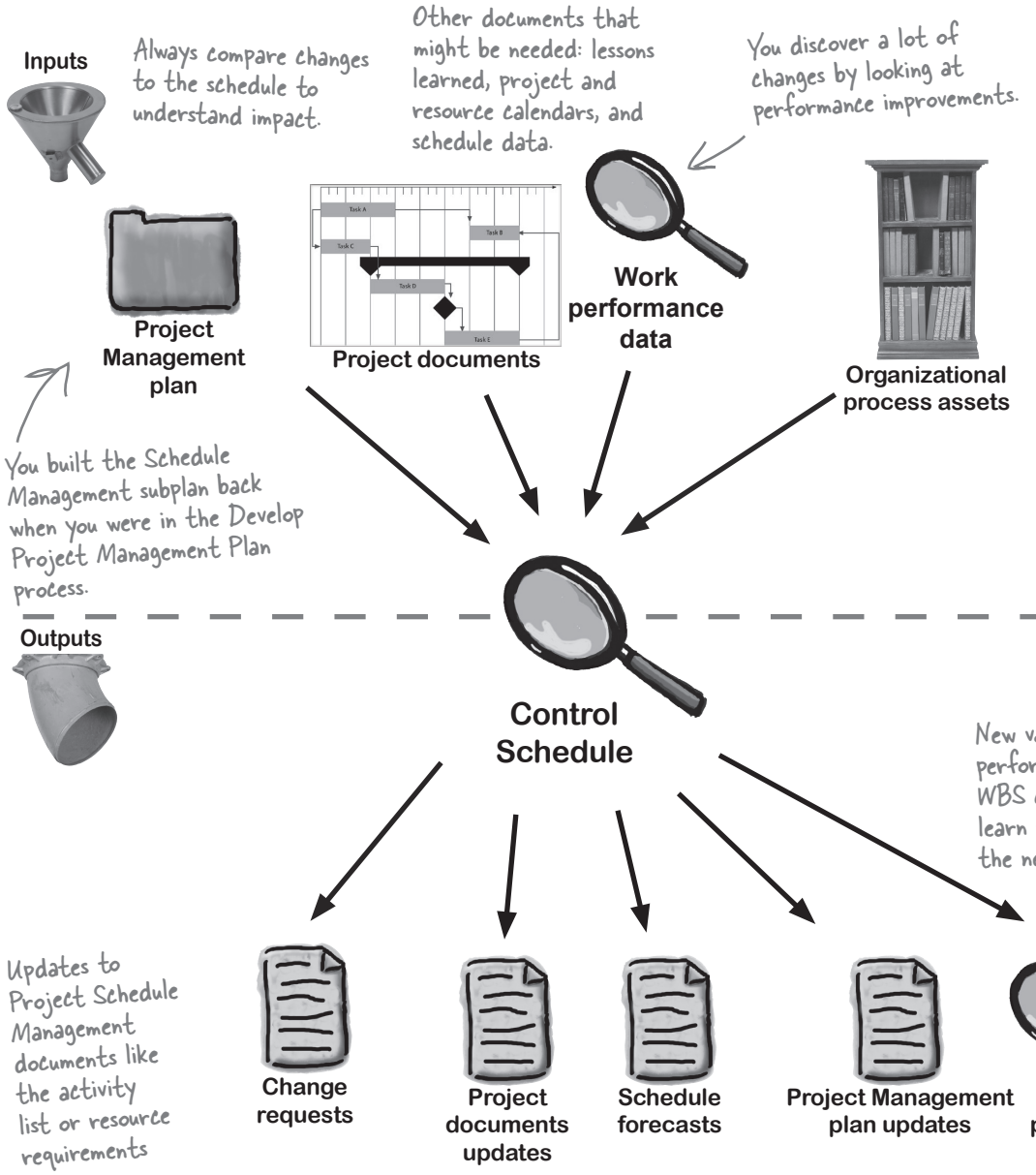
Joe: I didn't think of that; we'd better start figuring out how we'll handle it now.

By realizing that the convention across town will need waiters, too, Kathleen prevents a lot of changes before they cause schedule problems!

The project manager doesn't just wait for change to happen! She finds the things that cause change and influences them.

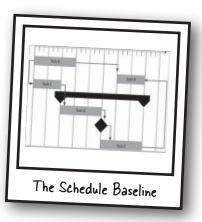
Control Schedule inputs and outputs

As the project work is happening, you can always discover new information that makes you reevaluate your plan, and use the **Control Schedule process** to make the changes. The inputs to Control Schedule cover the various ways you can discover that information. The outputs are the changes themselves.



What Control Schedule updates

All of the documents you made during the Develop Schedule process get updated during the Control Schedule process. Here's a closer look at what those updates mean.



Schedule baseline

Control Schedule

Project documents updates

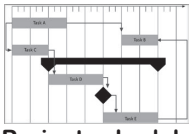
Assumption log

As your project is happening, you might need to revise your list of assumptions to include new information about activity sequencing or duration.

Lessons learned register

You may add supporting details to estimates—like assumptions that were made—to help people understand how the team came up with the estimate. As you make changes to your project schedule, you should be tracking your lessons learned so that other projects can benefit from your experience. Sometimes you might find changes to your basis of estimates as your project progresses.

Basis of estimates



Project schedule

Throughout your project, you'll update the project schedule with any new information you learn as you execute your plan.

Resource calendars

Changes to resource calendars and risks need to be updated as you go. You might find that resources who originally planned to be on vacation end up changing their plans, or you might identify new risks as you go.

Risk register

Schedule data

Schedule data is information about the schedule, like start date, end date, and information about the critical path. In some cases, things change so drastically while your project is executing that you need to create new activities and forecasted duration dates to get an accurate picture of your schedule.

Managing schedule change means keeping all of your project documents up to date.

Measuring and reporting performance

Most often, you identify changes by looking at performance data. It's just as important once you make a change to gather performance data as it was when you found the change in the first place. Here's how performance data feeds into the Control Schedule process.

The Control Schedule process turns work performance data into work performance information.

Work performance data

Routine performance measurements might show that you are lagging in your schedule. We'll learn more about how to measure this stuff in the next chapter.

Control Schedule

Putting the recommended changes through Control Schedule will help you to evaluate the impact and update all the necessary documents.

Now that you've been through the Control Schedule process, the work performance data has been evaluated and turned into work performance information.

Work performance information

During Control Schedule, you'll use the routine measurements you've taken on your schedule to come up with a better understanding of how your project is doing in relation to its baseline schedule. You might come up with new forecasts, or other information that will help your stakeholders know how you're doing. Those new forecasts and status indicators are called work performance information.

Control Schedule tools and techniques

The tools and techniques for Control Schedule are all about figuring out where your project schedule stands. By comparing your actual project to the schedule you laid out in the baseline and looking at how people are performing, you can figure out how to handle every schedule change.

Data analysis

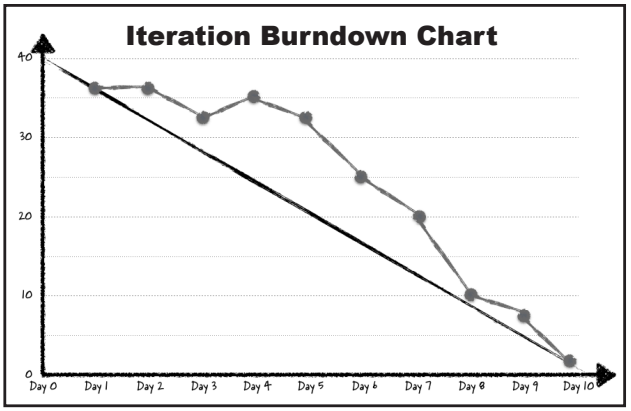
In this process you use data analysis to evaluate the information coming in from the project to forecast whether or not your team is going to meet its forecasted dates. There are two important calculations called schedule variance (SV) and schedule performance index (SPI) that give you valuable information about how your project is doing. Those two calculations are part of the **earned value technique**, which you'll learn all about in the next chapter.

Agile teams often use **iteration burndown** charts to gauge whether they are ahead or behind on work they've committed to accomplishing within a given timeboxed iteration.

Performance reviews are used to compare actual dates versus the dates in the schedule baseline. **Trend analysis** lets you see if performance of the team is getting better or worse over time. **Variance analysis** is when you dig in and try to understand the cause of the variance between actual dates and the dates in the baseline. **What-if scenario analysis** allows you to model possible schedule changes to mitigate risks or respond to changes.

Each item the team commits to is estimated in story points and the total story points in the plan are the high number on the y axis.

The top line represents how much work the team has left to do each day.



The straight line represents where the total number of points would be if the team accomplished the same amount of work every day.

Leads and lags, and schedule compression

Most of the tools from the last process apply to this one too. As you find variances in the schedule, you need to figure out the impact of those issues and change your schedule to account for the new information.

Resource optimization

As things change in your project, you need to make sure that resources are covering all of the activities in your plan. That means you need to distribute resources so that the work that needs to get done always has a resource available to do it.

Critical path method

Use the precedence diagramming method to figure out your early start and late finish for all of the tasks in your project. Then calculate the float to find which tasks are in the critical path. Once you know the critical path, you can choose to fast-track or crash the schedule to optimize the amount of time your project will take.

Project management information system

This is software like Microsoft Project that helps you organize and analyze all of the information you need to evaluate the schedule of any project.

there are no Dumb Questions

Q: When I create work performance information, who uses it?

A: The work performance information that you create is used by a lot of people. The team uses it to keep an eye on the project. If there's a schedule problem coming up, it alerts the team so that they can help you figure out how to avoid it.

Performance information is also used by your project's sponsor and stakeholders, who are very interested in whether or not your project is on track. That information gives them a good picture of how the project is doing…and that's especially important in Control Schedule, because most change control systems require that every change is approved by a change control board that includes sponsors and stakeholders.

Q: What's schedule data used for?

A: You use the schedule data to build the schedule, and you'll usually generate and analyze it using a schedule tool (like Microsoft Project). It includes detailed information about things like resource requirements, alternate best-case and worst-case schedules, and contingency reserves.

When you put together your schedule, you should look at all of these things in order to create an accurate plan. The more information you have when you're building your schedule, the more likely it is that you'll catch those little problems that add up to big schedule slips.

Q: One of the tools is project management software. Do I need to know how to use software in order to pass the exam?

A: No. The PMP exam does not require that you know how to use software like Microsoft Project. However, if you spend a lot of time using project management software, then you probably have become very familiar with a lot of the Project Schedule Management concepts. It's a good way to learn the basics of schedule management.

Q: How often am I supposed to update the project calendar?

A: The project calendar shows you the working days for your team, holidays, nonworking days, planned training, and the dates that could affect your project. Luckily, in most companies these dates don't change very often. You probably won't need to update it—and most project managers just use their company's existing project calendar.

When you're doing Develop Schedule, you may discover that you need to make a change to the project calendar. That's why updates to the project calendar are an output of Develop Schedule.

Q: What do I do with work performance data and work performance information once I've collected it?

A: When you're planning your project, you'll often look to your company's past projects to see what went well and what could have been planned better. And where do you look? That information is in the organizational process assets.
So where do you think that information comes from? It comes from project managers like you who added their work performance data and information to the company's organizational process asset library.

Any time you generate data about your project, you should add it to your organizational process assets so you can use it for future projects.

Control Schedule Magnets

You'll see change control over and over again—every single knowledge area has its own change control process! Luckily, you'll start to see how similar they all are. But Control Schedule has its own quirks, and they're important for understanding Project Schedule Management.

Inputs

Fill in the inputs up here! We've gotten you started with this one.

Work performance data

Tools

Leads and lags

Resource optimization

Data analysis

Critical path method

Write the tools and techniques in here.

Schedule compression

Outputs

The outputs go down here!

Write in the things that get updated here.

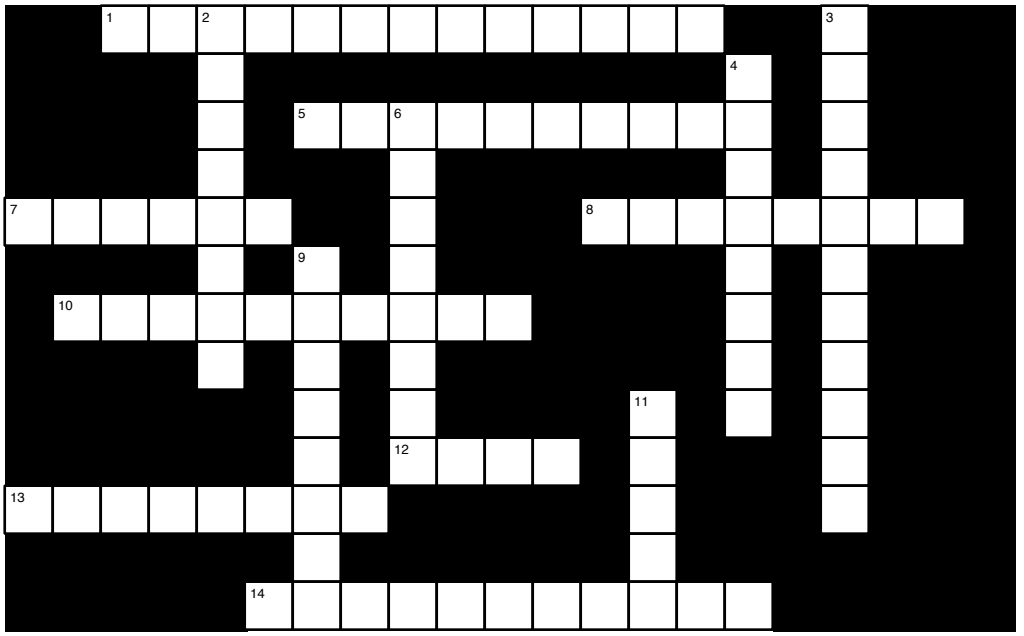
Work performance information

Updates to

Answers on page 337.

Schedulecross

Take some time to sit back and give your right brain something to do. It's your standard crossword; all of the solution words are from this chapter.



Across

1. Taking work packages from the WBS and breaking them down into activities.

5. The "P" in PDM.

7. The kind of analysis where you ask a lot of questions about possibilities.

8. A snapshot of the schedule that you can use for later comparison.

10. _____ estimation means plugging data about your project into a database of historical information to get an estimate of how long it will take to do the work.

12. Giving a successor task some time to start before a predecessor finishes.

13. Adding more resources to a project so you can get it done faster is called _____ the schedule.

14. A PERT three-point estimate is optimistic time + 4 × most likely time + _____ time and divided by 6.

Down

2. Any delay in an activity on the _____ path will delay the entire project.

3. You do this sort of planning when you get more information as the project progresses.

4. What you're doing to resources when you evaluate all of them to see if the critical path needs to change to accommodate their restrictions.

6. An activity with a dependency on something outside the project has an _____ predecessor.

9. _____ Activities is the process where you put the activities in order.

11. How long an activity can slip before the whole project is delayed.

Answers on page 338

Understanding how long it will take to do the work within your project is a core part of the job. **Project Schedule Management** is how you come to understand the way your work stacks up once you figure in the order you'll use to do it and how long each thing your team needs to do will take.

Key Concepts

We've talked about the processes you and your team will use when identifying and managing the schedule, but it's worth taking a minute to think about how your approach to schedule management affects the overall project.

- The main product of the Project Schedule Management processes is a **detailed plan**. Your plan will make the timeline for your project clear and will show your stakeholders how your team plans to meet its goal and how long each step they've identified will take.
- Most teams use **scheduling software** to figure out their planned dates once they've spent some time nailing down the list of activities they'll do and the estimated durations for those activities.
- Some teams who are working on projects with smaller scope and more near-term deadlines think of their entire scheduling process as one step. They figure out all of the activities they'll need to accomplish, the sequence they'll do them in, and their durations all in **one estimation session**.
- Since changes across all of the knowledge areas often affect the project timelines, the **schedule should be flexible** and updated frequently.

Schedule management is about getting a handle on how the team will work and when the project will be delivered.

Trends

Here are a few trends in Schedule Management that might help you to improve and manage the timeline for your projects more effectively.

- **Iterative scheduling** uses a backlog of requirements or user stories, and pulls items from that backlog into timeboxed iterations as a means of sequencing work at the last responsible moment. Agile teams use this technique to avoid determining all of their dependencies up front. This gives them the freedom to adapt to change without resetting detailed schedule expectations.
- **On-demand scheduling** is similar because it focuses on pulling work from a backlog and completing it as soon as possible. The main difference between this technique and iterative scheduling is that it doesn't rely on predetermined timeboxed iterations to forecast an end date. Instead, items are delivered as they are completed.

Tailoring

When you make changes to the processes your team will use during the course of your project, there are a few considerations, that might influence your decisions:

- What development lifecycle will your project follow? Should you focus on building a detailed schedule up front, or will you define iteration timeboxes, prioritize the work, and let the team deliver in priority order?
- Do you know if there are resources who won't be available for specific timeframes and if that will affect your schedule?
- Is your project innovative or highly uncertain? How will you know if your project plan is focused on reducing uncertainty as it progresses? How will you track your progress on the project?
- If your project is dependent on a tool or technology, will you be able to use that tool easily?

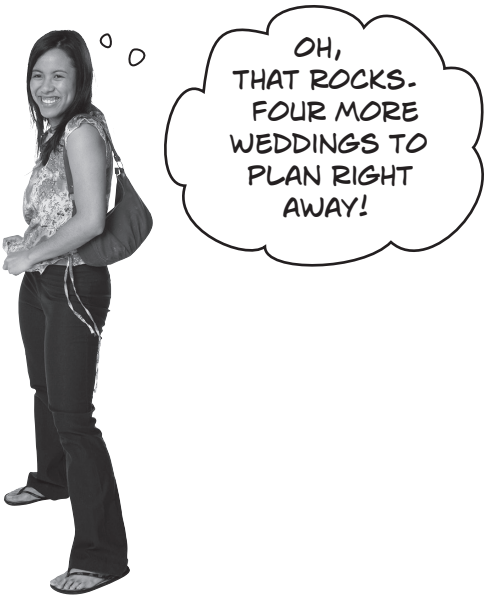
Agile considerations

Agile teams focus on team collaboration around commitments and making decisions at the last responsible moment. They use short iterations to create feedback loops that let them change the activities they'll do and their sequence when new information arises. Agile teams use timeboxes and an understanding of the rate at which work is accomplished (velocity) to give a sense of when items will be completed, but always leave the option to change the approach to delivering products when priorities change.

Another satisfied customer!

Rob and Rebecca had a beautiful wedding! Everything was perfect. The guests were served their meals, the band was just right, and everyone had a blast…

…and Kathleen got lots of referrals!



Each of these scenarios describes a different tool or technique from Estimate Activity Durations. Write down which tool or technique is being described.

