Network Planning and Analysis

1. Objective: What can you tell me about the project?

When will the project finish?

How long will the project take (project total duration)?

2. Why is this topic Important to the project manager?

My task leader wants to know how much s/he can be late before the next task is late?

My task leader wants to know how much s/he can be late before the entire project will be late?

This part will explain network analysis and show how to answer the above two questions.

3. Topics we will discuss

Network sequencing of tasks
Forward pass
Backward pass

Slack between tasks **(Free Slack)**
Total free slack along a sub path (sometimes referred to as **slack** or **total slack**)

Note: Come back to read this three or four times in the next few class periods.

What are the critical points to understand about network scheduling and analysis?

The critical concept is to understand dealing with the question, "How flexible is my project?" I.e., how much can tasks change and my project will still finish on time and be "safe", so to speak. The task duration could change because of new requirements or possibly because of delays in getting the work done. The finish dates could be delayed because of various kinds of uncertainties and/or causes outside the control of the task leader. Some workers could call in sick, or an accident happen on the job, or some machines malfunction or just simply break down.

So, if we can have some slack (a little extra time) to allow for these uncertainties, then the life of managing a project can go just a little easier and not make us so anxious. The really important point is if you can understand that there is only slack between tasks. **There is no such thing as project slack**—only the slack or flexibility that will naturally occur between two tasks. You will learn about total slack, but that is just the total sum of the slacks between tasks (free slack). This is what you will study and learn about in this part of the course. If you understand that total slack is the sum of free slacks and how that relates to the critical path, you will be well on your way to managing projects much more successfully. Read on to begin your journey with "slack" and flexibility.

Why is Network Planning and Scheduling of Tasks Important to Understand?

As the project manager, you will always be concerned about the following three important network questions:

- How long will the project take to be finished (days, weeks, months, years)?
- When will the project finish? (on what day and date?)
- Is this a tightly scheduled project or do I have flexibility in the scheduling of my tasks? Another perspective: How sensitive is the project to any small changes?

Everybody wants to know when something will be finished and/or how long it will last. But also, do I have much flexibility in my project? I would like to know how sensitive various tasks are to starting or finishing late (uncertainties of life).

Fundamental Network Analysis

- **Forward Pass**
  - **Earliest Time for Start and Finish**
- **Backward Pass**
  - **Latest Time for Start and Finish**
- **Critical Path**
  - **Determines the project duration (i.e., finish date)**
  - **Path with least slack (usually zero)**
  - **Longest Path**
  - **If CP is extended, then project finish date is extended (later).**
- **Total Slack**
  - **It's about making the Total Project Late.**
- **Free Slack**
  - **It's about making the next task (successor) late.**

Scheduling with Forward/Backward Passes

- **Forward Pass**
  - **Earliest Time for Start and Finish**
  - **EF (task) = ES + Duration**

  Note: ES (successor task) = *latest EF* of predecessor task**
  - **Cannot start the meeting until latest person arrives.**

  ** *Wed, 5pm is same as Thur, 8am for a project.*

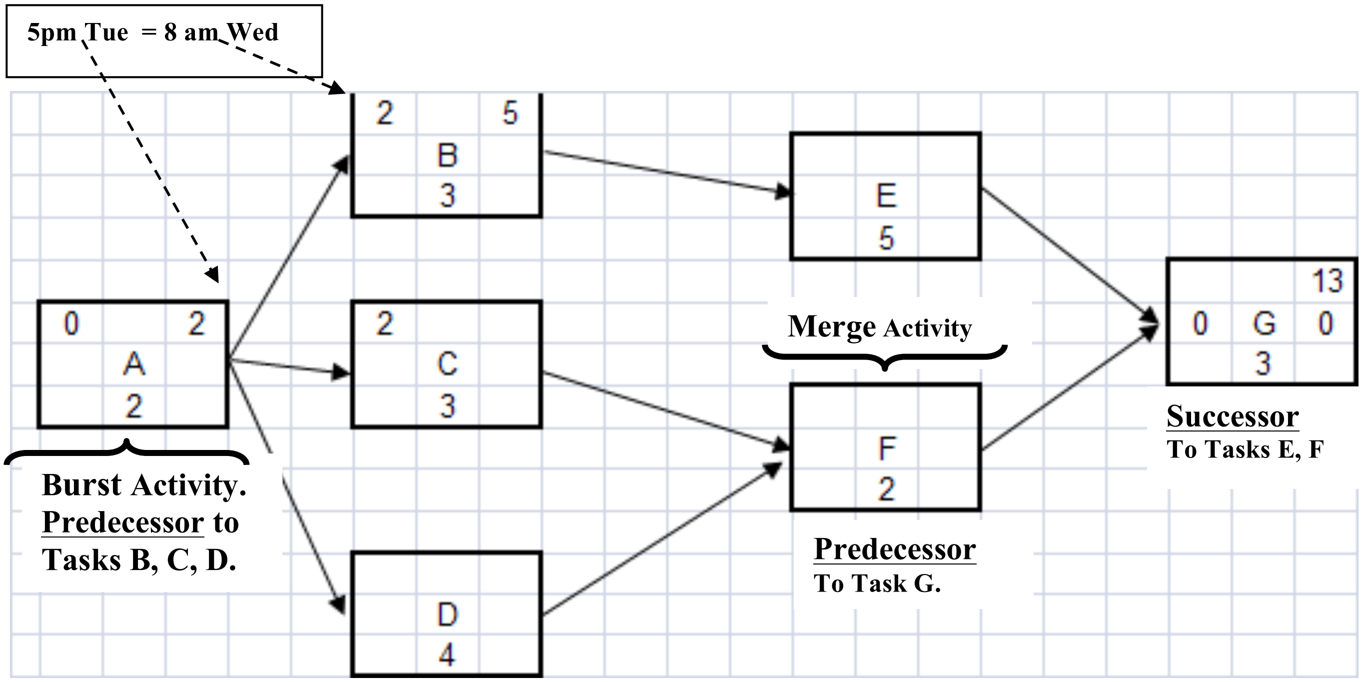
- **Backward Pass**
  - **Latest Time for Start and Finish**
  - **LF (predecessor task) = *earliest LS* of successor tasks**
  - **LS (task) = LF – Duration**

