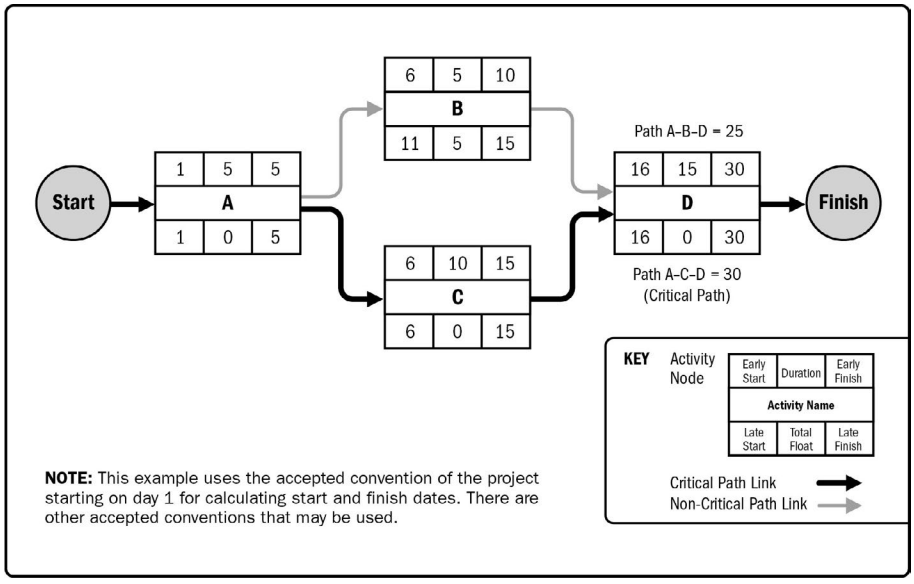
Develop Schedule Tools and Techniques

[1]**Critical path method (CPM)** is a method used to estimate the minimum project duration and determine the amount of scheduling flexibility on the logical network paths within the schedule. This method calculates the early start, early finish, late start, and late finish dates for all activities without regard for any resource limitations by performing a forward and backward pass analysis through the schedule network.

The following figure is an example of the critical path method, which shows the critical path (CP) and the forward and backward passes. This next section is long, but I want to make sure I explain it well enough for you to understand the methods without question. I'll explain critical path first, and then forward/backward passes.



[2] **Figure 6-16 (Guide).** Example of Critical Path Method

Critical Path

First, in order to calculate the critical path, you have to identify all the paths in the schedule. In this example, the first path is Start-A-B-D-Finish and the second is Start-A-C-D-Finish. Once you have the paths, you then add up the durations for each path, for example:

Start-A-B-D-Finish = 5+5+15 = 25

Start-A-C-D-Finish = 5+10+15 = 30

The CP is the longest path; therefore, path Start-A-C-D-Finish = 5+10+15 = 30 is the critical path.

Forward Pass

The forward pass is done to capture the early start (ES) (upper-left box) and early finish (EF) (upper-right box) durations for each activity. In order to calculate the forward pass, there's a formula to remember: Early start (ES) + Duration – 1.

Follow the example below as I go through the forward pass with you using the top boxes for each activity. Start with activity A. In the top-left box, there is a number 1. This represents the beginning of the first day of the project. (You can only count a single day once; that's why we subtract 1 in the formula.) You take 1 plus the duration (top-middle box), which is 5 and then subtract 1, which equals 5. It looks like this: 1+5-1=5. The 5 represents the end of the day on day 5.

Tip: Since this is the first activity in the project, the ES will always = 1 and the EF will = the duration, in this case, 5. (I hope that made sense.)