1. Kathleen comes up with three estimates (one where everything goes wrong, one where some things go wrong, and one where nothing goes wrong) for printing invitations, and averages them together to come up with a final number. Three-point estimate

2. There will be two different catering companies at the wedding. Kathleen asks the head chef at each of them to give her an estimate of how long it will take to do the job. Expert judgment

3. There's a spreadsheet Kathleen always uses to figure out how long it takes guests to RSVP. She enters the number of guests and their zip codes, and it calculates an estimate for her. Parametric estimating

4. Kathleen's done four weddings that are very similar to Rob and Rebecca's, and in all four of them it took exactly the same amount of time for the caterers to set up the reception hall. Analogous estimating

Here are some examples of three point estimates. Use the formula to figure out the expected time for each of these.

1. Expected duration = 50d; Optimistic duration = 30d; Most likely duration = 45d; Pessimistic duration = 90d

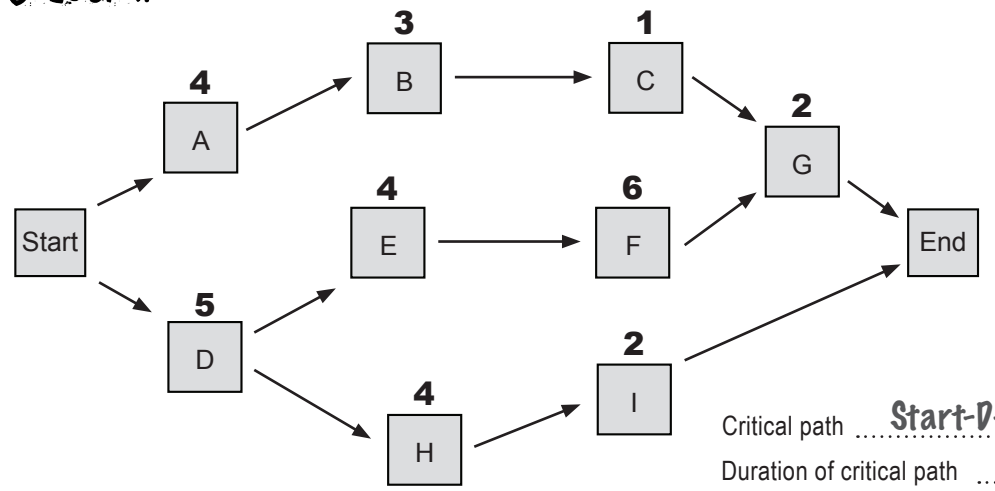
2. Expected duration = 20.3d; Optimistic duration = 12d; Most likely duration = 20d; Pessimistic duration = 30d

3. Expected duration = 25d; Optimistic duration = 10d; Most likely duration = 25d; Pessimistic duration = 40d

4. Expected duration = 51.8d; Optimistic duartion = 33d; Most likely duration = 49d; Pessimistic duration = 82d

Exercise Solution

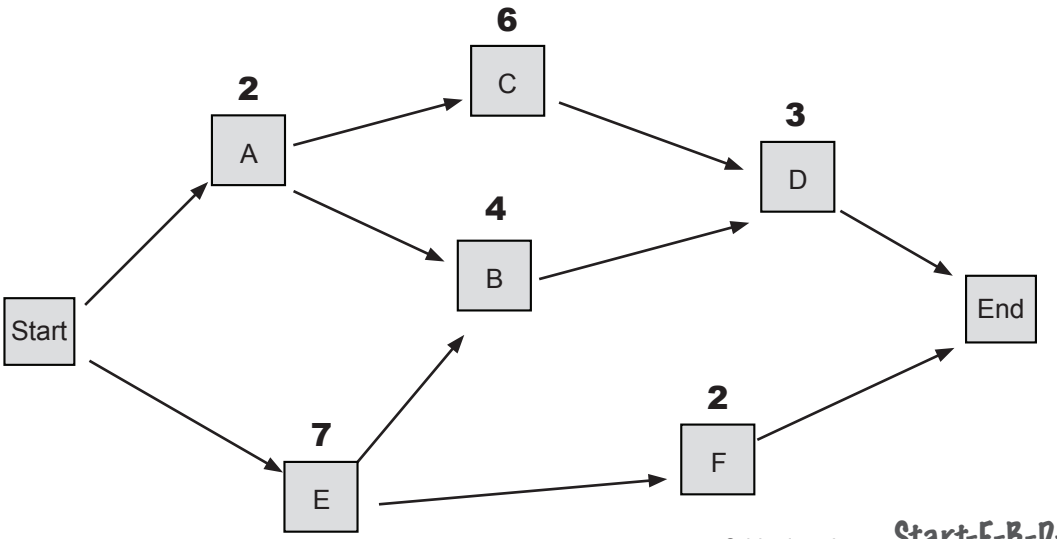
You may get questions on the exam asking you to identify the critical path in a network diagram. You had to practice that by finding the critical path and duration for this PDM.



Critical path ..... Start-D-E-F-G-End

Duration of critical path 17

Total number of paths 3



Critical path ..... Start-E-B-D-End

Duration of critical path 14

Total number of paths 4

You'll need to be able to calculate the float of an activity in a network diagram for the exam. Take another look at this PDM from the last exercise. Can you calculate the float for each activity?

1. What is the float for each activity on the critical path? 0

2. What is the total duration for path A – B – C – G? 10

3. What is the total duration for path A – B – F – G? 15

4. What is the total duration for path D – E – F – G? 17

5. What is the total duration for path D – H – I? 11

6. Which path is the critical path? D – E – F – G

7. Write down the float for each activity:

A 2 B 2 C 7 D 0 E 0

F 0 G 0 H 6 I 6

Each of these scenarios describes a schedule compression technique. Pick which are examples of fast-tracking and which are crashing.

1. Kathleen guesses that 70% of the invitees will RSVP. Instead of waiting for all of them to come in, she goes ahead and reserves the tables and chairs now.

   ☑ Fast-tracking ☐ Crashing

2. Rebecca is taking a really long time to choose the decorations, so Kathleen brings in a professional decorator to help, even though it will cost more.

   ☐ Fast-tracking ☑ Crashing

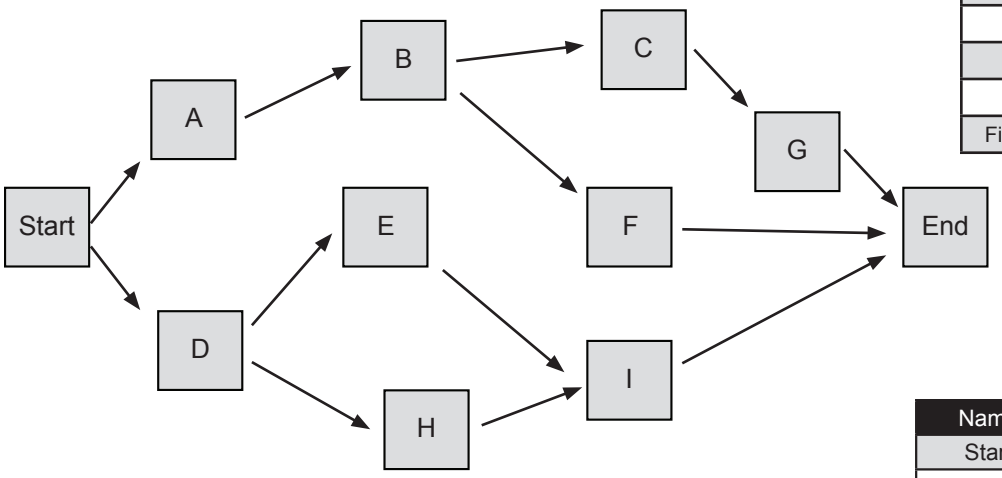
3. Kathleen needs to get the invitations out quickly, so she hires two temps to come in and help her stuff envelopes for a few days.

   ☐ Fast-tracking ☑ Crashing

Sharpen your pencil Solution

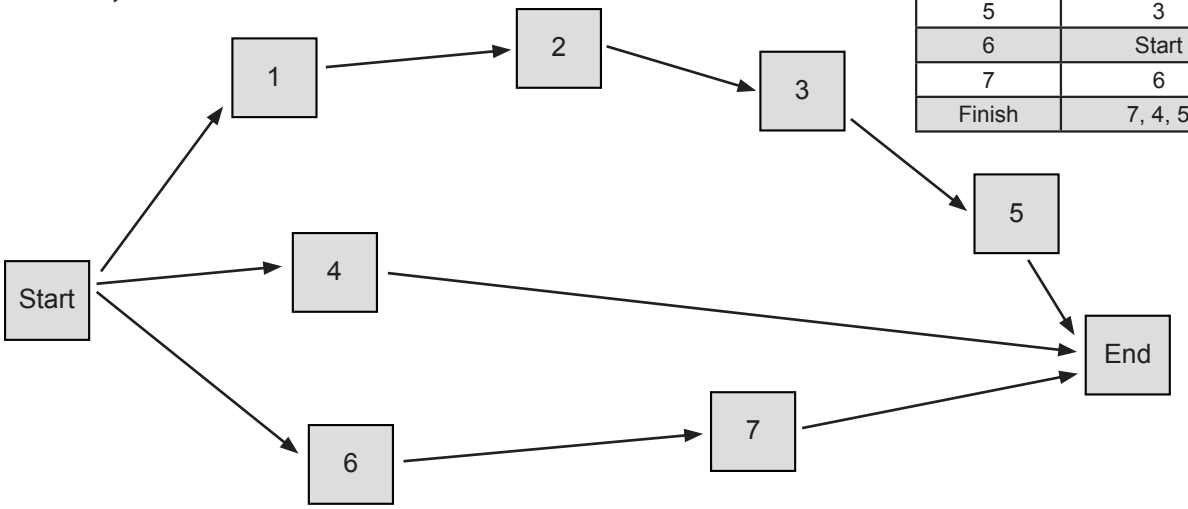
You'll need to know how to turn a table of nodes into a network diagram, so here's your chance to get some practice! Here's a list of nodes for a PDM network diagram. Try drawing the diagram based on it:

Name	Predecessor
Start	—
A	Start
B	A
C	B
D	Start
E	D
F	B
G	C
H	D
I	E, H
Finish	F, G, I



Now try another one!

Name	Predecessor
Start	—
1	Start
2	1
3	2
4	Start
5	3
6	Start
7	6
Finish	7, 4, 5



Control Schedule Magnets Answers

You'll see change control over and over again—every single knowledge area has its own change control process! Luckily, you'll start to see how similar they all are. But Control Schedule has its own quirks, and they're important for understanding Project Schedule Management.

This is just like Scope Management! You start with a plan, a baseline, and change requests.

Inputs

You use these to figure out which milestones you hit and which activities are slipping.

- Work performance data
- Project Management plan
- Project documents
- Organizational process assets

Tools

These tools are all about figuring out where you stand in relation to the baseline!

- Leads and lags
- Resource optimization
- Data analysis
- Critical path method
- Project management information system
- Schedule compression

Outputs

This should also look really familiar. When you go through change control, you end up with a bunch of updates and some corrective actions.

- Work performance information
- Schedule forecasts
- Change requests
- Updates to
  - Project documents
  - Project Management plan

Schedulecross solution

Did you get thrown because you thought using a historical database meant that you were doing analogous estimation? If you're plugging values into a database or spreadsheet, you're doing parametric estimation. A lot of people consider this a special type of analogous estimation, but describing it as parametric is more accurate.

	1 D	E	2 C	O	M	P	O	S	I	T	I	O	N			3 R		
			R												4 L	O		
			I		5 P	R	6 E	C	E	D	E	N	C	E		L		
			T				X							V		L		
7 W	H	A	T	I	F		T				8 B	A	S	E	L	I	N	E
			C		9 S		E							L		N		
	10 P	A	R	A	M	E	T	R	I	C				I		G		
			L		Q		N							N		W		
					U		A					11 F		G		A		
					E		12 L	E	A	D		L				V		
13 C	R	A	S	H	I	N	G					O				E		
					C							A						
				14 P	E	S	S	I	M	I	S	T	I	C				

Here are some examples of three-point estimates. Use the formula to figure out the expected time for each of these.

1. Expected duration = 50d; Optimistic duration = 30d; Most likely duration = 45d; Pessimistic duration = 90d

2. Expected duration = 20.3d; Optimistic duration = 12d; Most likely duration = 20d; Pessimistic duration = 30d

3. Expected duration = 25d; Optimistic duration = 10d; Most likely duration = 25d; Pessimistic duration = 40d

4. Expected duration = 51.8d; Optimistic duration = 33d; Most likely duration = 49d; Pessimistic duration = 82d

Exam Questions

1. You're managing a project when your client tells you that an external problem happened, and now you have to meet an earlier deadline. Your supervisor heard that in a situation like this, you can use schedule compression by either crashing or fast-tracking the schedule, but he's not sure which is which. What do you tell him?

A. Crashing the project adds risk, while fast-tracking adds cost.

B. When you crash a project, it always shortens the total duration of the project.

C. Crashing the project adds cost, while fast-tracking adds risk.

D. When you fast-track a project, it always shortens the total duration of the project.

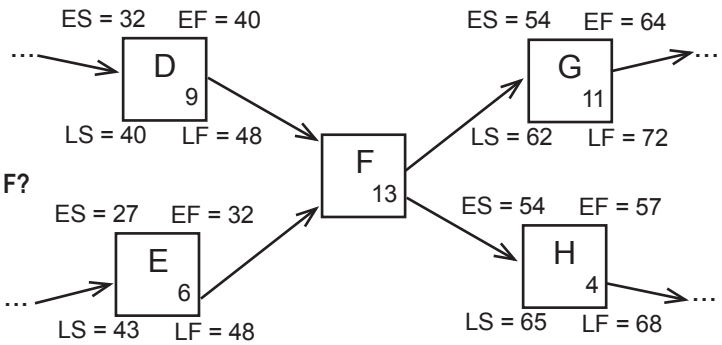
2. Given this portion of the network diagram to the right, what's the EF of activity F?

A. 41

B. 49

C. 53

D. 61



3. Given this portion of the network diagram to the right, what's the LS of activity F?

A. 41

B. 49

C. 53

D. 61

4. You are managing a software project. Your QA manager tells you that you need to plan to have her team start their test planning activity so that it finishes just before testing begins. But other than that, she says it can start as late in the project as necessary. What's the relationship between the test planning activity and the testing activity?

A. Start-to-Start (SS)

B. Start-to-Finish (SF)

C. Finish-to-Start (FS)

D. Finish-to-Finish (FF)

5. You're managing an industrial design project. You've come up with the complete activity list, created network diagrams, assigned resources to each activity, and estimated their durations. What's the next thing that you do?

A. Use rolling wave planning to compensate for the fact that you don't have complete information.

B. Create the schedule.

C. Consult the project scope statement and perform Sequence Activities.

D. Use fast-tracking to reduce the total duration.

Exam Questions

6. Which of the following is NOT an input to Develop Schedule?

A. Activity list
B. Project schedule network diagrams
C. Resource calendars
D. Schedule baseline

7. Three members of your project team want to pad their estimates because they believe there are certain risks that might materialize. What is the BEST way to handle this situation?

A. Estimate the activities honestly, and then use a contingency reserve to cover any unexpected costs.
B. Allow more time for the work by adding a buffer to every activity in the schedule.
C. Tell the team members not to worry about it, and if the schedule is wrong it's OK for the project to be late.
D. Crash the schedule.

8. You're managing a software project. You've created the schedule, and you need to figure out which activities cannot slip. You've done critical path analysis, identifying the critical path and calculating the early start and early finish for each activity. Which activities cannot slip without making the project late?

A. The ones with the biggest difference between ES and LF
B. The activities on the critical path
C. The activity with the most lag
D. The last activity in the project, because it has no float

9. What is the critical path in the activity list to the right?

A. Start-A-B-C-Finish
B. Start-A-D-E-F-Finish
C. Start-G-H-I-J-Finish
D. Start-A-B-J-Finish

10. What is the float for activity F in the activity list to the right?

A. 0
B. 7
C. 8
D. 10

Name	Predecessor	Duration
Start	—	—
A	Start	6
B	A	4
C	B	8
D	A	1
E	D	1
F	E	2
G	Start	3
H	G	3
I	H	2
J	B, I	3
Finish	F, J, C	—

11. You're managing an interior decoration project when you find out that you need to get it done earlier than originally planned. You decide to fast-track the project. This means:

A. Starting the project sooner and working overtime
B. Assigning more people to the tasks at a greater total cost, especially for activities on the critical path
C. Starting activities earlier and overlapping them more, which will cost more and could add risks
D. Shortening the durations of the activities and asking people to work overtime to accommodate that

Exam Questions

12. Slack is a synonym for:

A. Float
B. Lag
C. Buffer
D. Reserve

13. You're managing a construction project. You've decomposed work packages into activities, and your client needs a duration estimate for each activity that you come up with. Which of the following will you use for this?

A. Milestone list
B. Activity list
C. Critical path analysis
D. Project schedule network diagram

14. What's the correct order of the Project Schedule Management planning processes?

A. Sequence Activities, Define Activities, Estimate Activity Resources, Estimate Activity Durations, Develop Schedule
B. Plan Schedule Management, Define Activities, Sequence Activities, Develop Schedule, Estimate Activity Resources, Estimate Activity Durations
C. Plan Schedule Management, Define Activities, Sequence Activities, Estimate Activity Resources, Estimate Activity Durations, Develop Schedule
D. Plan Schedule Management, Develop Schedule, Define Activities, Sequence Activities, Estimate Activity Resources, Estimate Activity Durations

15. Which of the following is NOT a tool or technique used in Estimate Activity Durations?

A. SWAG estimation
B. Parametric estimation
C. Analogous estimation
D. Three-point estimation

16. You're managing a project to build a new project management information system. You work with the team to come up with an estimate of 27 weeks. In the best case, this could be shortened by two weeks because you can reuse a previous component. But there's a risk that a vendor delay could cause the project to be delayed by five weeks. Use PERT to calculate a three-point estimate for this project.

A. 25.83 weeks
B. 26 weeks
C. 27.5 weeks
D. 28.3 weeks

Exam Questions

17. Given the network diagram below, what's the critical path?

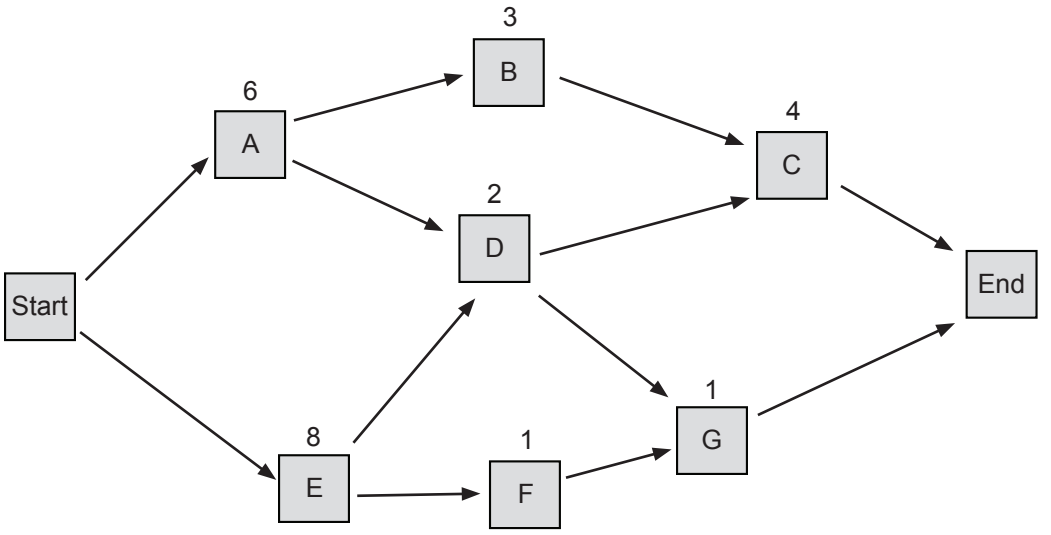
A. Start-A-B-C-End
B. Start-A-D-G-End
C. Start-E-D-C-End
D. Start-E-F-G-End

18. For that same network diagram below, what's the float for activity A?

A. 0 weeks
B. 1 week
C. 2 weeks
D. 4 weeks

19. For that same network diagram below, what's the float for activity E?

A. 0 weeks
B. 1 week
C. 2 weeks
D. 4 weeks



Exam Questions

20. You're managing a software project when your customer informs you that a schedule change is necessary. Which is the BEST thing to do?

A. Consult the schedule management plan.
B. Notify the team and the sponsor that there's going to be a schedule change.
C. Influence the factors that cause change.
D. Refuse to make the change because there's already a schedule baseline.

21. Your company has previously run other projects similar to the one you're currently managing. What is the BEST way to use that information?

A. Check the organizational process assets for lessons learned and other information about the past projects.
B. Use parametric estimation to estimate your project based on past projects' performance.
C. Start from scratch because you don't want mistakes from past projects to influence you.
D. Reuse the Project Management plan from a past project.

22. You're planning the schedule for a highway construction project, but the final date you came up with will run into the next budget year. The state comes up with capital from a reserve fund, and now you can increase the budget for your resources. What's the BEST way to compress the schedule?

A. Go back to your three-point estimates and use the most optimistic ones.
B. Use the extra budget to increase your contingency reserve.
C. Hire more experts to use expert judgment so your estimates are more accurate.
D. Crash the schedule.

23. You're managing a construction project. You've decomposed work packages into activities, and your client needs a duration estimate for each activity that you came up with. Which of the following BEST describes what you are doing?

A. Evaluating each activity to figure out how much effort it will take
B. Estimating the number of person-hours that will be required for each activity
C. Understanding, in calendar time, how long each activity will take
D. Estimating how many people it will take to perform each activity

Exam Questions

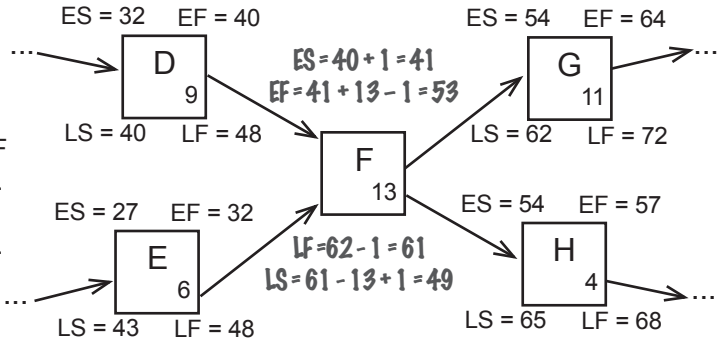
Answers

1. Answer: C

You're likely to get some questions that ask you about crashing and fast-tracking, and it's important to know the difference between them. When you crash the project, it means that you add resources to it, especially to the critical path. There's no real risk in doing that—in the worst-case scenario, the extra people just sit around!—but it does cost more. Fast-tracking means adjusting the schedule so that activities overlap. The same resources are doing the work, so it's not going to cost more, but it's definitely riskier, because now you've eliminated buffers and possibly broken some dependencies! And remember that crashing or fast-tracking won't always work to make the project go faster!

2. Answer: C

To calculate EF for a task with two predecessors, start by calculating the ES: choose the highest EF of the predecessors and add 1: ES = 40 + 1 = 41. Then use that ES to calculate EF by adding the duration and subtracting 1: EF = 41 + 13 - 1 = 53.



3. Answer: B

To calculate LS for a task that's the predecssor to two other tasks, start by calculating the LF. Take the lowest LS and subtract 1: LF = 61 - 1 = 61. Then use that LF to calculate LS by subtracting the duration and adding 1: LS = 61 - 13 + 1 = 49.

4. Answer: C

Don't let the jargon fool you! You don't need to know anything about software testing to answer this question. When you have two activities, and the first activity has to be timed so that it finishes before the second one starts, then you've got a Finish-to-Start relationship, or FS.

5. Answer: B

Did answer A trick you? No need for rolling wave planning when you've got enough info to define all the activities!

This is a which-is-next question that describes a project that's completed the Define Activities, Sequence Activities, Estimate Activity Resources, and Estimate Activity Durations processes. The next process in Project Schedule Management is Develop Schedule, which means that the next thing you do is create the schedule!

Exam ~~Questions~~ Answers

6. Answer: D

The schedule baseline is an output of the Develop Schedule process, not an input. You should definitely know what goes into the schedule baseline: it's a specific version of the schedule that you set aside and use for comparison later on, when you want to know if the project is running late.

I GET IT: WE CAN USE THE SCHEDULE BASELINE THE SAME WAY THAT WE USE THE SCOPE BASELINE! WE TAKE A SNAPSHOT OF IT AND THEN SAVE IT, SO WE CAN COMPARE THE PROJECT'S PERFORMANCE AGAINST IT LATER!

7. Answer: A

You always want to be honest with your estimates. Every project has unknowns and risks, and there's no way to estimate any activity exactly! Luckily, we have tools to deal with this. You can use reserve analysis, a tool of Estimate Activity Durations, to come up with a contingency reserve that you can use to plan for these risks.

8. Answer: B

The critical path is the path in the network diagram where any delay will cause a delay in the schedule. These are the activities that cannot slip without making the project late.

9. Answer: A

When you draw out a network diagram for the activities in the table, you end up with four paths. And you definitely should draw out the activity diagram for a question like this! You're allowed to use scratch paper on the exam, and this is one place where you should definitely do it. Of the four paths, only one has the longest duration: Start-A-B-C-Finish, which has a duration of 6 + 4 + 8 = 18. That's the critical path.

Exam Questions Answers

10. Answer: C

Activity F is in the path Start-A-D-E-F-Finish. This path has a duration of 6 + 1 + 1 + 2 = 10. The float of an activity is the longest time it can slip before it affects the critical path. In this case, activity F can slip by 8 without causing the path that it's on to go beyond the critical path. But any more than that, and its path becomes the new critical path!

Did you notice answer A? Don't forget that the float of any activity in the critical path is zero!

11. Answer: C

This is the definition of fast-tracking, and you're probably getting the hang of this one by now. You may get a question like this, but you'll almost certainly see fast-tracking as an incorrect answer to several questions.

12. Answer: A

Remember that when you see *slack*, it's the same thing as float. Either term could appear on the exam.

When a question asks what you'd use for a process, it's asking you to pick an input, tool, or technique that's part of the process.

13. Answer: B

This question is asking about the Estimate Activity Durations process. Take a look at the answers—there's only one answer that's used in that process: you need to start with the activity list in order to do the estimates for the activities. The other answers are things that are inputs, tools, or techniques for other processes.

14. Answer: C

It's not hard to remember the order in which the Project Schedule Management processes are performed. If you use a little common sense, you can reason your way through a question like this. You need to define your activities before you can sequence them, you need to know who's going to be doing an activity before you can estimate how long it's going to take, and you need to do all of that before you can build a schedule!

Control Schedule isn't included in the list of processes because if a schedule change happens, you'll have to go back and revisit the other Project Schedule Management processes. So it doesn't have a specific order!

15. Answer: A

You'll have to know the different kinds of estimating techniques for the exam. You don't necessarily have to be good at doing them, but you should recognize which are which. Parametric estimating is when you plug values into a formula, program, or spreadsheet and get an estimate. Analogous estimating uses similar activities from past projects to calculate new estimates. Three-point estimating uses an optimistic, pessimistic, and realistic estimate.

Exam Questions Answers

16. Answer: C

This question is asking you to apply the PERT three-point estimation formula: (optimistic time + 4 × most likely time + pessimistic time) ÷ 6. When a question gives you these values directly, it's easy. But in this case, to answer the question you had to figure out the values for the optimistic time and pessimistic time, which meant that you needed to look at the assumptions that the team was making. The most likely time was given: 27 weeks. The best-case scenario would come in two weeks earlier, at 25 weeks, and the worst case would come in five weeks late, at 32 weeks. So the estimate is (25 weeks + 4 × (27 weeks) + 32 weeks) ÷ 6 = 27.5 weeks.

Sometimes you'll get a question about applying a formula, but you'll need to read the text in the question to figure out all of the variables.

17. Answer: C

The path Start-E-D-C-End has a duration of 8 + 2 + 4 = 14, which is the longest total duration in the entire network.

18. Answer: B

Activity A is on three different paths: Start-A-B-C-End (13), Start-A-D-C-End (12), and Start-A-D-G-End (9). To calculate its float, you take the longest path's length and subtract it from the length of the critical path: 14 – 13 = 1.

Can you think of how a question might quiz you on this information without actually asking you to look at a network diagram?

19. Answer: A

Since Activity E is on the critical path, its float is zero, because the float of any activity on the critical path is zero.

20. Answer: A

The Schedule Management plan tells you how changes to the schedule are to be handled. Any time there's a change, the first thing you should do is consult the plan to see how it should be handled.

Exam Questions Answers

21. Answer: A

The organizational process assets contain historical information about past projects. When you write up your lessons learned, or create work performance information, you store it in your company's organizational process asset library! Also, did you notice that answer B was the wrong definition of parametric estimation?

22. Answer: D

Crashing the schedule is the form of schedule compression that increases cost. This is a difficult question because all of the answers sound good, and one or two are a little misleading! Don't fall into the trap of choosing an answer because you recognize a valid tool or technique in it. Reserve analysis and three-point estimates are very useful techniques, but they're not the answer to this question.

23. Answer: C

This question was really about the definition of *duration*, and the key to answering it is to understand how duration is different from effort. The correct answer talks about "calendar time," which is what a duration is: it's a measurement (or estimate) of how long the activity will take in real life, taking into account the number of people who will be doing the work, the availability of the people and other resources, everyone's vacation time, time taken away from the schedule because people are pulled off of the activity to work on higher-priority activities, and other real-world factors. That's different from effort (which is often measured in person-hours), and it's different from resource estimating (which involves estimating how many people and what other resources will be used for the activity).

7 Cost management

Watching the bottom line

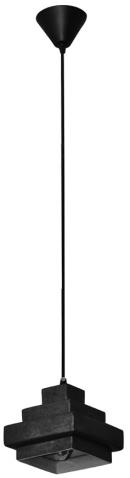
Every project boils down to money. If you had a bigger **budget**, you could probably get more people to do your project more quickly and deliver more. That's why no project plan is complete until you come up with a budget. But no matter whether your project is big or small, and no matter how many **resources** and **activities** are in it, the process for figuring out the bottom line is *always the same!*

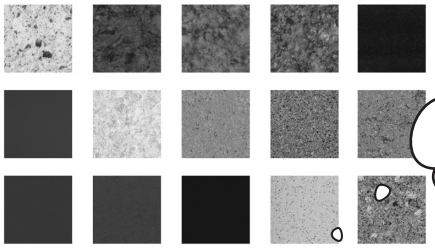
Time to expand Head First Kitchen

The Head First Kitchen is doing so well that their owners are going to go ahead and open a second location near you! They found a great location, and now all they need to do is renovate it.

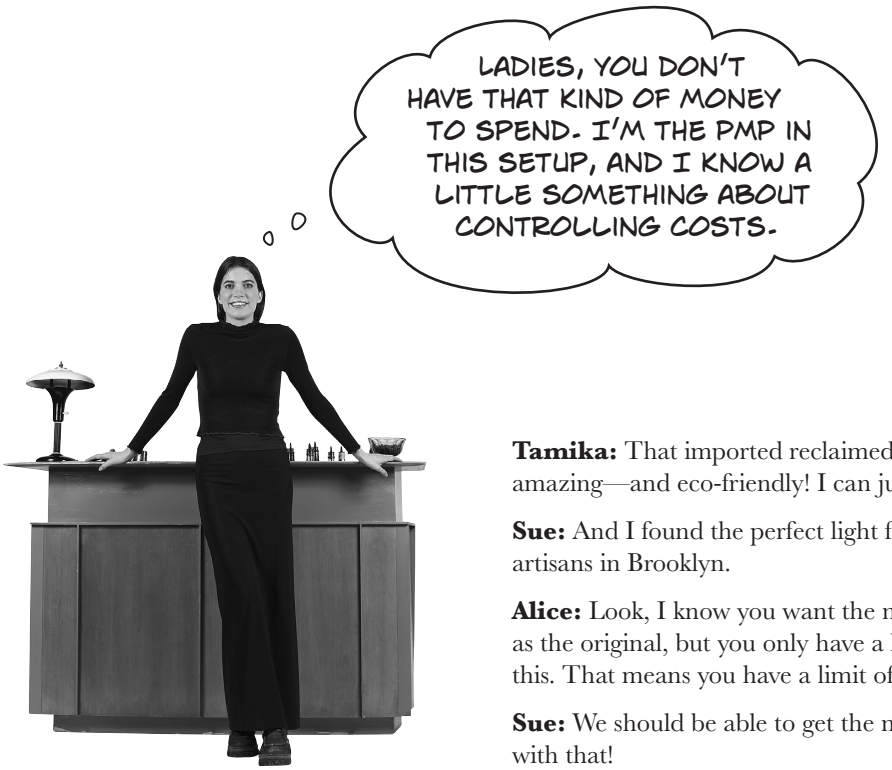
The renovation goes overboard

When they start planning out what to buy, they want really expensive furniture and fixtures for the dining room—antique tables, luxury flooring, even a historic bar shipped in from another city. This is going to cost a lot of money…





Kitchen conversation



Alice, the Head First Kitchen's hostess—and project manager, since she got her PMP certification.

Tamika: That imported reclaimed wood flooring is amazing—and eco-friendly! I can just imagine how it will look.

Sue: And I found the perfect light fixtures made by hand by artisans in Brooklyn.

Alice: Look, I know you want the new Kitchen to look as good as the original, but you only have a little spare cash to spend on this. That means you have a limit of $10,000.

Sue: We should be able to get the new place looking amazing with that!

Alice: Costs can creep up on you if you don't watch what you're doing. The best way to handle this is to create a budget and check your progress against it as you go.

Tamika: You always turn everything into a project! Can't you see that we have a vision?

Alice: Of course...but you don't want that vision to drive you into the red.

Introducing the Cost Management processes

To make sure that they don't go over budget, Tamika, Sue, and Alice sit down and come up with detailed estimates of their costs. Once they have that, they add up the cost estimates into a budget, and then they track the project according to that budget while the work is happening.

Plan Cost Management

Just like all of the other knowledge areas, you need to plan out all of the processes and methodologies you'll use for Cost Management up front.

Estimate Costs

This means figuring out exactly how much you expect each work activity you are doing to cost. So each activity is estimated for its time and materials cost, and any other known factors that can be figured in.

You need to have a good idea of the work you're going to do and how long it will take to do that work.

Determine Budget

Here's where all of the estimates are added up and baselined. Once you have figured out the baseline, that's what all future expenditures are compared to.

This is just like the scope baseline from Chapter 5 or the schedule baseline from Chapter 6.

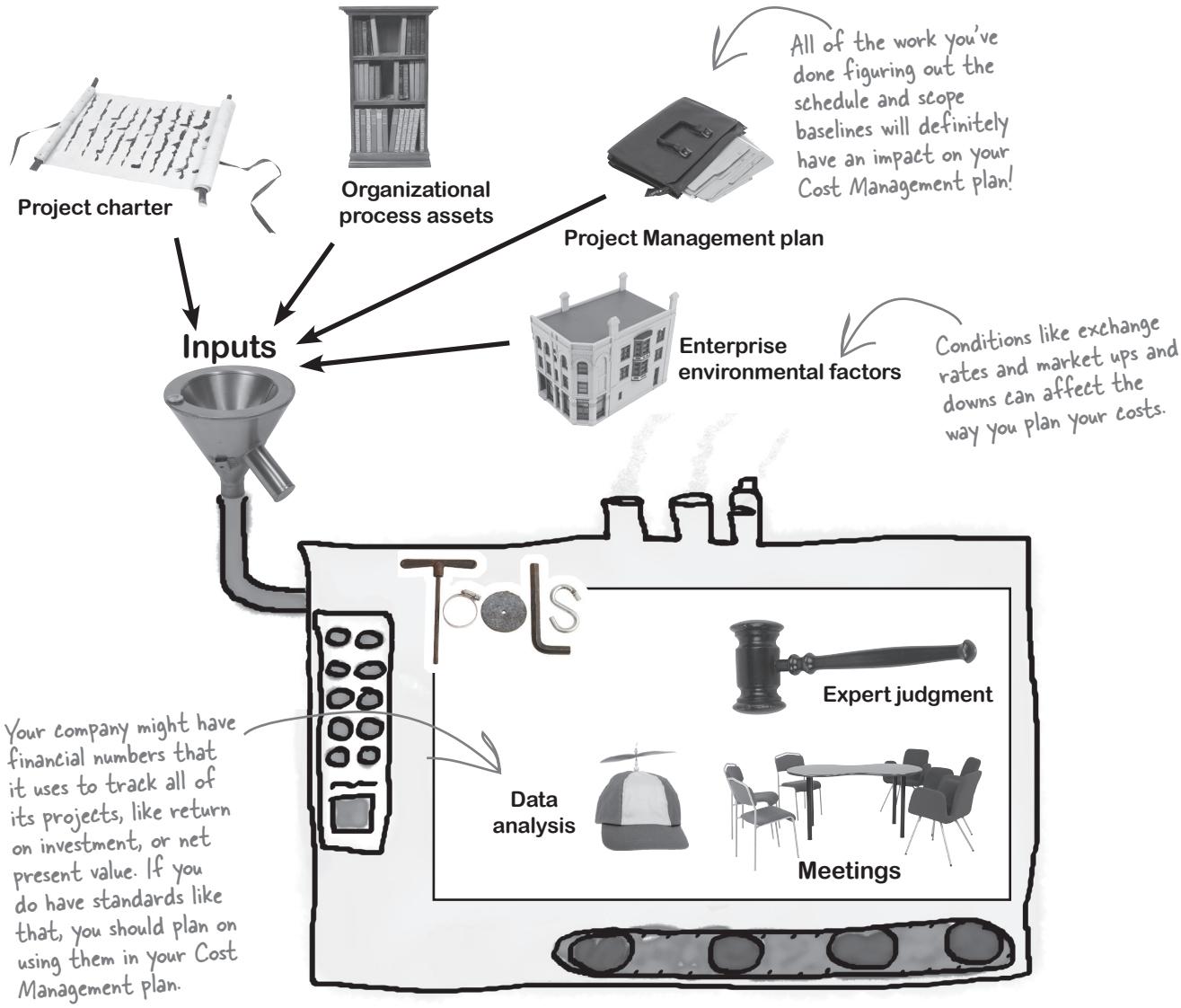
Control Costs

This just means tracking the actual work according to the budget to see if any adjustments need to be made.