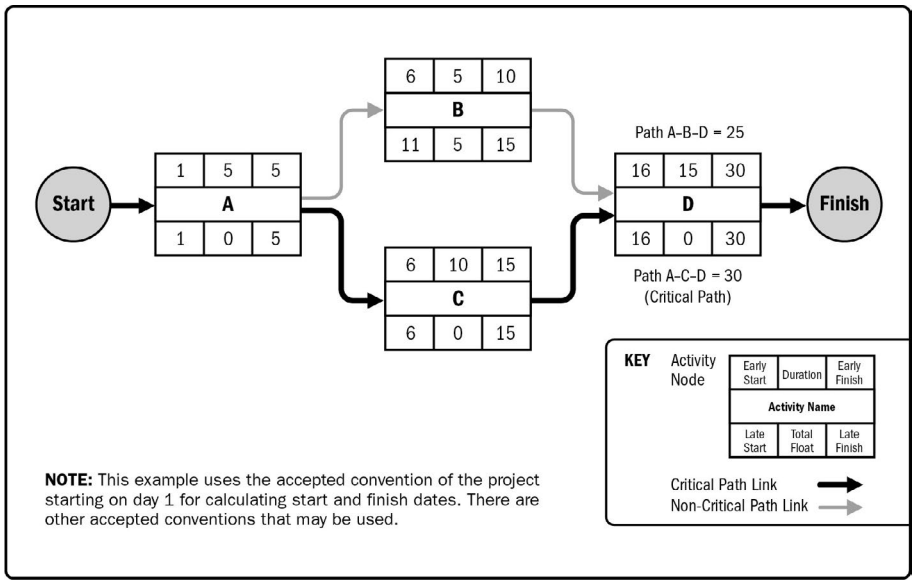
Let's go through the rest of the activities. Next, since the end of the day for activity A was 5, the next activity, activity B, starts the morning of day 6. So, the ES for activity B is 6. If you apply the formula, it looks like this: 6+5-1 = 10.

Now, here's where it gets tricky. You'll notice that activities B and C feed into activity D. To figure out the ES for activity D, you need to take the largest EF from activities B and C and move that forward to activity D. That means we need to complete activity C first.

For activity C, since the end of the day for activity A was 5, the morning of activity C will be 6. So, the ES for activity C is 6. If you apply the formula, it looks like this: 6+10-1 = 15.

So, if you take the largest EF number from activities B (10) and C (15), it will be 15.

Let's finish with activity D. Since the EF is 15, the ES for activity D will be 16. It'll be 16+15-1 = 30 days. That is the end of the forward pass for this example. You'll see that we have all the ESs and EFs for each activity. You might also notice that the EF equals the critical path (30). That's one way you can double-check you've done the forward pass correctly. Now, let's do the backward pass.



[2] **Figure 6-16 (Guide).** Example of Critical Path Method

Backward Pass

The backward pass is done to capture the late start (LS) (lower-left box) and late finish (LF) (lower-right box) durations for each activity. In order to calculate the backward pass, there's a formula to remember: Late finish (LF) - Duration + 1.

Since we are working backward, you need to add the day back in so we add 1 in the formula.

Follow the example below as I go through the backward pass with you using the bottom boxes for each activity. Using the same example, let's work backward starting with activity D. Since the EF from the forward pass was 30, we'll start with that number when calculating the backward pass.

Using the formula on activity D, LF-Dur+1, it looks like this: 30-15+1=16. You may have noticed that the ES/LS and EF/LF are the same numbers; this indicates this activity is on the critical path.

You then move onto activity B. Since the first day of activity D was 16, the last day for activity B would be 15—you always subtract one day when moving backward. Applying the formula, it looks like this: 15-5+1 =11. You'll notice that the ES/LS and EF/LF are not the same numbers; this indicates they are not on the critical path.