Controlling costs means always knowing how you are doing compared to how you thought you would do.

Plan how you'll estimate, track, and control your costs

When you've got your project charter written and you're starting to put together your Project Management plan, you need to think about all of the processes and standards you'll follow when you estimate your budget and track to that estimate. By now, you're pretty familiar with the inputs, outputs, tools, and techniques you'll use in the **Plan Cost Management** process.



Now you've got a consistent way to manage costs

There's only one output of the Plan Cost Management process, and that's the Cost Management plan. You'll use this document to specify the accuracy of your cost estimates, the rules you'll use to determine whether or not your cost processes are working, and the way you'll track your budget as the project progresses. When you've planned out your Cost Management processes, you should be able to estimate how much your project will cost using a format consistent with all the rest of your company's projects. You should also be able to tell your management how you'll know if your project starts costing more than you estimated.

Outputs

Cost Management plan

Here's where you write down the subsidiary plan inside the Project Management plan that deals with costs. You plan out all of the work you'll do to figure out your budget and make sure your project stays within it.

You'll want to define the units you'll use to manage your budget. For some projects, that's total person-hours; for others, it's an actual value in money. However you plan to track your costs, you need to let everybody on the project know up front.

The Plan Cost Management process is where you plan out all the work you'll do to make sure your project doesn't cost more than you've budgeted.

What Alice needs before she can estimate costs

Alice wants to keep the Kitchen project's costs under control, and that starts with the **Estimate Costs** process. Before Alice can estimate costs, she needs the scope baseline. Once she knows who's doing what work, and how long it'll take, she can figure out how much it will cost.

Information about the costs for specific resources and quality activities make it possible for Alice to make the overall cost estimates.

Information about past cost estimates helps her make a more realistic estimate.

The way that Sue and Tamika keep their books figures into how Alice will do their estimates as well.

Project Management plan

Organizational process assets

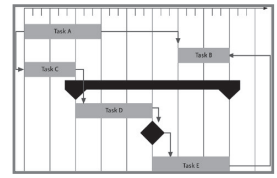
Enterprise environmental factors

This includes the Cost Management plan you created in the Plan Cost Management process as well as the scope baseline.

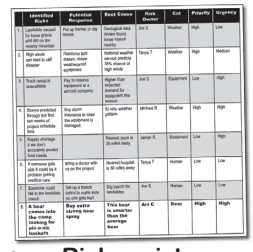
Project Documents

These are all project documents.

Project schedule



Resource requirements

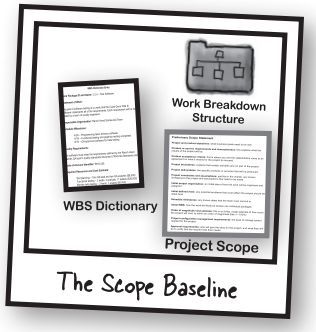


Risk register

The risk register identifies risks that could add costs to your project. You'll learn more about this document in Chapter 11.

Lessons learned

Inputs



The work breakdown structure will list all of the work packages that are in the scope of the project. That tells her what she needs to estimate.

Estimate costs

Sharpen your pencil

You've actually seen five of the tools and techniques in the Estimate Costs process before. Take a look at the list of tools below, and try to figure out which one of them Alice is using when she estimates costs. Can you write down which tool is being used in each scenario?

A. Bottom-up estimating

B. Analogous estimating

C. Expert judgment

D. Parametric estimating

E. Three-point estimates

1. The café across the street opened just a few months ago. Alice sits down with the contractor who did the work there and asks him to help her figure out how much it will cost. He takes a look at the equipment Sue and Tamika want to buy and the specs for the cabinets and seating and tells her what she can afford to do with the budget she has.

Tool: .....

2. Alice creates a spreadsheet with all of the historical information from similar remodeling projects that have happened on her block. She sits down and types in Tamika and Sue's desired furnishings and the square footage of the room to generate an estimated cost.

Tool: .....

3. Before Alice finishes her schedule, she gathers all of the information she has about previous projects' costs (like how much labor and materials cost). She also talks to a contractor, who gives valuable input.

Tool: .....

4. Alice sits down and estimates each and every activity and resource that she is going to need. Then she adds up all of the estimates into "rolled-up" categories. From there she adds up the categories into an overall budget number.

Tool: .....

5. Tamika sets up an appointment with the same contractor her friend used for some remodeling work. The contractor comes to the house, takes a look at the room, and then gives an estimate for the work.

Tool: .....

6. Alice figures out a best-case scenario, a most likely scenario, and a worst-case scenario. Then she uses a formula to come up with an expected cost for the project.

Tool: .....

Sharpen your pencil Solution

Did you work out which estimating tool from Schedule Management Alice is using when she estimates costs in each of these scenarios?

1: **B. Analogous estimating**
Since Alice is using the contractor's experience with a similar project to figure out how long her project will take, she is assuming that her project will go like the café one did.

2: **D. Parametric estimating**
In this one Alice is just applying some numbers particular to her project to some historical information she has gathered from other projects and generating an estimate from that.

3: **C. Expert judgment**
Expert judgment often involves going back to historical information about past projects as well as consulting with experts or using your own expertise.

4: **A. Bottom-up estimating**
Starting at the lowest level and rolling up estimates is bottom-up estimating. Alice started with the activities on her schedule and rolled them up to categories and finally to a budget number.

5: **C. Expert judgment**
This is another example of asking somebody who has direct experience with this kind of work to give an estimate.

6: **E. Three-point estimate**
Alice came up with the three estimates and then performed a triangular distribution calculation.

Watch it!

Analogous estimating is sometimes called "top-down estimating."

Take a minute and think about why it would be called "top-down." When you're doing bottom-up estimating, first you break it down into pieces, estimate each piece, and add them up. Analogous estimation is the opposite: you start with the whole project (without breaking it up at all), find other projects that were like it, and use those projects to come up with a new estimate.

HOLD ON! HOW CAN YOU USE THE SAME TOOLS TO ESTIMATE **BOTH TIME AND COST**?

Good question.

Not all of the estimation techniques for cost are the same as the ones we used for time. Often, people only have a certain amount of time to devote to a project, and a fixed amount of money too. So, it makes sense that some of the tools for estimating both would overlap. We'll learn a few new ones next.

Other tools and techniques used in Estimate Costs

A lot of times you come into a project and there is already an expectation of how much it will cost or how much time it will take. When you make an estimate really early in the project and you don't know much about it, that estimate is called a **rough order of magnitude** estimate. (You'll also see it called a **ROM** or a **ballpark estimate**.) It's expected that it will get more refined as time goes on and you learn more about the project. Here are some more tools and techniques used to estimate cost:

This estimate is REALLY rough! It's got a range of −25% to +75%, which means it can be anywhere from half to one and a half times the actual cost! So you only use it at the very beginning of the project.

Data analysis

These techniques are part of the data analysis necessary to create cost estimates:

Vendor bid analysis

Sometimes you will need to work with an external contractor to get your project done. You might even have more than one contractor bid on the job. This tool is all about evaluating those bids and choosing the one you will go with.

Reserve analysis

You need to set aside some money for cost overruns. If you know that your project has a risk of something expensive happening, it's better to have some cash laying around to deal with it. Reserve analysis means putting some cash away just in case.

Cost of quality

You will need to figure the cost of all of your quality-related activities into the overall budget, too. Since it's cheaper to find bugs earlier in the project than later, there are always quality costs associated with everything your project produces. Cost of quality is just a way of tracking the cost of those activities.

Project management information system

Project managers will often use specialized estimating software to help come up with cost estimates (like a spreadsheet that takes resource estimates, labor costs, and materials costs and performs calculations).

Decision making

You'll need to work with groups of people to figure out your costs. It's important that your team feels like they can commit to the overall budget and schedule.

Let's talk numbers

There are a few numbers that can appear on the test as definitions. You won't need to calculate these, but you should know what each term means.

You'll get exam questions asking you to use BCR or NPV to compare two projects. The higher these numbers are, the better!

Benefit-cost ratio (BCR)

This is the amount of money a project is going to make versus how much it will cost to build it. Generally, if the benefit is higher than the cost, the project is a good investment.

Money you'll get in three years isn't worth as much to you as money you're getting today. NPV takes the "time value" of money into consideration, so you can pick the project with the best value in today's dollars.

Net present value (NPV)

This is the actual value at a given time of the project minus all of the costs associated with it. This includes the time it takes to build it as well as labor and materials. People calculate this number to see if it's worth doing a project.

If a project will make your company $150,000, then the opportunity cost of selecting another project instead is $150,000 because that's how much your company's missing out on by not doing the project.

Opportunity cost

When an organization has to choose between two projects, it's always giving up the money it would have made on the one it doesn't do. That's called opportunity cost. It's the money you don't get because you chose not to do a project.

Internal rate of return

This is the amount of money the project will return to the company that is funding it. It's how much money a project is making the company. It's usually expressed as a percentage of the funding that has been allocated to it.

Depreciation

This is the rate at which your project loses value over time. So, if you are building a project that will only be marketable at a high price for a short period of time, the product loses value as time goes on.

Lifecycle costing

Before you get started on a project, it's really useful to figure out how much you expect it to cost—not just to develop, but to support the product once it's in place and being used by the customer.

Match each scenario to the cost numbers that Alice is using in each one.

1. Alice does such a good job planning out her entertainment center remodeling that the Smiths down the street ask if they can have her help with their home theater upgrade. Since she is too busy doing the work on the Kitchen, she has to say no. Rob Smith says, "That's a shame; we were willing to pay $1,000 to someone to help us out with this."

2. The minute the TV gets installed, Alice starts inviting all of her friends over to the Kitchen to watch the games on the weekend. She charges a $2 cover charge for her football Saturdays and has been clearing about $20 per week even though the room isn't finished.

3. Even though the system she is currently installing is state of the art, Alice knows that within a year or so it will be on sale for half as much as she is paying now.

4. Alice wants to figure out how much the project is worth so far. So she adds up the value of all of the materials she has used, and subtracts the labor and any depreciation that needs to be accounted for. The number she ends up with gives the value of the overall project right now.

5. Before Tamika and Sue decided to do the remodeling, they compared how much the project was going to cost to how much good they thought it would do for them.

A. Opportunity cost

B. Benefit-cost ratio

C. Internal rate of return

D. Depreciation

E. Net present value

Answers: 1–A, 2–C, 3–D, 4–E, 5–B

Now Alice knows how much the Kitchen will cost

Once you've applied all of the tools in the Estimate Costs process, you'll get an estimate for how much your project will cost. It's always important to keep all of your supporting estimate information, too. That way, you know the assumptions you made when you were coming up with your numbers.

Outputs

Cost estimates

This is the cost estimate for all of the activities in your activity list. It takes into account resource rates and estimated duration of the activities.

Activity cost estimates

Basis of estimates

Just like the WBS has a WBS dictionary, and the activity list has activity attributes, the cost estimate has a supporting detail called the **basis of estimates**. Here is where you list out all of the rates and reasoning you have used to come to the numbers you are presenting in your estimates.

Basis of estimates

Updates to project documents

Along the way, you might find that you need to change the way you measure and manage cost. These updates allow you to make changes to the Project Management plan to deal with those improvements.

Project document updates

Once Alice has an estimate of the project's cost, what should she do with that information?

Kitchen conversation

Tamika: OK, how do we start? There are a lot of things to buy here.

Alice: We already have your savings, and the rest will come in July at the end of the quarter. The Kitchen is having another great year, so the profits are pretty good. Your savings are around $4,000 and the profits will probably be closer to $6,000. That's definitely enough money to work with.

Sue: Well, the furnishings I want aren't back in stock until June.

Alice: OK, so we have to time our costs so that they're in line with our cash flow.

Tamika: Oh! I see. So we can start building now, but we'll still have money in June and July when the furnishings come in. Perfect.

The Determine Budget process

Once Alice has cost estimates for each activity, she's ready to put a budget together. She does that using the **Determine Budget** process. Here's where you take the estimates that you came up with and build a budget out of them. You'll build on the activity cost estimates and basis of cost estimates that you came up with in Estimate Costs.

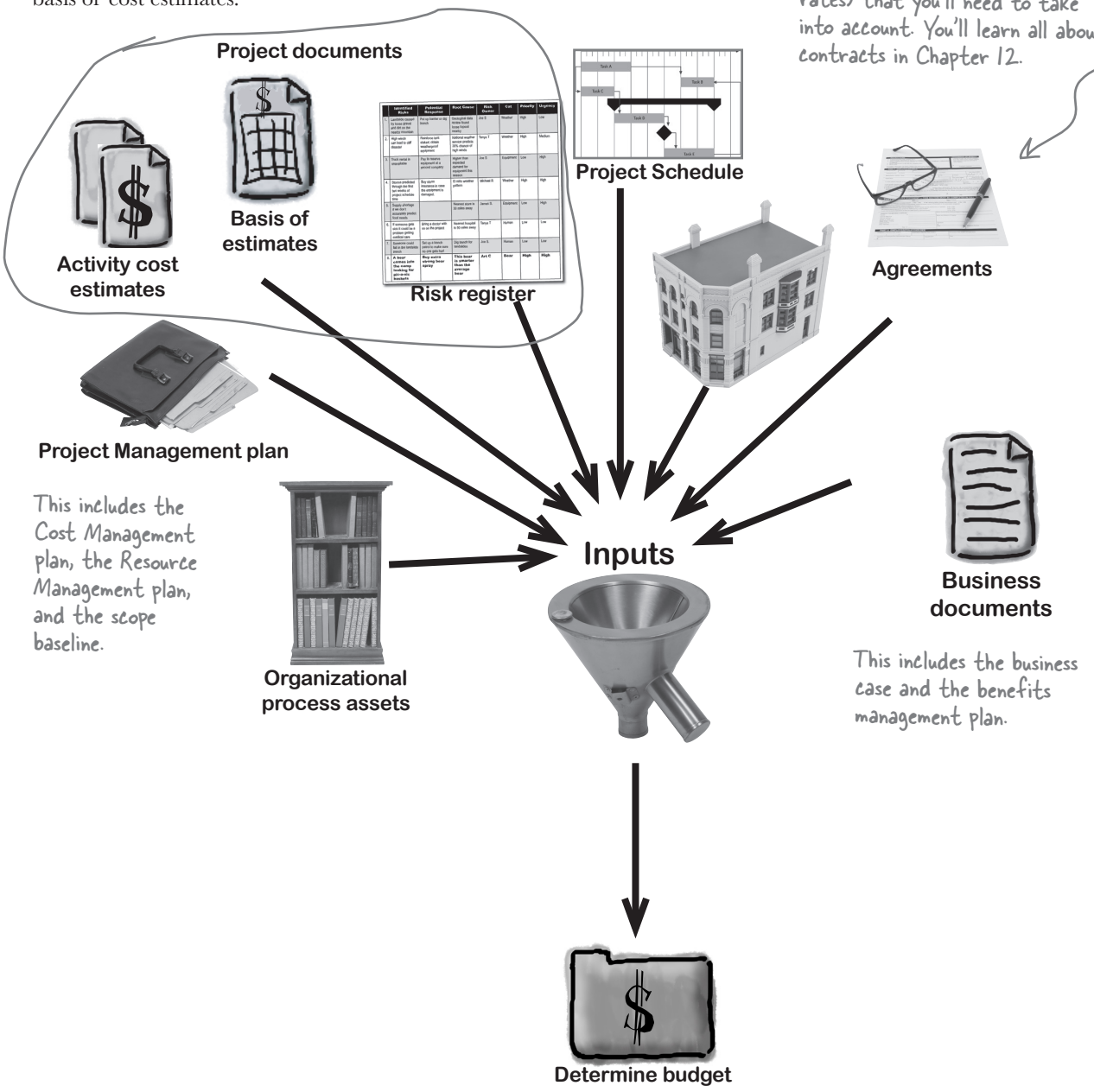
You use the outputs from the last process, where you created estimates, as inputs to this one. Now you can build your budget.

The two main outputs from Estimate Costs turn into the inputs for Determine Budget, because you build your budget based on the activity estimates.

What you need to build your budget

The **inputs** to Determine Budget are largely the same ones that you saw in Estimate Costs, with the notable additions of activity cost estimates and basis of cost estimates.

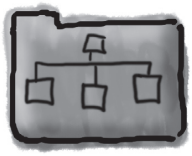
If you're doing work that's been contracted, then your agreement will have information (like fees or rates) that you'll need to take into account. You'll learn all about contracts in Chapter 12.



Determine budget: how to build a budget

1 Roll up your estimates into control accounts.

This tool is called **cost aggregation**. You take your activity estimates and roll them up into control accounts on your work breakdown structure. That makes it easy for you to know what each work package in your project is going to cost.



Outputs

2 Come up with your reserves.

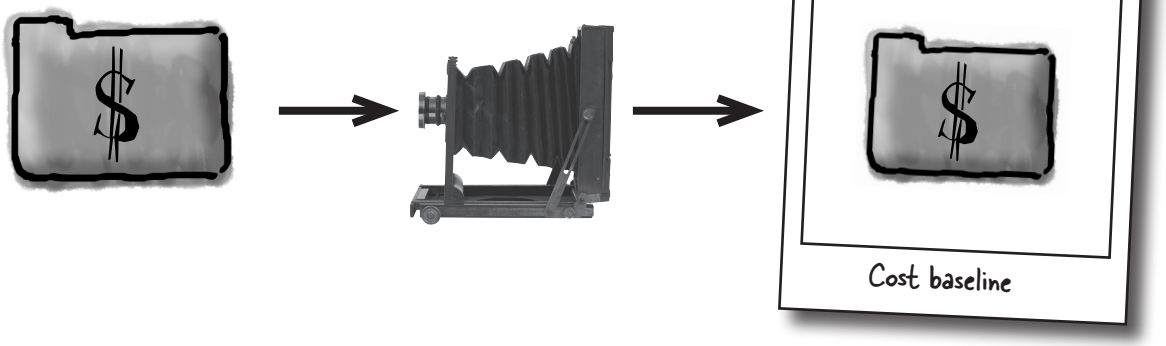
When you evaluate the risks to your project, you will set aside some cash reserves to deal with any issues that might come your way. This tool is called **data analysis**.

3 Use your expert judgment.

Here's where you compare your project to historical data that has been collected on other projects to give your budget some grounding in real-world **historical information**, and you use your own expertise and the expertise of others to come up with a realistic budget to cover your project's costs.

6 Build a baseline.

Just like your scope and schedule baselines, a **cost baseline** is a snapshot of the planned budget. You compare your actual performance against the baseline so you always know how you are doing versus what you planned.



Your company's management plans for project overruns!

Just because you plan out a budget in your cost baseline, that doesn't mean your project is 100% guaranteed to fall inside that budget. It's common for a company to have a standard policy for keeping a **management reserve** to cover unexpected, unplanned costs. When you need to get your project funded, that funding has to cover both the budget in your cost baseline *and* the management reserve.

4 Make sure you haven't blown your limits.

This tool is **funding limit reconciliation**. Since most people work in companies that aren't willing to throw unlimited money at a project, you need to be sure that you can do the project within the amount that your company is willing to spend.

It's true that not everybody has access to historical data to do a check like this. But, for the purposes of the test, you need to know that it's a tool for making your budget accurate.

If you blow your limit, you need to replan or go to your sponsor to figure out what to do. It could be that a scope change is necessary, or the funding limit can be increased.

5 Secure funding for your project.

This tool is **financing**. Since some companies go to external organizations to fund specific projects, you might need to meet special external requirements to get the financing. In this tool, you make sure you meet those requirements and get the finance commitments to make your project a success.

7 Figure out funding requirements.

It's not enough to have an overall number that everyone can agree to. You need to plan out how and when you will spend it, and document those plans in the **project funding requirements**. This output is about figuring out how you will make sure your project has money when it's needed, and that you have enough to cover unexpected risks as well as known cost increases that change with time.

So these requirements need to cover both the budget and the management reserve.

8 Update your Project Management plan and project documents.

Once you have estimated and produced your baseline and funding requirements, you need to update your Cost Management plan, cost baseline, and performance measurement baseline with the new information you've obtained. You might have updates to project documents as well.

What tool or technique is Alice using to estimate costs and/or build the budget?

1. Alice reads a newspaper article that says that there has been a sharp increase in lumber costs recently. She knows this wasn't in her contractor's original plan and decides to put a few hundred dollars aside to deal with the price hike if it should happen.

☐ Parametric estimating ☐ Reserve analysis ☐ Cost aggregation ☐ Funding limit reconciliation

2. Tamika helps Alice add up all of the estimates they have done into control accounts so that they can figure out how much the stereo installation is going to cost versus building the entertainment center.

☐ Parametric estimating ☐ Reserve analysis ☐ Cost aggregation ☐ Funding limit reconciliation

3. Once the budget is close to done, Alice looks over their financial plans for the year to be sure that they can afford everything at the time that it is needed.

☐ Parametric estimating ☐ Reserve analysis ☐ Cost aggregation ☐ Funding limit reconciliation

Answers: 1. Reserve analysis 2. Cost aggregation 3. Funding limit reconciliation

BULLET POINTS: AIMING FOR THE EXAM

- **Parametric estimation** is used in Estimate Costs and Determine Budget.
- **Cost aggregation** is rolling up costs from the work package level to the control account level so that the numbers can be followed down through the WBS hierarchy.
- **Control accounts** are high-level WBS items that are used to track cost estimates. They do not represent activities or work packages. They represent the cost of the work packages and activities that appear under them in the WBS.
- The main outputs of Estimate Costs are the activity cost estimate and the basis of estimates. The main outputs of Determine Budget are the cost baseline and project funding requirements.
- You will get questions on the exam asking you to select between projects using **net present value** (NPV) or **benefit-cost ratio** (BCR). Always choose the project with the biggest NPV or BCR!
- **Lifecycle costing** means estimating the money it will take to support your product or service when it has been released.
- **Rough order of magnitude estimation** is estimating with very little accuracy at the beginning of a project and then refining the estimate over time. It's got a range of –25% to +75%.
- A **management reserve** is money set aside to cover unplanned, unexpected costs. Your project's funding requirements need to cover both the budget in the cost baseline and the management reserve.

there are no Dumb Questions

Q: Isn't it enough to know my project's scope and schedule, and then trust the budget to come out all right?

A: Even if you don't have a strict budget to work within, it makes sense to estimate your costs. Knowing your costs means that you have a good idea of the value of your project all the time. That means you will always know the impact (in dollars) of the decisions you make along the way. Sometimes understanding the value of your project will help you to make decisions that will keep your project healthier.

Many of us do have to work within a set of cost expectations from our project sponsors. The only way to know if you are meeting those expectations is to track your project against the original estimates.

It might seem like fluff. But knowing how much you are spending will help you relate to your sponsor's expectations much better as well.

Q: In my job I am just handed a budget. How does estimating help me?

A: In the course of estimating, you might find that the budget you have been given is not realistic. It's better to know that while you're planning, before you get too far into the project work, rather than later.

You can present your findings to the sponsor and take corrective action right away if your estimate comes in pretty far off target. Your sponsor and your project team will thank you for it.

Take a minute to think about what "value" really means. How does the sponsor know if he's getting his money's worth halfway through the project? Is there an easy way you can give the sponsor that information?

Q: What if I don't have all of this information and I am supposed to give a ballpark estimate?

A: This is where those rough order of magnitude estimates come in. That's just a fancy way of saying you take your best guess, knowing that it's probably inaccurate, and you let everybody know that you will be revising your estimates as you learn more about the project.

Q: My company needs to handle maintenance of projects after we release them. How do you estimate for that?

A: That's called lifecycle costing. The way you handle it is just like you handle every other estimate. You sit down and try to think of all of the activities and resources involved in maintenance, and project the cost. Once you have an estimate, you present it along with the estimate for initially building the product or service.

Q: I still don't get net present value. What do I use it for?

A: The whole idea behind net present value is that you can figure out which of two projects is more valuable to you. Every project has a value—if your sponsor's spending money on it, then you'd better deliver something worth at least that much to him! That's why you figure out NPV by coming up with how much a project will be worth, and then subtracting how much it will cost. But for the exam, all you really need to remember are two things: net present value has the cost of the project built into it, and if you need to use NPV to select one of several projects, always choose the one with the biggest NPV. That's not hard to remember, because you're just choosing the one with the most value!

Q: Hold on just a minute. Can we go back to the rough order of magnitude estimate? I remember from my math classes that an order of magnitude has something to do with a fixed ratio. Wouldn't –50% to +100% make more sense as an order of magnitude?

A: Yes, it's true that in science, math, statistics, or engineering, an order of magnitude typically involves a series of magnitudes increasing by a fixed ratio. So if an order of magnitude down is 50%, then you'd typically maintain that same 2:1 ratio between orders of magnitude, so the next order of magnitude higher would be 100%.

However, the *PMBOK® Guide* defines it as follows: "a project in the initiation phase could have a rough order of magnitude (ROM) estimate in the range of –25% to +75%." [5th Edition, p. 201] Since that's the definition in the *PMBOK® Guide*, that's what to remember for the exam.

Estimate Costs is just like Estimate Activity Durations. You get the cost estimate and the basis of cost estimates, updates to the plan, and requested changes when you are done.

Question Clinic: The red herring

SOMETIMES A QUESTION WILL GIVE YOU A LOT OF EXTRA INFORMATION THAT YOU DON'T NEED. IT'LL INCLUDE A RAMBLING STORY OR A BUNCH OF EXTRA NUMBERS THAT ARE IRRELEVANT.

104. You are managing a highway construction project. You have to build a three-mile interchange at a cost of $75,000 per quarter-mile. Your project team consists of a road planner, an architect, an engineer, a foreman, and 16 highway workers. The workers will not be available until week 10 of the project. Your business case document is complete, and you have met with your stakeholders and sponsor. Your senior managers are now asking you to come up with an estimate. Your company has done four other highway projects very similar to this one, and you have decided to make your estimate by looking at the costs of those previous projects.

What kind of estimate involves comparing your project to a previous one?

A. Parametric
B. Analogous
C. Bottom-up
D. Rough order of magnitude

Did you read that whole paragraph, only to find out the question had nothing to do with it?

You only needed to read this sentence to get the answer right.

WHEN YOU SEE A RED HERRING QUESTION, YOUR JOB IS TO FIGURE OUT WHAT PART OF IT IS RELEVANT AND WHAT'S INCLUDED JUST TO DISTRACT YOU. IT SEEMS TRICKY, BUT IT'S ACTUALLY PRETTY EASY ONCE YOU GET THE HANG OF IT.

HEAD  LIBS

Fill in the blanks to come up with your own red herring question!

You are managing a _____ project.
(kind of project)

You have _____ at your disposal, with _____ . Your
(describe a resource) (how that resource is restricted)

_____ contains _____. The _____
(a project document) (something that document would contain) (a team member)

alerts you that _____, and suggests _____.
(a problem that affected your project) (a suggested solution)

_____?
(a question vaguely related to one of the things in the paragraph above)

A. _____
(wrong answer)

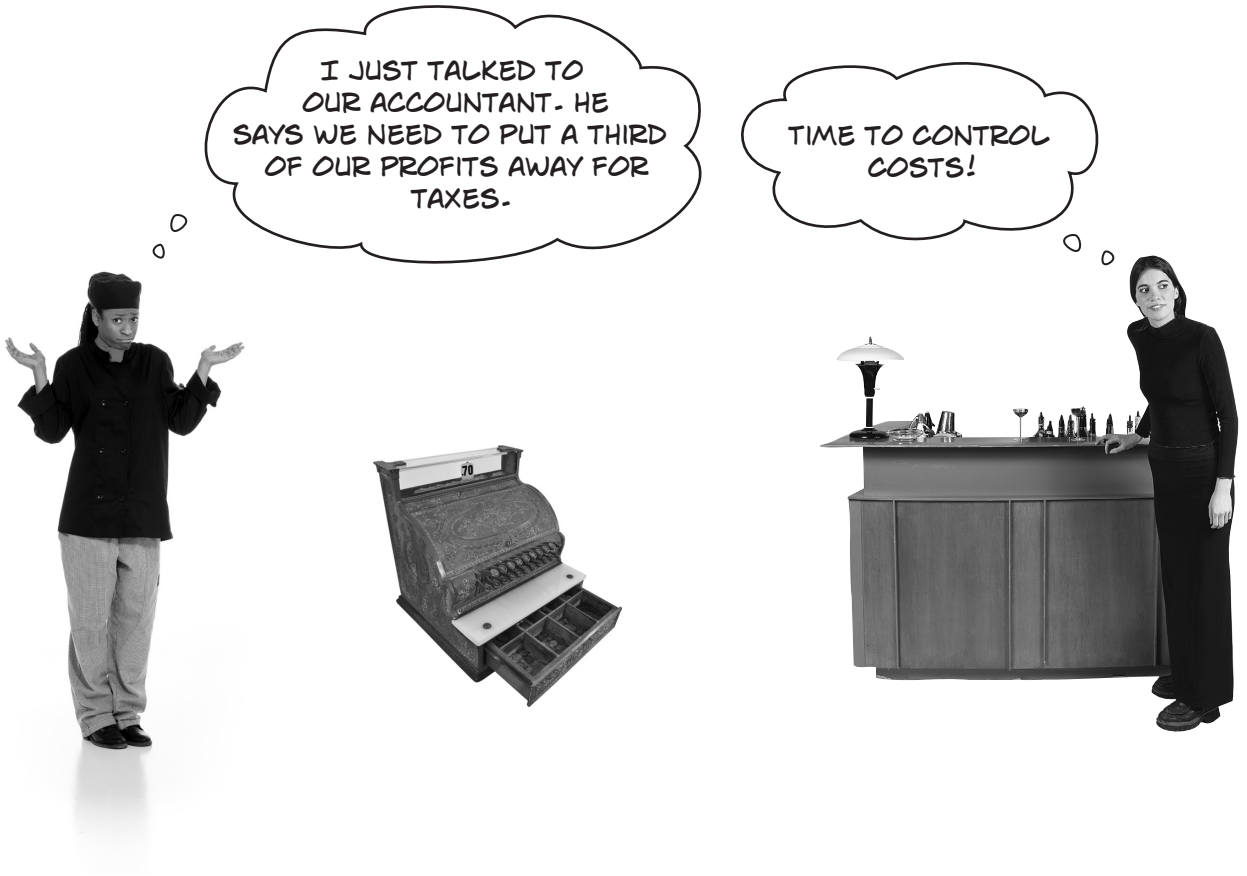
B. _____
(trickily wrong answer)

C. _____
(correct answer)

D. _____
(ridiculously wrong answer)

The Control Costs process is a lot like schedule control

When something unexpected comes up, you need to understand its impact on your budget and make sure that you react in the best way for your project. Just as changes can cause delays in the schedule, they can also cause cost overruns. The **Control Costs process** is all about knowing how you are doing compared to your plan and making adjustments when necessary.



BRAIN POWER

Given what you already know about controlling your scope and schedule, how would you handle this problem?

Sharpen your pencil

Using what you already know about the Control Scope and Control Schedule processes, can you take a guess at what each of these inputs will be used for?

Project funding requirements

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Project documents: Lessons learned register

Remember the Cost Management plan? It's the subplan that you built back in the Develop Project Management Plan process.

Project Management plan

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Work performance data

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Organizational process assets

Sharpen your pencil Solution

Using what you already know about the Control Scope and Control Schedule processes, can you take a guess at what each of these inputs will be used for?

Project funding requirements

On top of the baseline cost, you have added some reserves to deal with known risks. You've also spread your budget out, so that you always have money when you need it. Changes to your project might also mean changes to your funding requirements.

As your project is progressing you're noting all of the lessons you're learning. It's a good idea to use those lessons to maintain control or your project costs as well.

Project documents: Lessons learned register

Project Management plan

You may find that you need to change the PM plan and its Cost Management subplan as a result of information coming from your project. So, you'll need to evaluate your work performance information in relation to it.

This is the actual data being generated by your project. It tells how are you spending your budget right now. You'll need this information to figure out if you need to make any changes to stay on track.

Work performance data

Your company probably has some guidance on how to control costs and report on your budget. Here's where you'll find that information.

Organizational process assets

A few new tools and techniques

The tools in Control Costs are all about helping you figure out where to make changes so you don't overrun your budget.

Data Analysis

Earned value management

Here's where you measure how your project is doing compared to the plan. This involves using the earned value formulas to assess your project.

You'll learn more about the formulas in just a few pages!

Performance reviews

Reviews are meetings where the project team reviews performance data to examine the variance between actual performance and the baseline. Earned value management is used to calculate and track the variance. Over time, these meetings are a good place to look into trends in the data.

Forecasting

Use the information you have about the project right now to predict how close it will come to its goals if it keeps going the way it has been. Forecasting uses some earned value numbers to help you come up with preventive and corrective actions that can keep your project on the right track.

Reserve analysis

Throughout your project, you are looking at how you are spending versus the amount of reserve you've budgeted. You might find that you are using reserved money at a faster rate than you expected or that you need to reserve more as new risks are uncovered.

Expert judgment

Project management information system

You can use software packages to track your budget and make it easier to know where you might run into trouble.

To-complete performance index

The to-complete performance index (TCPI) is a calculation that you can use to help you figure out how well your project needs to perform in the future in order to stay on budget.

You'll learn more about TCPI, too!

The outputs for Control Costs should be really familiar by now—they're very similar to the other Monitoring and Controlling process outputs.

Outputs

Work performance information

Cost forecasts

Change requests

Project Management plan updates

Project documents updates

Look at the schedule to figure out your budget

The tools in Control Costs are all about helping you figure out where to make changes so you don't overrun your budget.

• $10,000

Budget at completion (BAC)

How much money are you planning on spending on your project? Once you add up all of the costs for every activity and resource, you'll get a final number…and that's the total project budget. If you only have a certain amount of money to spend, you'd better make sure that you haven't gone over!

How to calculate planned value

Once you figure this out, you can figure out your project's planned value.

If you look at your schedule and see that you're **supposed to have done** a certain percentage of the work, then that's the percent of the total budget that you've "earned" so far. This value is known as planned value. Here's how you calculate it.

1 ***First, write down your***

BAC—Budget at completion

This is the ***first number you think of*** when you work on your project costs. It's the **total budget** that you have for your project—how much you plan to spend on your project.

BAC x

The name "BAC" should make sense—it's the budget of your project when it's complete!

2 ***Then multiply that by your***

Planned % complete

If the schedule says that your team should have done 300 hours of work so far, and they will work a total of 1,000 hours on the project, then your planned % complete is 30%.

BAC x Planned % complete

Planned % complete is easy to work out, as it's just the calculation Given amount ÷ Total amount.

3 ***The resulting number is your***

PV—Planned value

This is how much of your budget you planned on using so far. If the BAC is $200,000, and the schedule says your planned % complete is 30%, then the planned value is $200,000 × 30% = $60,000.

BAC x Planned % complete = PV

BAC x Planned % complete = PV

PV = BAC x Planned % complete

You may also see the planned value formula flipped around and written with the PV out front, but it's exactly the same formula.

Sharpen your pencil

Now it's your turn! See if you can figure out BAC and PV for a typical project.

1. You're managing a project to install 200 windows in a new skyscraper and need to figure out your budget. Each week of the project costs the same: your team members are paid a total of $4,000 every week, and you need $1,000 worth of parts each week to do the work. If the project is scheduled to last 16 weeks, what's the BAC for the project?

   BAC = ...

   Even though we are at the beginning of the project now, we can still figure out what the PV will be in four weeks.

2. What will the planned % complete be four weeks into the project?

   Planned % complete = ...

   This is the part that takes some thinking. How do you know what % you are through the project?

3. What should the PV be four weeks into the project?

   PV = ... × ..... = ...

Answers on page 404.

Not yet, it doesn't.

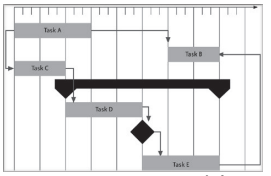
But wouldn't be nice if, when your schedule said you were supposed to be 37.5% complete with the work, then you knew that you'd actually spent 37.5% of your budget?

Well, in the real world things don't always work like that, but there are ways to work out—approximately—how far on (or off) track your budget actually is.