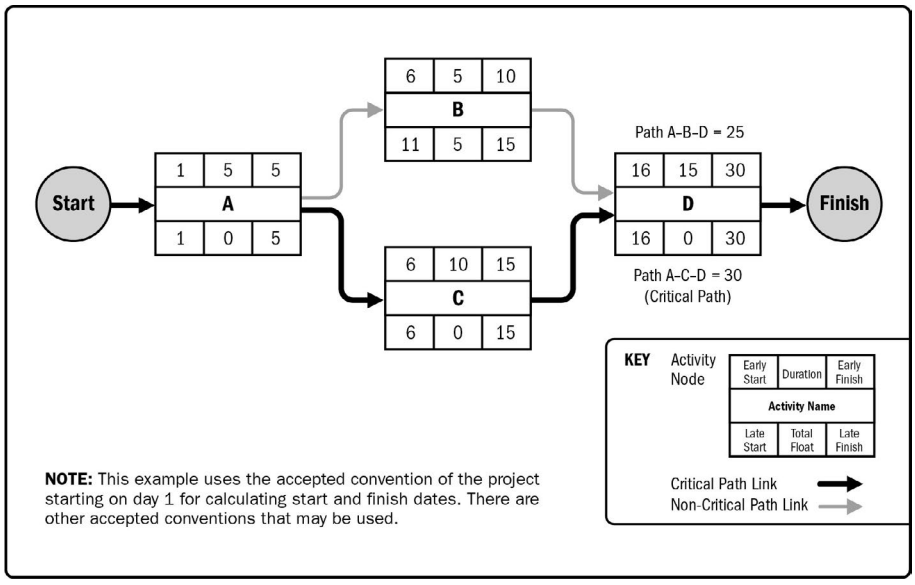
Now, here's another tricky part. You'll notice that activity A has two successors going into it, activities B and C. To figure out the LF for activity A, you need to take the smallest LS from activities B and C and move that backward to activity A. That means we need to complete activity C first.

For activity C, the formula would look like this: 15-10+1 = 6. Now you have the LS for activities B (11) and C (6). Since the smallest LS number is 6, you use this for activity A.

Applying the formula to activity A looks like this: 5-5+1 = 1. Again, you may have noticed that the ES/LS and EF/LF are the same numbers; this indicates this activity is on the critical path.

Tip: When you complete the backward pass, you'll notice that, in this case (activity A), the ES and LS are both the number 1. If you've calculated the backward pass correctly, this should always equal one.

Tip: As you complete the forward and backward pass, you'll notice that for each of the activities on the critical path, the ES/LS and EF/LF will be the same number; for example, activity C has 6/6 and 15/15. This is another way to double-check that you've calculated the forward and backward pass correctly. Also, each of the activities that are on the critical path will have a float equal to 0.



[2] **Figure 6-16 (Guide).** Example of Critical Path Method

[1]**Float:** Schedule flexibility is measured by the amount of time that an activity can be delayed or extended from its early start date without delaying the project finish date or violating a schedule constraint, and is termed total float. The critical path is typically characterized by 0 total float. To calculate float for each activity, use the following formula LS-ES or LF-EF. Using the same example network diagram, let's calculate the float for each activity:

- Activity A: 1-1=0
- Activity B: 11-6=5
- Activity C: 6-6=0
- Activity D: 16-16=0

You'll notice that activities A, C, and D all have 0 float. They are all on the critical path and critical path items have 0 float. Which means, there is no wiggle room for these activities. If one or more of these activities is delayed, the project will be delayed. It's a day-for-day delay.

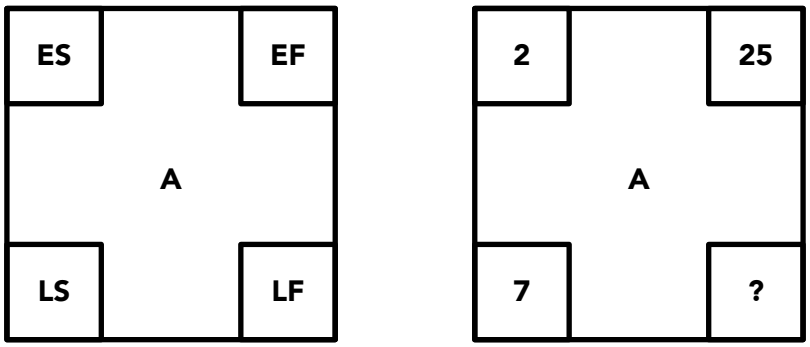
Activity B has 5 days of float, which means it can be delayed by up to 5 days before it affects the successor activity (activity D) and the critical path.

You may be presented with a diagram like the one below on the exam and be asked to figure out the duration or LF, where the question mark is. If you have three corners, you can figure out the fourth.

To figure out the duration, you would take 25 – 2 + 1 = 24. Therefore, duration is 24. You can double-check by taking 2 + 24 – 1 = 25.

Once you have duration, you can figure out LF by taking LS + duration – 1 or 7 + 24 – 1 = 30. LF = 30. Another easier way to calculate LF would be to figure out the float first by taking ES from LS, 7 – 2= 5. Then add 5 to EF, 25 + 5 = 30.