Earned value tells you how you're doing

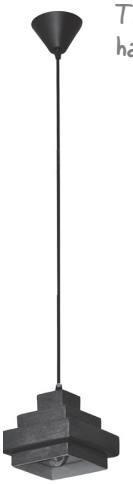
When Alice wants to track how her project is doing versus the budget, she uses **earned value**. This is a technique where you figure out how much of your project's value has been delivered to the customer so far. You can do this by comparing the value of **what your schedule says** you should have delivered against the value of what you **actually** delivered.

Your schedule tells you a lot about where you are supposed to be right now.



Today is May 14

The schedule says we should have delivered this by now...



...but we only delivered this.

• $2,200

• $1,650

The actual cost of this project on May 14th is $1,650.
The planned value was $2,200.

How to calculate earned value

If you could estimate each activity exactly, every single time, you wouldn't need earned value. Your schedule would always be perfectly accurate, and you would always be exactly on budget.

But you know that real projects don't really work that way! That's why earned value is so useful—it helps you put a number on how far off track your project actually is. And that can be a really powerful tool for evaluating your progress and reporting your results. Here's how you calculate it.

When you do work, you convert the money your sponsor invests in your project into value. So, **earned value** is about **how much work you have been able to accomplish with the money you've been given**. When you calculate earned value, you're showing your sponsor how much value that investment has earned.

1 ***First, write down your***

BAC—Budget at completion

BAC x

Remember, this is the **total budget** that you have for your project.

2 ***Then multiply that by your***

Actual % complete

BAC x Actual % complete

Say the schedule says that your team should have done 300 hours of work so far, out of a total of 1,000. But you talk to your team and find out they actually completed 35% of the work. That means the actual % complete is 35%.

If your team actually got 35% of the work done when the schedule says they should only have gotten 30% done, that means they're more efficient than you planned!

3 ***The resulting number is your***

EV—Earned value

BAC x Actual % complete = EV

This figure tells you how much your project *actually* earned. Every hour that each team member works adds value to the project. You can figure it out by taking the percentage of the hours that the team has actually worked and multiplying it by the BAC. If the total cost of the project is $200,000, then the earned value is $200,000 × 35% = $70,000.

Again, you might see the earned value formula flipped around and written with the EV out front, but remember, it's exactly the same formula.

EV = BAC x Actual % complete

What's the difference between actual cost and planned value? What does it mean if your AC is bigger than your PV? What if it's smaller?

This is a harder problem to solve than it seems! Take a minute and really think about it before you turn the page.

You'll be doing a lot of calculations in a minute. The best way to approach any calculation is to understand what it's for and why you use it. So before you go on, grab a cup of coffee and think for a few minutes about the difference between BAC and PV. Also, how do you compute actual % complete on a real project? Doing that will really help you get these ideas firmly embedded into your brain!

Put yourself in someone else's shoes

Earned value is one of the most difficult concepts that you need to understand for the PMP exam. The reason it's so confusing for so many people is that these calculations seem a little weird and arbitrary to a lot of project managers.

But ***they make a lot more sense*** if you **think about your project the way your sponsor thinks about it**. If you put yourself into the sponsor's shoes, you'll see that this stuff actually makes sense!

Think about earned value from the sponsor's perspective. It all makes a lot more sense then.

Let's say you're an executive:
You're making a decision to spend $300,000 of your company's money on a project. To a project manager, that's a project's budget. But to you, the sponsor, that's $300,000 of value you expect to get!

That's the total budget, or the BAC.

So how much value is the project delivering?
If you're the sponsor, you're thinking about the bottom line. And that bottom line is whether or not you're getting your money's worth from the project. If the team's done 50% of the work, then you've gotten $150,000 of value so far.

If you put the value in dollar terms, your sponsor knows what return she's getting for her investment.

That's earned value—it's based on how much work the team actually did.

But if the schedule says that they should have done 60% of the work by now, then *you're getting less value than you were promised!*

Look at the schedule to figure out how much value you planned to deliver to your sponsor.

The sponsor doesn't care as much about how you spend the budget. She just wants to get the most value for her money!

Sharpen your pencil

Let's get back to that 16-week project from page 378. In the last exercise you figured out what the project should look like by using planned value. Now you can use earned value to figure out if your project is really going the way you planned.

1. Fast-forward four weeks into the project installing those 200 skyscraper windows. Fill in the BAC and PV you figured out before. (Check your answer at the top of page 404 to make sure you got it right!)

BAC = ... PV = ...

Figure out the actual % complete by dividing the actual work done into the total amount you're planning on.

2. You've checked with your team, but they have bad news. The schedule says they were supposed to have installed 50 windows by now, but they've only installed 40. Can you figure out the actual % complete?

Actual % complete = ... / ..... =

Fill in the number of windows the team's actually installed.

Fill in the total number of windows that will be installed over the course of the project.

3. What should the earned value be right now?

EV = ... × ..... = ...

Fill in the BAC

Fill in the actual % complete

4. Look at the planned value, and then look at the earned value. Are you delivering all the value you planned on delivering?

☐ Yes ☐ No

Answers on page 404.

NEAT. I THINK I CAN USE THESE FORMULAS TO TRACK MY SCHEDULE AND MY BUDGET!

You can definitely use them to track the schedule and budget on smaller projects.

But once your projects start getting more complex, your formulas are going to need to take into account that you've got several people all doing different activities, and that could make it harder to track whether you're ahead of schedule or over budget.

So now that you know how to calculate PV and EV, they're all you need to stay on top of everything. What are you waiting for? Flip the page to find out how!

Is your project behind or ahead of schedule?

Figuring out if you're on track in a small project with just a few people is easy. But what if you have dozens or hundreds of people doing lots of different activities? And what if some of them are on track, some are ahead of schedule, and some of them are behind? It starts to get hard to even figure out whether you're meeting your goals.

Wouldn't it be great if there were an easy way to figure out if you're ahead or behind schedule? Well, good news: that's exactly what earned value is used for!

Schedule performance index (SPI)

If you want to know whether you're ahead of or behind schedule, use SPIs. The key to using this is that when you're ***ahead of schedule***, you've ***earned more value*** than planned! So **EV will be bigger than PV**.

To work out your SPI, you just divide your EV by your PV.

$$SPI = \frac{EV}{PV}$$

If SPI is greater than 1, that means EV is bigger than PV, so you're ahead of schedule!

If SPI is less than 1, then you're behind schedule because the amount you've actually worked (EV) is less than what you'd planned (PV).

Schedule variance (SV)

It's easy to see how variance works. The **bigger the difference** between ***what you planned*** and ***what you actually earned***, the **bigger the variance**.

So, if you want to know how much ahead or behind schedule you are, just subtract PV from EV.

Remember, for the sponsor's benefit, we measure this in dollars...

$$SV = EV - PV$$

...so if the variance is positive, it tells you exactly how many dollars you're ahead. If it's negative, it tells you how many dollars you're behind.

Don't get freaked out by the thought of all these formulas.

They're really not very complex. All you need to remember is that they all use EV and PV in different ways. Once you've learned how EV and PV interact in each one, you're golden!

Sharpen your pencil

Meanwhile, back in the Kitchen, Alice is working out if the project's coming in on schedule and on budget. Here are the steps she's taking and her notes. She was called away, so it's up to you to work out whether Tamika and Sue need to push the schedule.

1. **Start with the schedule and budget.** Figure out how much work you planned, how much the team has done, and the total budget (BAC).

BAC= _____

Tamika and Sue have a total budget of $10,000, and they're currently halfway through the schedule.

Planned % complete = _____

2. **Figure out PV.** Multiply the BAC by the percentage of the work that your schedule says the team should have worked so far to get the planned value.

So their planned value is?

PV = $ x % = $ _____

PV = BAC x Planned % complete

3. **Figure out EV.** This is the part that actually takes some thinking! You need to figure out what percentage of work the team has actually done. Once you have that, multiply it with the BAC to find the earned value.

Uh-oh! On a closer look, it seems they've really only gotten 40% of the work done.

EV = $ x = $ _____

EV = BAC x Actual % complete

4. **Now you can calculate SPI and SV.** Once you've figured out EV and PV, you can do the calculations.

Now that you have the EV and PV, you can tell Tamika and Sue if they're getting their money's worth!

SPI = $ ÷ $ = 0.8

SV = $ - $ = $

5. **How's the schedule looking?** What do all these figures tell us?

So are we ahead of schedule or behind it?

Answers on page 405.

Are you over budget?

You can do the same thing for your budget that you can do for your schedule. The calculations are almost exactly the same, except instead of using planned value—which tells you how much work the schedule says you should have done so far—you use **actual cost** (AC). That's the amount of money that you've spent so far on the project.

Remember, EV measures the work that's been done, while AC tells you how much you've spent so far.

Cost performance index (CPI)

$$CPI = \frac{EV}{AC}$$

If you want to know whether you're over or under budget, use CPI.

Cost variance (CV)

$$CV = EV - AC$$

This tells you the difference between what you planned on spending and what you actually spent.

So, if you want to know how much under or over budget you are, just take AC away from EV.

Remember what CV means to the sponsor: EV says how much of the total value of the project has been earned back so far. If CV is negative, then she's not getting good value for her money.

To-complete performance index (TCPI)

This tells you how well your project will need to perform to stay on budget.

$$TCPI = \frac{(BAC-EV)}{(BAC-AC)}$$

We'll talk about this in just a few pages...

Measuring your cost difference in dollars is easy, but what if your schedule variance is negative?

A lot of people worry about that, but it's actually not bad. Planned value just means that you planned on delivering a certain amount of value to your sponsor at a certain time. An SV of, say, –$5,000 tells you that you haven't delivered all the value you promised.

You're within your budget if...

CPI is greater than or equal to 1 and CV is positive. When this happens, your actual costs are less than earned value, which means the project is delivering more value than it costs.

Now Alice can take a look at the Kitchen's checkbook. She figures out that she spent $5,750 on the project so far.

CPI = $4,000 ÷ $5,750 = 0.696

Since CPI is less than 1, it means that Tamika and Sue have blown their budget.

You've blown your budget if...

CPI is less than 1 and CV is negative. When your actual costs are more than earned value, that means that your sponsor is not getting her money's worth of value from the project.

CV = $4,000 – $5,750 = –$1,750

And that's how much they've gone over! Tamika, Sue, and Alice had better figure out how to contain those runaway costs, or they'll have a nasty surprise later.

The earned value management formulas

Earned value management (EVM) is just one of the tools and techniques in the Control Costs process, but it's a big part of PMP exam preparation. When you use these formulas, you're measuring and analyzing how far off your project is from your plan. Remember, think of everything in terms of how much value you're delivering to your sponsor! Take a look at the formulas one more time:

Remember, your sponsor always cares most about what the project is worth to him. BAC says how much value he's getting for the whole project, and EV tells him how much of that value he's gotten so far.

Name	Formula	What it says	Why you use it
BAC—Budget at completion	No formula—it's the project budget	How much money you'll spend on the project	To tell the sponsor the total amount of value that he's getting for the project
PV—Planned value	$PV = BAC \times$ Planned % complete	What your schedule says you should have spent	To figure out what value your plan says you should have delivered so far
EV—Earned value	$EV = BAC \times$ Actual % complete	How much of the project's value you've really earned	To translate how much work the team's finished into a dollar value
AC—Actual cost	What you've actually spent on the project	How much you've actually spent so far	The amount of money you spend doesn't always match the value you get!
SPI—Schedule performance index	$SPI = \frac{EV}{PV}$	Whether you're behind or ahead of schedule	To figure out whether you've delivered the value your schedule said you would
SV—Schedule variance	$SV = EV - PV$	How much behind or ahead of schedule you are	To put a dollar value on exactly how far ahead or behind schedule you are
CPI—Cost performance index	$CPI = \frac{EV}{AC}$	Whether you're within your budget or not	Your sponsor is always most interested in the bottom line!
TCPI—To-complete performance index	$TCPI = \frac{BAC-EV}{BAC-AC}$	How well your project must perform to stay on budget	To forecast whether or not you can stick to your budget
CV—Cost variance	$CV = EV - AC$	How much above or below your budget you are	Your sponsor needs to know how much it costs to get him the value you deliver

Interpret CPI and SPI numbers to gauge your project

The whole idea behind earned value management is that you can use it to easily put a number on how your project is doing. That's why there will be exam questions that test you on your ability to interpret these numbers! Luckily, it's pretty easy to evaluate a project based on the EVM formulas.

If the SPI is below 1, then your project is behind schedule. But if you see a CPI under 1, your project is over budget!

If your project is on track, that means you're delivering the value you promised.

You can tell that your project is on track because the two index numbers—CPI and SPI—are both very close to 1, and the variance numbers—CV and SV—are very close to zero dollars. It's very rare that you'll get exactly to a CPI of 1 or an SV of $0, but an SPI of 1.02 means you're slightly ahead of schedule, and a CV of –$26 means you're slightly over budget.

A lot of PMOs have a rule where a CPI or SPI between 0.95 and 1.10 is absolutely fine!

Sometimes you'll see negative values written in parentheses—in this case, ($26).

Ahead of schedule or under budget

You can tell if your project is ahead of schedule or under budget by looking for larger numbers.

If the **CPI** is much **bigger than 1**, it means you're ***under budget***. And you can tell how much under by looking at the CV—that's what variance is for! It helps you see just how much the actual cost **varies** from the value you were supposed to earn by now.

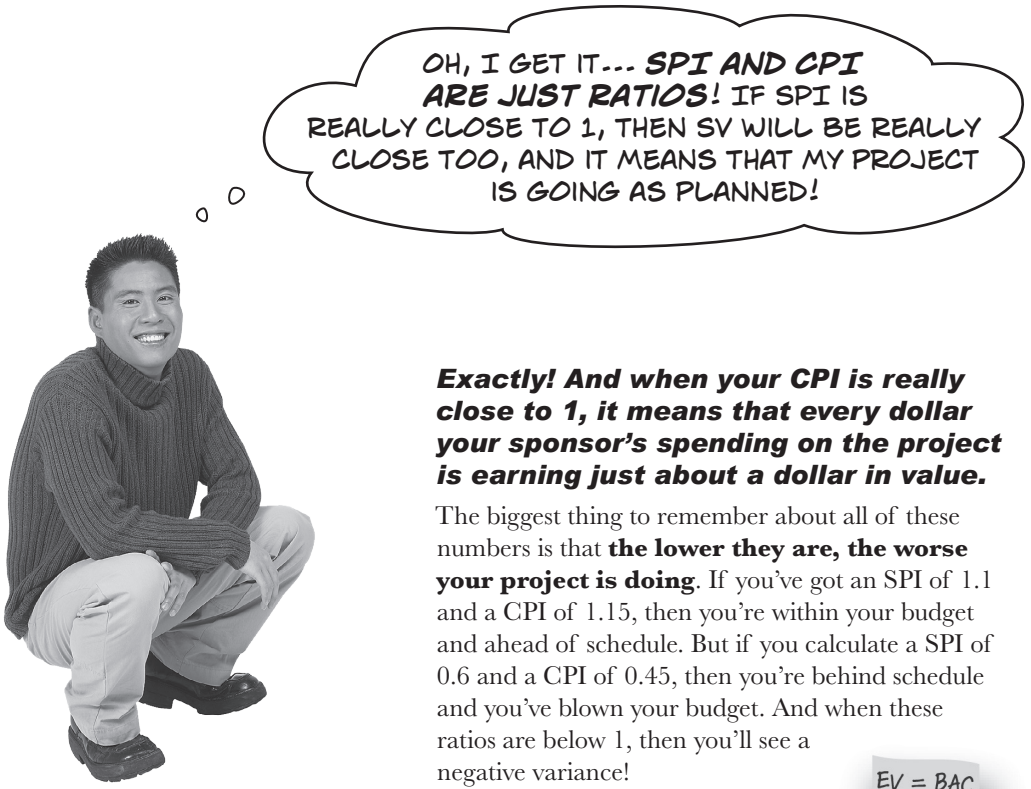
Being a long way under budget isn't always a good thing. It means you asked for and were given resources that you didn't need—and which your company could have used elsewhere.

Behind schedule or over budget

A project that's behind schedule or over budget will have lower numbers.

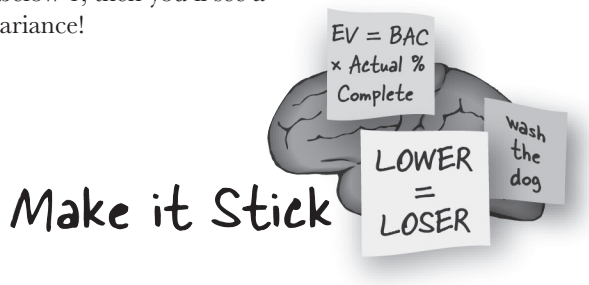
When you see an **SPI** that's **between 0 and 1**, that tells you that the project is ***behind schedule***…and that means you're not delivering enough value to the sponsor! That's when you check the SV to see how much less value you're delivering. And the same goes for cost—a **low CPI** means that your project is ***over budget***, and CV will tell you how much more value you promised to deliver to the sponsor.

CPI and SPI can't be below zero, because they're ratios!



Exactly! And when your CPI is really close to 1, it means that every dollar your sponsor's spending on the project is earning just about a dollar in value.

The biggest thing to remember about all of these numbers is that **the lower they are, the worse your project is doing**. If you've got an SPI of 1.1 and a CPI of 1.15, then you're within your budget and ahead of schedule. But if you calculate a SPI of 0.6 and a CPI of 0.45, then you're behind schedule and you've blown your budget. And when these ratios are below 1, then you'll see a negative variance!



Make it Stick

Remember:

Lower = Loser

If CPI or SPI is below 1, or if CV or SV is negative, then you've got trouble!

You'll definitely need to be able to calculate earned value numbers for the exam! But remember, like planning that trip way back in Chapter 4, the best way to do that is with practice.

Your project has a total budget of $300,000. You check your records and find that you've spent $175,000 so far. The team has completed 40% of the project work, but when you check the schedule it says that they should have completed 50% of the work. **Calculate the following:**

BAC = $ .....

AC = $ .....

There were two dollar values given in the problem. Which is AC, and which is BAC?

PV = $ ..... x ..... % = $ .....

EV = $ ..... x ..... % = $ .....

The trick is figuring out which percentage you need to put here!

SV = $ ..... – $ ..... = $ .....

CV = $ ..... – $ ..... = $ .....

Now you just need to figure out which numbers that you've already calculated are being divided into one another!

$$SPI = \frac{\$\ .....}{\$\ .....} = ...$$

$$CPI = \frac{\$\ .....}{\$\ .....} = ...$$

Answers on page 406.

You're managing a highway construction project. Your total budget is $650,000, and there is a total of 7,500 hours of work scheduled on the project. You check with your accounting department, and they tell you that you've spent a total of $400,000. According to the schedule, your crew should have worked 4,500 hours, but your foreman says that the crew was allowed to work some overtime, and they've actually put in 5,100 hours of work. **Calculate these earned value numbers:**

BAC = ...

AC = ...

SV = ...

SPI = ...

PV = ...

EV = ...

CV = ...

CPI = ...

You are the project manager at an industrial design firm. You expect to spend a total of $55,000 on your current project. Your plan calls for six people working on the project eight hours a day, five days a week, for four weeks. According to the schedule, your team should have just finished the third week of the project. When you review what the team has done so far, you find that they have completed 50% of the work, at a cost of $25,000. **Based on this information, calculate the earned value numbers:**

BAC = ... PV = ...

AC = ... EV = ...

SV = ... CV = ...

SPI = ... CPI = ...

Check all of the following that apply:

..... The project is ahead of schedule

..... The project is behind schedule

..... You should consider crashing the schedule

..... The project is over budget

..... The project is under budget

..... You should find a way to cut costs

Your current project is an $800,000 software development effort, with two teams of programmers that will work for six months, at a total of 10,000 hours. According to the project schedule, your team should be done with 38% of the work. You find that the project is currently 40% complete. You've spent 50% of the budget so far. **Calculate these numbers:**

BAC = ... PV = ...

AC = ... EV = ...

SV = ... CV = ...

SPI = ... CPI = ...

Check all of the following that apply:

..... The project is ahead of schedule

..... The project is behind schedule

..... You should consider crashing the schedule

..... The project is over budget

..... The project is under budget

..... You should find a way to cut costs

Answers on page 407.

Forecast what your project will look like when it's done

There's another piece of earned value management, and it's part of the last tool and technique in Cost Management: **forecasting**. The idea behind forecasting is that you can use earned value to come up with a pretty accurate prediction of what your project will look like at completion.

If you know your CPI now, you can use it to predict what your project will actually cost when it's complete. Let's say that you're managing a project with a CPI of 0.8 today. If you assume that the CPI will be 0.8 for the rest of the project—and that's not an unreasonable assumption when you're far along in the project work—then you can predict your total costs when the project is complete. We call that **estimate at completion** (EAC).

There are a bunch of different ways to calculate EAC, but this one is sufficient for the PMP exam.

If your CPI is below 1, that means you're running over budget—which will give you an EAC that's larger than your current budget.

$$EAC = \frac{BAC}{CPI}$$

If your CPI is above 1, you're running under budget, so the estimate will end up smaller than your BAC.

Meanwhile, back in the Kitchen

Alice is forecasting how the new Kitchen project will look when it's done.

IF TAMIKA AND SUE HAVE A CPI OF 0.869 AND A TOTAL BUDGET OF $10,000, THEN THEY CAN FORECAST THEIR FINAL COSTS: EAC = BAC ÷ CPI...

Here's what Alice wrote down first...

$$\frac{\$10{,}000}{0.869} = \$11{,}507$$

...now Alice can take a look at the Kitchen's checkbook. She figures out that she spent $5,750 on the project so far...

Once you've got an estimate, you can calculate a variance!

There are two useful numbers that you can compute with the EAC. One of them is called **estimate to complete** (ETC), which tells you how much more money you'll probably spend on your project. And the other one, **variance at completion** (VAC), predicts what your variance will be when the project is done.

You can use EAC, ETC, and VAC to predict what your earned value numbers will look like when your project is complete.

$$ETC = EAC - AC$$

Since EAC predicts how much money you'll spend, if you subtract the AC, you'll find out how much money the rest of the project will end up costing.

$$VAC = BAC - EAC$$

If you end up spending more than your budget, the VAC will be negative...just like CV and SV!

IF THE EAC IS $11,507, AND THE AC IS $5,750, THEN I CAN FIGURE OUT WHAT TAMIKA AND SUE HAVE LEFT TO SPEND. ETC = EAC – AC.

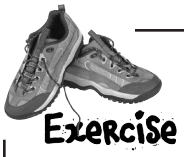
SO, WE'RE OVER BUDGET. BUT WHAT WILL THE DAMAGE BE? AT LEAST NOW I CAN FIGURE OUT THE FINAL VARIANCE. VAC = BAC – EAC.

$\$11{,}507 - \$5{,}750 = \$5{,}757$

...and now she knows how much money the rest of the project is likely to cost...

$\$10{,}000 - \$11{,}507 = -\$1{,}507$

...but will Tamika and Sue be able to come up with the extra money?



You're a project manager working on a large project scheduled to last for two years. You've got six different teams working on five major functional areas. Some teams are ahead of schedule, and others are falling behind. That means that you have cost overruns in some areas, but you've saved costs in others—and that's making it very hard to get an intuitive grasp on whether your project is over or under budget!

It's nine months into your project. The total budget for your project is $4,200,000. You've spent $1,650,000 so far, and you've got a CPI of .875. Use the earned value management formulas from forecasting to figure out where things stand.

EAC = $\frac{\$\ldots\ldots}{\ldots\ldots}$ = $\$\ldots\ldots$

ETC = $\$\ldots\ldots$ – $\$\ldots\ldots$ = $\$\ldots\ldots$

VAC = $\$\ldots\ldots$ – $\$\ldots\ldots$ = $\$\ldots\ldots$

Will the project be over or under budget when it's complete? (Check one.)

..... The project will be over budget ..... The project will be within its budget

How much will the project be over or under budget? $\$\ldots\ldots$

Now it's six months later, and your project looks very different. You need to work out a new forecast for what your budget situation will be like at project completion. You've now spent a total of $2,625,000. You look at all of the activities done by the team, and you find that the project is 70% complete. Can you come up with a new forecast for your project?

BAC = $ .....

AC = $ .....

EV = ...

CPI = ...

EAC = ...

ETC = ...

VAC = ...

Your project will be **over/under** budget at completion.
(Circle one.)

How much will the project be over or under budget?

$ .....

Answers on page 408.

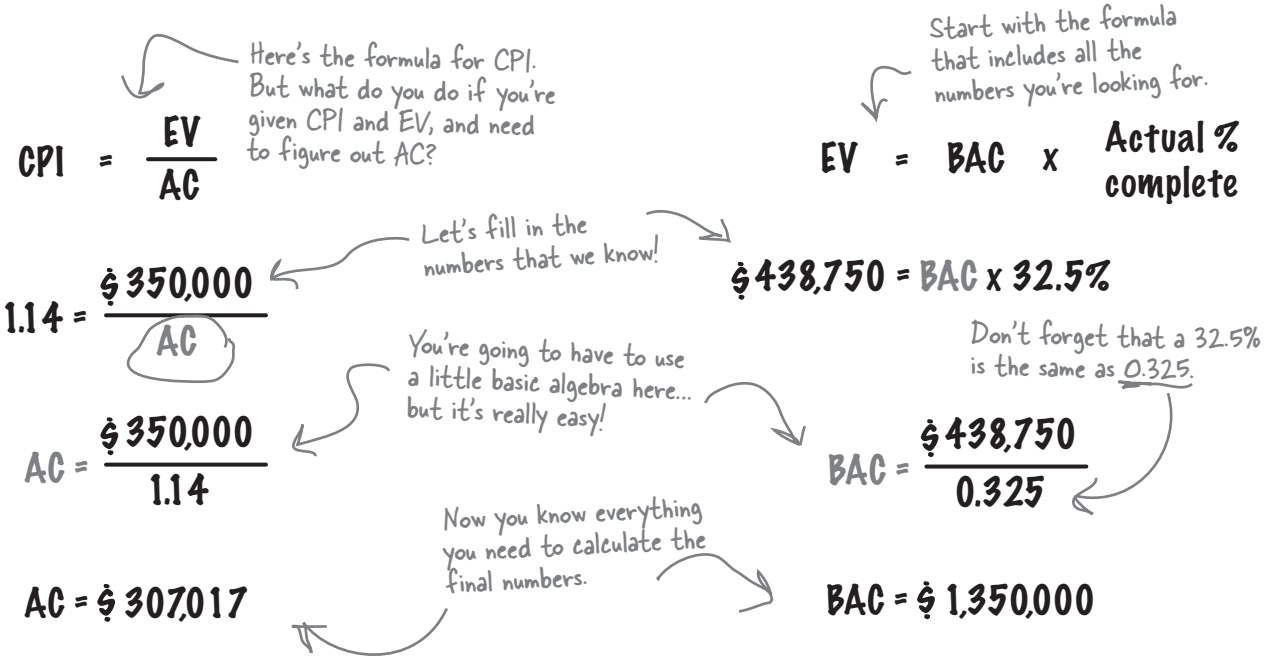
Finding missing information

Most of the earned value questions on the exam will be pretty straightforward: you'll be given the numbers that you need to plug into a formula, and when you do it you'll get the answer. But once in a while, you'll get a question that isn't quite so straightforward.

Let's say you're given...

…the CPI and earned value, and you want to figure out the actual costs. Why would you ever see this? Sometimes it's hard to figure out how important a project is unless you know how much it's really spending—if a project is more expensive, people in your company probably care more about it. If you're told that **a project's CPI is 1.14 and its EV is $350,000**, how do you figure out the actual costs?

…the earned value and actual percent complete, and you want to figure out the project's budget. This can be really helpful when you need to "read between the lines" to make a decision about a project when someone doesn't want to give you all the information you need. When you have **a project's EV of $438,750 and its actual % complete of 32.5%**, how do you figure out the total budget (BAC)?



There are some times when you'll need to flip the formulas upside down! Sometimes you're going to be on the receiving end of earned value numbers. If you're working at a company with a bunch of project managers, then sometimes you'll get a report from one of them that only gives you part of the picture!

Sharpen your pencil

You'll probably get a question or two where you'll need to flip your formulas over to figure out one of the values you'd normally be given. **Don't worry if you're math-phobic!** This is really easy—you'll definitely get it with a little practice.

If EV is \$93,406 and SPI is 0.91, what is the planned value?

Write down the formula for SPI.

SPI = ... / ..... = ... = \$ ..... / .....

Fill in the numbers that you have.

Now flip around the formula so PV is on the left.

PV = ... / ..... PV = ...

And now you can solve for PV!

If PV is \$252,000 and BAC is \$350,000, what is the planned % complete?

Fill in the numbers that you have.

Start with the formula for PV.

PV = ... × ..... = \$ ..... \$ ..... × .....

Now flip around the formula so % complete is on the left.

% complete = \$ ..... / \$ ..... % complete = ...

And now you can solve it!

Now try one on your own. If BAC is \$126,500 and EAC is \$115,000, what is the CPI?

1. First write out the formula that has EAC, CPI, and BAC.

.....

2. Next fill in the numbers that you know.

.....

3. Now flip around the formula so the number you're looking for is on the left.

.....

4. Now you can solve the problem!

.....

Answers on page 409.

there are no Dumb Questions

Q: What does CPI really mean, and why can it predict your final budget?

A: Doesn't it seem a little weird that you can come up with a pretty accurate forecast of what you'll actually spend on your project just by dividing CPI into your BAC, or the total amount that you're planning to spend on the project? How can there be one "magic" number that does that for you?

But when you think about it, it actually makes sense. Let's say that you're running 15% over budget today. If your budget is $100,000, then your CPI will be $100.000 ÷ $115,000 = .87. One good way to predict what your final budget will look like is to assume that you'll keep running 15% over budget. Let's say your total budget is $250,000. If you're still 15% over at the end of the budget, your final CPI will still be $250,000 ÷ $287,500 = .87! Your CPI will always be .87 if you're 15% over budget.

That's why we call that forecast EAC—it's an *estimate* of what your budget will look like *at completion*. By dividing CPI into BAC, all you're doing is calculating what your final budget will be if your final budget overrun or underrun is exactly the same as it is today.

Q: Is that really the best way to estimate costs? What if things change between now and the end of the project?

A: EAC is a good way to estimate costs, because it's easy to calculate and relatively accurate—assuming that nothing on the project changes too much. But you're right, if a whole lot of unexpected costs happen or your team members figure out a cheaper and better way to get the job done, then an EAC forecast could be way off!

It turns out that there are over 25 different ways to calculate EAC, and the one in this chapter is just one of them. Some of those other formulas take risks and predictions into account. But for the PMP exam, you just need to know EAC = BAC ÷ CPI.

Q: Wow, there are a lot of earned value formulas! Is there an easy way to remember them?

A: Yes, there are a few ways that help you remember the earned value formulas. One way is to notice that the performance reporting formulas all have something either being divided into or subtracted from EV. This should make sense—the whole point of earned value management is that you're trying to figure out how much of the value you're delivering to your sponsor has been earned so far. Also, remember that a variance is always subtraction, and an index is always division. The schedule formulas SV and SPI both involve PV numbers you got from your schedule, while the cost formulas CV and CPI both involve AC numbers from your budget.

And remember, the lower the index or variance, the worse your project is doing! A negative variance or an index that's below 1 is bad, while a positive variance or an index that's above 1 is good!

The earned value formulas have numbers divided into or subtracted from EV. SV and SPI use PV, while CV and CPI use AC.

Keep your project on track with TCPI

Have you ever wondered halfway through a project just how much you'd have to cut costs in order to get it within your budget? This is how you figure that out!

You can use earned value to gauge where you need to be to get your project in under budget. TCPI can help you find out not just whether or not you're on target, but exactly where you need to be to make sure you get things done with the money you have.

To-complete performance index (TCPI)

This number represents a **target that your CPI would have to hit** in order to hit your forecasted completion cost. If you're performing within your budgeted cost, it'll be based on your BAC. If you're running over your budget, you'll have to estimate a new EAC and base your TCPI on that.

There are two different formulas for TCPI. One is for when you're trying to get your project within your original budget, and the other is for when you are trying to get your project done within the EAC you've determined from earned value calculations.

BAC based:

$$TCPI = \frac{(BAC-EV)}{(BAC-AC)}$$

How much budgeted work is left divided by how much budgeted money is left

EAC based:

$$TCPI = \frac{(BAC-EV)}{(EAC-AC)}$$

How much budgeted work is left divided by how much estimated money is left

TCPI for the Head First Kitchen renovation project

Alice figured out the BAC and EAC for the project and realized that the Kitchen was over budget, so she did a TCPI calculation to figure out exactly where she needed to keep her CPI if she wanted to get the project in without blowing the budget. Alice's earned value calculations have put the renovation project's numbers here:

EAC= $11,507 AC= $5,750 BAC=$10,000 EV=$5000

The project is over budget! So Alice uses the BAC-based formula to figure out where she needs to keep the CPI for the project if she wants to complete it within the original budget. Here's the calculation:

$$TCPI = \frac{(BAC-EV)}{(BAC-AC)} \qquad TCPI = \frac{(\$10{,}000-\$5{,}000)}{(\$10{,}000-\$5{,}750)} = 1.17$$

So, if the project were going to get back on budget, it would have to run at a 1.17 CPI for the rest of the project to make up for the initial overage. Alice doesn't think that's going to happen. Tamika and Sue pushed for an antique tin ceiling in the dining room that cost an extra $750 in the beginning, and, the way things are going, it's probably a safe bet that there will be a few more cost overruns like that as the project goes on. She prepared a second TCPI to see what the numbers would be to complete the project based on the current EAC.

$$TCPI = \frac{(BAC-EV)}{(EAC-AC)} \qquad TCPI = \frac{(\$10{,}000-\$5{,}000)}{(\$11{,}507-\$5{,}750)} = .87$$

A high TCPI means a tight budget

When you're looking at the TCPI for a project, a higher number means it's time to take a stricter cost management approach. The higher the number, the more you're going to have to rein in spending on your project and cut costs. When the number is lower than 1, you know you're well within your budget and you can relax a bit.

Remember "lower = loser"? Well, with TCPI, it's the opposite. A higher number means that your budget is too tight. You want it lower to give you more room to spend money!

Sharpen your pencil

You'll need to know the formula for TCPI and be ready to calculate it for the exam. Here are a couple of problems to help you get a little practice.

BAC is $40,000 and EAC is $30,000, EV is $17,000, and AC is $15,000. What is the BAC-based TCPI?

Write down the formula for TCPI.

TCPI = ... / ..... = $ ..... / ..... = ...

Fill in the numbers and solve the problem.

BAC is $100,000 and EAC is $107,000, EV is $68,000, and AC is $70,000. What is the EAC-based TCPI?

Write down the formula for TCPI.

TCPI = ... / ..... = $ ..... / ..... = ...

Fill in the numbers and solve the problem.

BAC is $20,000 and EAC is $20,000, AC is $15,000, and the project is 75% complete. What is the EAC-based TCPI?

First, write down the formula for EV.

EV =

Write down the formula for TCPI.

TCPI = ... / ..... = $ ..... / ..... = ...

Fill in the numbers and solve the problem.

Answers on page 400

Party time!

Tamika and Sue finished the new Kitchen! It looks great, and they're really happy about it…because Alice managed their costs well. She used earned value to correct their budget problems, and they managed to cut a few costs while they still had time. And they had just enough money left over at the end to throw a great opening party!

Since Alice used earned value to stay on top of the budget throughout the project, Tamika and Sue were able to renovate the Kitchen in style and still manage to stay within their spending limits.

The goal of **Project Cost Management** is to plan, estimate, budget, and control your project's costs. When your project is in its early stages, that's when you have the greatest influence on the project's costs. And even a small project needs to estimate and budget costs, even if those activities are simple enough to be done by a single person.

Key Concepts

We've talked about the processes you and your team will use when planning, controlling, and managing costs, but it's worth taking a minute to think about how your approach to Project Cost Management affects the overall project.

- Don't lose sight of the big picture. Making "penny-wise, pound-foolish" cost cuts today can increase your entire product's costs tomorrow. For example, you could reduce your budget by cutting out testing tasks, but that will likely increase the operating costs for your project.

Spoiler alert—you'll learn more about this in the next chapter!

- Different stakeholders measure your project's costs in different ways, and even change the way they measure costs over time. A chef may think about the costs of ingredients and kitchen staff, while an owner or partner might consider accounting and financing costs.
- The way costs are managed can differ a LOT from one organization to another. One company may do predictions of financial performance and analysis of project costs entirely outside of the project, while another company might include those activities as part of its day-to-day project management work.
- When project teams are responsible for financial analysis, their Project Cost Management activities might include some advanced financial management techniques (which we didn't cover in this chapter because they aren't in the *PMBOK® Guide* or on the exam).

Project Cost management is about understanding and managing the costs of your project's resources and activities.

Trends

Here are a few trends in Project Cost Management that might help you to improve and manage your projects' costs more effectively.

- **Earned schedule** (or ES) is an extension to earned value management (EVM) to track progress against your schedule. Instead of using PV and EV to measure how much value has been planned or delivered, ES and actual time (AT) use the *schedule* to determine planned versus actual project performance.
- **Earned schedule theory** gives project managers new ways to calculate schedule variance (SV) and schedule performance index (SPI). Earlier we learned about using earned value (EV) and planned value (PV) to calculate schedule variance (SV = EV – PV). With earned schedule theory, we use earned schedule (ES) and actual time (AT) in place of EV, calculating SV = ES – AT and SPI = ES ÷ AT.