You can double-check the float by subtracting ES from LS, 7 – 2 = 5, or EF from LF, 30 – 25 = 5.



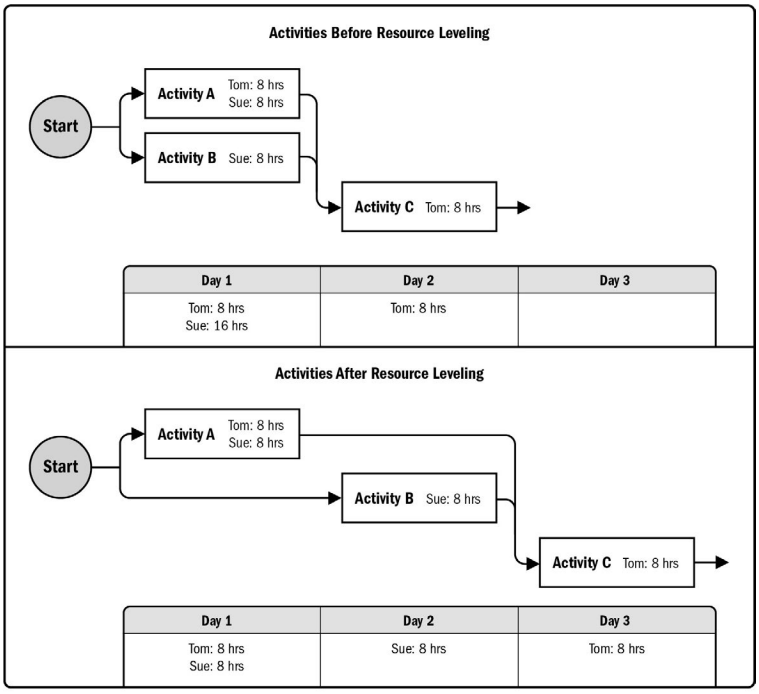
Now that we've covered the critical path method, let's move onto the critical chain method.

[1]**Critical chain method (CCM)** is a schedule method that allows the project team to place buffers on any project schedule path to account for limited resources and project uncertainties. What this means is that the schedule is built by estimating each activity aggressively. For example, an activity may be estimated at realistically at 5 days, but optimistically at 2. The 2 days go into the schedule and the remaining 3 days go into the buffer. The extra time is taken from each activity and put at the end of the schedule as a buffer. The project is managed to the aggressive schedule, only using the buffer, if needed.

Resource optimization techniques adjust the schedule due to demand and supply of resources.

- [1]**Resource leveling** is a technique in which start and finish dates are adjusted based on resource constraints with the goal of balancing demand for resources with the available supply. Resource leveling can sometimes cause the critical path to change, usually to increase.

The following figure shows an example of resource leveling. You can see that Sue was over committed on day one, so activities B and C were moved out so Sue could still complete the work. It's important to see if this type of maneuvering changes the critical path.



[3] **Figure 6-17 (Guide).** Resource Leveling

- [1]**Resource smoothing** is a technique that adjusts the activities of a schedule such that the requirements for resources on the project do not exceed certain predefined resource limits. This technique does not affect the critical path. An example of resource smoothing may look like this:
- Tammy is scheduled to work the following hours:
  - 30 hours, first week
  - 10 hours, second week
  - 20 hours, third week
- With resource smoothing it looks like this:
  - 20 hours, first week
  - 20 hours, second week
  - 20 hours, third week
  - It's the same amount of hours for the three weeks, but it's smoothed out so the resource doesn't go over predefined limits per week.

[1]These definitions are taken from the Glossary of Project Management Institute, *A Guide to the Project Management Body of Knowledge, (PMBOK® Guide)* – Sixth Edition, Project Management Institute Inc., 2017.

[2]Project Management Institute, *A Guide to the Project Management Body of Knowledge, (PMBOK® Guide)* – Sixth Edition, Project Management Institute Inc., 2017, Fig. 6-16, Page 211.

[3]Project Management Institute, *A Guide to the Project Management Body of Knowledge, (PMBOK® Guide)* – Sixth Edition, Project Management Institute Inc., 2017, Fig. 6-17, Page 212.