Tailoring

When you make changes to the processes your team will use during the course of your project, there are a few considerations that might influence your decisions:

- Are project managers required to use a financial database repository? Do they have access to it?
- Are there existing policies that drive how project managers do cost estimation or build budgets?
- Is your company already using earned value management? Is it new to the company?
- Has there been an agile adoption effort at the organization? That can have an impact on how project costs are handled.
- Are there audits or other governance procedures that your projects must comply with? This is especially common in regulated industries like financial services or health care.

Agile considerations

Agile teams are often comfortable working in an environment with a high degree of uncertainty. While this may sound like a "high-risk/high-reward" situation that could have severe consequences, many agile teams are actually very good at managing their project costs using lightweight estimation techniques, which can be at least as accurate as more traditional techniques for long-term costs. They'll save detailed estimation for near-term costs—just-in-time estimation tends to be accurate because it's based on recent information.

Sharpen your pencil Solution

Now it's your turn! See if you can figure out BAC and PV for a typical project.

1. You're managing a project to install 200 windows in a new skyscraper and need to figure out your budget. Each week of the project costs the same: your team members are paid a total of $4,000 every week, and you need $1,000 worth of parts each week to do the work. If the project is scheduled to last 16 weeks, what's the BAC for the project?

BAC = $5,000 x 16 = $80,000

The project's 16 weeks long. Multiply that by the costs per week to get the total budget for the project.

Each week costs $4,000 for labor and $1,000 for parts.

2. What will the planned % complete be four weeks into the project?

Planned % complete = 25%

You're 4 weeks into a 16-week project. That means you're 25% of the way through.

3. What should the PV be four weeks into the project?

Fill in the BAC from question 1.

Fill in the planned % complete from question 2. Now multiply them to get the PV.

PV = $80,000 x 25% = $20,000

Sharpen your pencil Solution

Let's get back to that 16-week project from page 378. Can you figure out how to use EV?

1. Fast-forward four weeks into the project installing those 200 skyscraper windows. Fill in the BAC and PV you figured out above. (Check your answer above to make sure you got it right!)

BAC = $80,000 PV = $20,000

2. You've checked with your team, but they have bad news. The schedule says they were supposed to have installed 50 windows by now, but they've only installed 40. Can you figure out the actual % complete?

Actual % complete = $\frac{40}{200}$ = 20%

The team installed 40 windows out of a total of 200. That means they're 20% of the way done with the work.

3. What should the earned value be right now?

EV = $80,000 x 20% = $16,000

4. Look at the planned value, and then look at the earned value. Are you delivering all the value you planned on delivering?

☐ Yes ☑ No

You planned on delivering $20,000 worth of value, but you've only delivered $16,000 worth. That means the customer isn't getting all the value he's paying for!

Sharpen your pencil Solution

Meanwhile, back in the Kitchen, Alice is working out if the project's coming in on schedule and on budget. Here are the steps she's taking and her notes. She was called away, so it's up to you to work out whether Tamika and Sue need to push the schedule.

1. **Start with the schedule and budget.** Figure out how much work you planned, how much the team has done, and the total budget (BAC).

Tamika and Sue have a total budget of $10,000, and they're currently halfway through the schedule.

BAC = $10,000

Planned % complete = 50%

2. **Figure out PV.** Multiply the BAC by the percentage of the work that your schedule says the team should have worked so far to get the planned value.

So their planned value is?

PV = $10,000 x 50% = $5,000

PV = BAC x Planned % complete

3. **Figure out EV.** This is the part that actually takes some thinking! You need to figure out what percentage of work the team has actually done. Once you have that, multiply it with the BAC to find the earned value.

Uh-oh! On a closer look, it seems they've really only gotten 40% of the work done.

EV = $10,000 x 40% = $4,000

EV = BAC x Actual % complete

4. **Now you can calculate SPI and SV.** Once you've figured out EV and PV, you can do the calculations.

Now that you have the EV and PV, you can tell Tamika and Sue if they're getting their money's worth!

SPI = $4,000 ÷ $5,000 = 0.8

SV = $4,000 – $5,000 = –$1,000

5. **How's the schedule looking?** What do all these figures tell us?

So are we ahead of schedule or behind it?

The Kitchen project is behind schedule.

You'll definitely need to be able to calculate earned value numbers for the exam! But remember, like planning that trip way back in Chapter 4, the best way to do that is with practice.

Your project has a total budget of $300,000. You check your records and find that you've spent $175,000 so far. The team has completed 40% of the project work, but when you check the schedule it says that they should have completed 50% of the work. **Calculate the following:**

BAC = $ 300,000

PV = $ 300,000 x 50 % = $ 150,000

Planned value uses what's on the schedule; earned value uses what actually happened.

AC = $ 175,000

EV = $ 300,000 x 40 % = $ 120,000

Did you notice how the formulas for SV and SPI use the same numbers? You subtract for one, and divide for the other!

SV = $ 120,000 – $ 150,000 = $ –30,000

You may have to round the CPI and SPI numbers. Don't worry; since the PMP exam is multiple choice, you'll see a match!

CV = $ 120,000 – $ 175,000 = $ –55,000

SPI = $120,000 / $150,000 = 0.8

The formulas for CV and CPI use the same numbers, too.

CPI = $120,000 / $175,000 = 0.68

You're managing a highway construction project. Your total budget is $650,000, and there is a total of 7,500 hours of work scheduled on the project. You check with your accounting department, and they tell you that you've spent a total of $400,000. According to the schedule, your crew should have worked 4,500 hours, but your foreman says that the crew was allowed to work some overtime, and they've actually put in 5,100 hours of work. **Calculate these earned value numbers:**

BAC = $ 650,000

4,500 out of a total of 7,500 hours you planned to work: 4,500 ÷ 7,500 = 60%

PV = $ 650,000 x 60% = $ 390,000

AC = $ 400,000

Do the same for actual hours: 5,100 ÷ 7,500 = 68%

EV = $ 650,000 x 68% = $ 442,000

SV = $ 442,000 – $ 390,000 = $ 52,000

CV = $ 442,000 – $ 400,000 = $ 42,000

SPI = $442,000 / $390,000 = 1.13

CPI = $442,000 / $400,000 = 1.11

You are the project manager at an industrial design firm. You expect to spend a total of $55,000 on your current project. Your plan calls for six people working on the project eight hours a day, five days a week, for four weeks. According to the schedule, your team should have just finished the third week of the project. When you review what the team has done so far, you find that they have completed 50% of the work, at a cost of $25,000. **Based on this information, calculate the earned value numbers:**

BAC = $55,000

AC = $25,000

The schedule says the team should have just finished the third week of a four-week project, so the planned % complete is 75%.

PV = $55,000 x 75% = $41,250

EV = $55,000 x 50% = $27,500

SV = $27,500 – $41,250 = ($13,750)

CV = $27,500 – $25,000 = $2,500

Get used to seeing negative numbers in parentheses instead of using a minus sign.

$$SPI = \frac{\$27,500}{\$41,250} = 0.67$$

$$CPI = \frac{\$27,500}{\$25,000} = 1.1$$

Check all of the following that apply:

An SPI below 1 means your project's behind schedule. It's time to think about schedule compression!

- [ ] The project is ahead of schedule
- [x] The project is behind schedule
- [x] You should consider crashing the schedule
- [ ] The project is over budget
- [x] The project is under budget
- [ ] You should find a way to cut costs

Your current project is an $800,000 software development effort, with two teams of programmers that will work for six months, at a total of 10,000 hours. According to the project schedule, your team should be done with 38% of the work. You find that the project is currently 40% complete. You've spent 50% of the budget so far. **Calculate these numbers:**

BAC = $800,000

AC = $400,000

This SPI means that the project is ahead of schedule, but it's very close to 1, which means the schedule is pretty accurate.

PV = $800,000 x 38% = $304,000

EV = $800,000 x 40% = $320,000

SV = $320,000 – $304,000 = $16,000

CV = $320,000 – $400,000 = ($80,000)

$$SPI = \frac{\$320,000}{\$304,000} = 1.05$$

$$CPI = \frac{\$320,000}{\$400,000} = 0.8$$

Since CPI is below 1 and CV is negative, the project is over budget. Cost-cutting is definitely a good idea!

Check all of the following that apply:

- [x] The project is ahead of schedule
- [ ] The project is behind schedule
- [ ] You should consider crashing the schedule
- [x] The project is over budget
- [ ] The project is under budget
- [x] You should find a way to cut costs

You're a project manager working on a large project scheduled to last for two years. You've got six different teams working on five major functional areas. Some teams are ahead of schedule, and others are falling behind. That means that you have cost overruns in some areas, but you've saved costs in others—and that's making it very hard to get an intuitive grasp on whether your project is over or under budget!

It's nine months into your project. The total budget for your project is $4,200,000. You've spent $1,650,000 so far, and you've got a CPI of .875. Use the earned value management formulas from forecasting to figure out where things stand.

EAC = $\frac{\$ 4,200,000}{0.875}$ = $ 4,800,000

You're starting to get the hang of this stuff! These formulas look a little intimidating at first, but they're really not that bad once you get used to them.

ETC = $ 4,800,000 – $ 1,650,000 = $ 3,150,000

VAC = $ 4,200,000 – $ 4,800,000 = ($ 600,000)

Since VAC is negative, it means that you'll be $600,000 over budget at the end of the project.

Will the project be over or under budget when it's complete? (Check one.)

✓ The project will be over budget ..... The project will be within its budget

How much will the project be over or under budget? $ 600,000

Now it's six months later, and your project looks very different. You need to work out a new forecast for what your budget situation will be like at project completion. You've now spent a total of $2,625,000. You look at all of the activities done by the team, and you find that the project is 70% complete. Can you come up with a new forecast for your project?

BAC = $ 4,200,000

EV = $ 4,200,000 x 70% = $ 2,940,000

EAC = $\frac{\$ 4,200,000}{1.12}$ = $ 3,750,000

VAC = $ 4,200,000 – $ 3,750,000

= $ 450,000

Take a second to think about what these numbers really mean. Are you delivering good value to the sponsor?

AC = $ 2,625,000

CPI = $\frac{\$ 2,940,000}{\$ 2,625,000}$ = 1.12

ETC = $ 3,750,000 – $ 2,625,000

= $ 1,125,000

Your project will be **over** / **under** budget at completion. (Circle one.)

How much will the project be over or under budget?

$ 450,000

This VAC means your project is $450,000 under budget.

Sharpen your pencil Solution

You'll probably get a question or two where you'll need to flip your formulas over to figure out one of the values you'd normally be given. **Don't worry if you're math-phobic!** This is really easy—you'll definitely get it with a little practice.

If EV is $93,406 and SPI is 0.91, what is the planned value?

$$SPI = \frac{EV}{PV} = 0.91 = \$\frac{\$93{,}406}{PV}$$

When you're dividing, you just need to swap these two numbers.

$$PV = \frac{\$93{,}406}{0.91}$$

$$PV = \$102{,}644$$

Sometimes your answers aren't nice, round numbers. That doesn't mean that they're wrong!

If PV is $252,000 and BAC is $350,000, what is the planned % complete?

$$PV = BAC \times \text{Scheduled \% complete}$$

$$\$\,252{,}000 = \$\,350{,}000 \times \text{Scheduled \% complete}$$

$$\%\text{ complete} = \frac{\$\,252{,}000}{\$\,350{,}000}$$

$$PV = 72\%$$

Don't forget that when you're calculating a percentage, 72% is the same as 0.72.

Now try one on your own. If BAC is $126,500 and EAC is $115,000, what is the CPI?

1. First write out the formula that has EAC, CPI, and BAC.

$$EAC = \frac{BAC}{CPI}$$

If you're still stumped here, don't worry! You'll only see one or two questions like this on the exam.

2. Next fill in the numbers that you know.

$$\$\,115{,}000 = \frac{\$126{,}500}{CPI}$$

3. Now flip around the formula so the number you're looking for is on the left.

$$CPI = \frac{\$126{,}500}{\$115{,}000}$$

4. Now you can solve the problem!

$$CPI = 1.1$$

Sharpen your pencil Solution

You'll need to know the formula for TCPI and be ready to calculate it for the exam. Here are a couple of problems to help you get a little practice.

BAC is $40,000 and EAC is $30,000, EV is $17,000, and AC is $15,000. What is the BAC-based TCPI?

$$TCPI = \frac{BAC-EV}{BAC-AC} = \$\frac{40{,}000-17{,}000}{40{,}000-15{,}000} = .92$$

The index number is under 1. No need to tighten the belt here.

BAC is $100,000 and EAC is $107,000, EV is $68,000, and AC is $70,000. What is the EAC-based TCPI?

$$TCPI = \frac{BAC-EV}{EAC-AC} = \$\frac{100{,}000-68{,}000}{107{,}000-70{,}000} = .86$$

This project should have no trouble hitting its budget goals.

BAC is $20,000 and EAC is $20,000, AC is $15,000, and the project is 75% complete. What is the EAC-based TCPI?

$$EV = 20{,}000 \times .75$$

This project is right on budget.

$$TCPI = \frac{BAC-EV}{EAC-AC} = \$\frac{20{,}000-15{,}000}{20{,}000-15{,}000} = 1$$

Exam Questions

1. You are creating your cost baseline. What process are you in?

A. Determine Budget
B. Control Costs
C. Estimate Costs
D. Cost Baselining

Some of the earned value numbers have alternate four-letter abbreviations. This one stands for "budgeted cost of work scheduled." Don't worry—you don't need to memorize them!

2. You're working on a project that has an EV of $7,362 and a PV (BCWS) of $8,232. What's your SV?

A. –$870
B. $870
C. 0.89
D. Not enough information to tell

3. You are managing a project for a company that has previously done three projects that were similar to it. You consult with the cost baselines, lessons learned, and project managers from those projects, and use that information to come up with your cost estimate. What technique are you using?

A. Parametric estimating
B. Net present value
C. Rough order of magnitude estimation
D. Analogous estimating

4. You are working on a project with a PV of $56,733 and an SPI of 1.2. What's the earned value of your project?

A. $68,079.60
B. $47,277.50
C. $68,733
D. .72

5. Your company has two projects to choose from. Project A is a billing software project for the Accounts Payable department; in the end it will make the company around $400,000 when it has been rolled out to all of the employees in that department. Project B is a payroll application that will make the company around $388,000 when it has been put to use throughout the company. After a long deliberation, your board chooses to go ahead with Project B. What is the opportunity cost for choosing Project B over Project A?

A. $388,000
B. $400,000
C. $12,000
D. 1.2

Exam Questions

6. Your company has asked you to provide a cost estimate that includes maintenance, installation, support, and upkeep costs for as long as the product will be used. What is that kind of estimate called?

A. Benefit-cost ratio
B. Depreciation
C. Net present value
D. Lifecycle costing

7. You are working on a project with an SPI of .72 and a CPI of 1.1. Which of the following BEST describes your project?

A. Your project is ahead of schedule and under budget.
B. Your project is behind schedule and over budget.
C. Your project is behind schedule and under budget.
D. Your project is ahead of schedule and over budget.

8. Your project has a BAC of $4,522 and is 13% complete. What is the earned value (EV)?

A. $3,934.14
B. There is not enough information to answer.
C. $587.86
D. $4,522

9. A project manager is working on a large construction project. His plan says that the project should end up costing $1.5 million, but he's concerned that he's not going to come in under budget. He's spent $950,000 of the budget so far, and he calculates that he's 57% done with the work, and he doesn't think he can improve his CPI above 1.05. Which of the following BEST describes the current state of the project?

A. The project is likely to come in under budget.
B. The project is likely to exceed its budget.
C. The project is right on target.
D. There is no way to determine this information.

10. You are managing a project laying underwater fiber optic cable. The total cost of the project is $52/meter to lay 4 km of cable across a lake. It's scheduled to take eight weeks to complete, with an equal amount of cable laid in each week. It's currently the end of week 5, and your team has laid 1,800 meters of cable so far. What is the SPI of your project?

A. 1.16
B. 1.08
C. .92
D. .72

Exam Questions

11. During the execution of a software project, one of your programmers informs you that she discovered a design flaw that will require the team to go back and make a large change. What is the BEST way to handle this situation?

A. Ask the programmer to consult with the rest of the team and get back to you with a recommendation.
B. Determine how the change will impact the project constraints.
C. Stop all work and call a meeting with the sponsor.
D. Update the cost baseline to reflect the change.

12. If AC (ACWP) is greater than your EV (BCWP), what does this mean?

A. The project is under budget.
B. The project is over budget.
C. The project is ahead of schedule.
D. The project is behind schedule.

13. A junior project manager is studying for her PMP exam, and asks you for advice. She's learning about earned value management, and wants to know which of the variables represents the difference between what you expect to spend on the project and what you've actually spent so far. What should you tell her?

A. Actual cost (AC)
B. Cost performance index (CPI)
C. Earned value (EV)
D. Cost variance (CV)

14. You are managing an industrial architecture project. You've spent $26,410 so far to survey the site, draw up preliminary plans, and run engineering simulations. You are preparing to meet with your sponsor when you discover that there is a new local zoning law that will cause you to have to spend an additional estimated $15,000 to revise your plans. You contact the sponsor and initiate a change request to update the cost baseline.

What variable would you use to represent the $26,410 in an earned value calculation?

A. PV
B. BAC
C. AC
D. EV

Exam Questions

15. You are working on the project plan for a software project. Your company has a standard spreadsheet that you use to generate estimates. To use the spreadsheet, you meet with the team to estimate the number of functional requirements, use cases, and design wireframes for the project. Then you categorize them into high, medium, or low complexity. You enter all of those numbers into the spreadsheet, which uses a data table derived from past projects' actual costs and durations, performs a set of calculations, and generates a final estimate. What kind of estimation is being done?

A. Parametric
B. Rough order of magnitude
C. Bottom-up
D. Analogous

16. Project A has an NPV of $75,000, with an internal rate of return of 1.5% and an initial investment of $15,000. Project B has an NPV of $60,000 with a BCR of 2:1. Project C has an NPV of $80,000, which includes an opportunity cost of $35,000. Based on these projects, which is the BEST one to select:

A. Project A
B. Project B
C. Project C
D. There is not enough information to select a project.

17. What is the range of a rough order of magnitude estimate?

A. –5% to +10%
B. –25% to +75%
C. –50% to +50%
D. –100% to +200%

18. You are managing a software project when one of your stakeholders needs to make a change that will affect the budget. What defines the processes that you must follow in order to implement the change?

A. Perform Integrated Change Control
B. Monitoring and Controlling process group
C. Change control board
D. Cost baseline