  NOTE the following:
  - **LF = ES + Dur + TS**
  - **LS = ES + TS**

NOTE: Late finish (LF) is the last day a task can be late before making the project late. This is because the LF is just the early finish (EF) with the Total Slack (TS) added on. And Total Slack is the amount that a task can be late before the project is late.

In-Class Example

Objective: Complete forward and backward passes and draw the Gantt chart for the simple network.



0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

A														
B														
C														
D														
E														
F														
G		↑												

Mon Tues Wed Thur Fri Mon . . . .

Time Period

5pm Mon = 8 am Tue

What is the LONGEST PATH? ______________________

What is the path with the LEAST SLACK (late - early times)?

____

Explanation of Slack

1. Free Slack

- **Affects *next neighbor* (successor) task only. Refers ONLY to a single task.**
- **Free slack for a Task (FS):**
    - **Calculated as start (of next task) – finish (of current task)**
        - **FS = ES (successor) - EF (task)**
    - **Only possible with Merge Activities (2 or more paths converging on a task)**
    - **Makes next task late if exceeded**

- **FS = 0 when EF (task) = ES (successor)**
- **FS > 0 when EF (task) < ES (successor)**
    - **Example: If EF = 20 and ES (successor) = 30, then FS = 10.**

2. Slack (sometimes referred to as TOTAL SLACK)

- **ONLY REFERS to a single task—there is NO PROJECT total slack.**
- **Calculated as Total free slack along a sub-path up to a critical path task.**
- **TOTAL SLACK = SUM of Free Slack along sub-path to a critical task**
- **Affects whether a project is late or on time.**

Total Slack (or float) is for *entire the path*. If delay an activity, then all subsequent activities are delayed along the path delayed.

- **Calculation-1: *Late - Early* for a *task activity*.**
- **Calculation-2: Sum of free slacks along a sub-path until hit a critical task.**
- **Makes project late if exceeded**
- **Positive: LF later (>) than EF**
- **Zero: LF equal (=) to EF**
- **Negative: LF earlier (<) than EF**

3. Critical Path

- **Network path with least slack** *(usually zero, but could be negative or positive)*
- **Longest path in the network**
- **No flexibility. Task delays will delay the project**
- **Usually path with slack = 0**

What condition for Slack = 0? EF (or ES) ______ LF (or LS) (less than, equals, greater than)

Negative slack occurs if the project is delayed, i.e., EF > LF or if project LF is *promised earlier* than EF, i.e., LF < EF.

- Example #1: EF = 250, but politician promises project in 220 days. TS would = -30.
- This means that the project would have to start 30 days earlier.

Example:

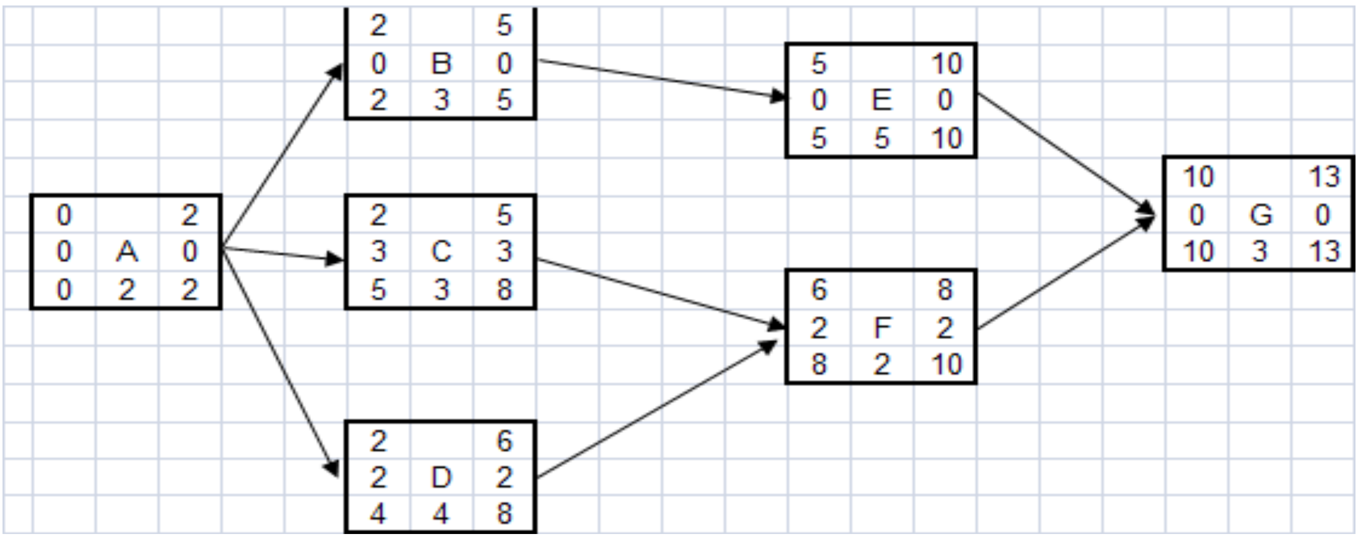
- Politician promises that the bridge will be completed (LF) **earlier** than Network EF.

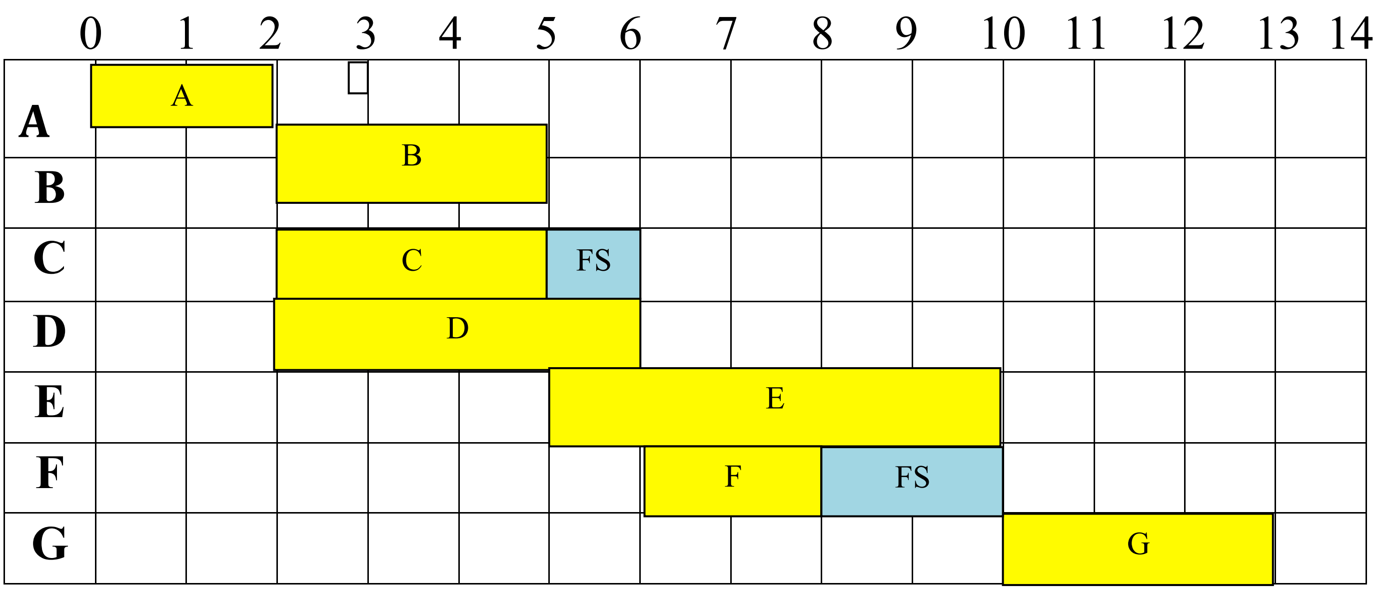
On Your Own:

Change the latest finish date in the network above (also, next page) to be **10**. Now, work the backward pass and you should get an LS value of -3. What does that LS = -3 mean?

Answer in 3 or 4 pages at the bottom of the page.

Slack Analysis: Free Slack and Total Slack





Notice:

- Task C can move over one time period (be late) and F can still start on time.
  - This is FREE SLACK for Task C.
- Task F can move over two time periods (be late) and G can still finish on time.
  - Task G is end of project.
  - It must finish on time or the project WILL BE LATE.
  - This is FREE SLACK for Task F.

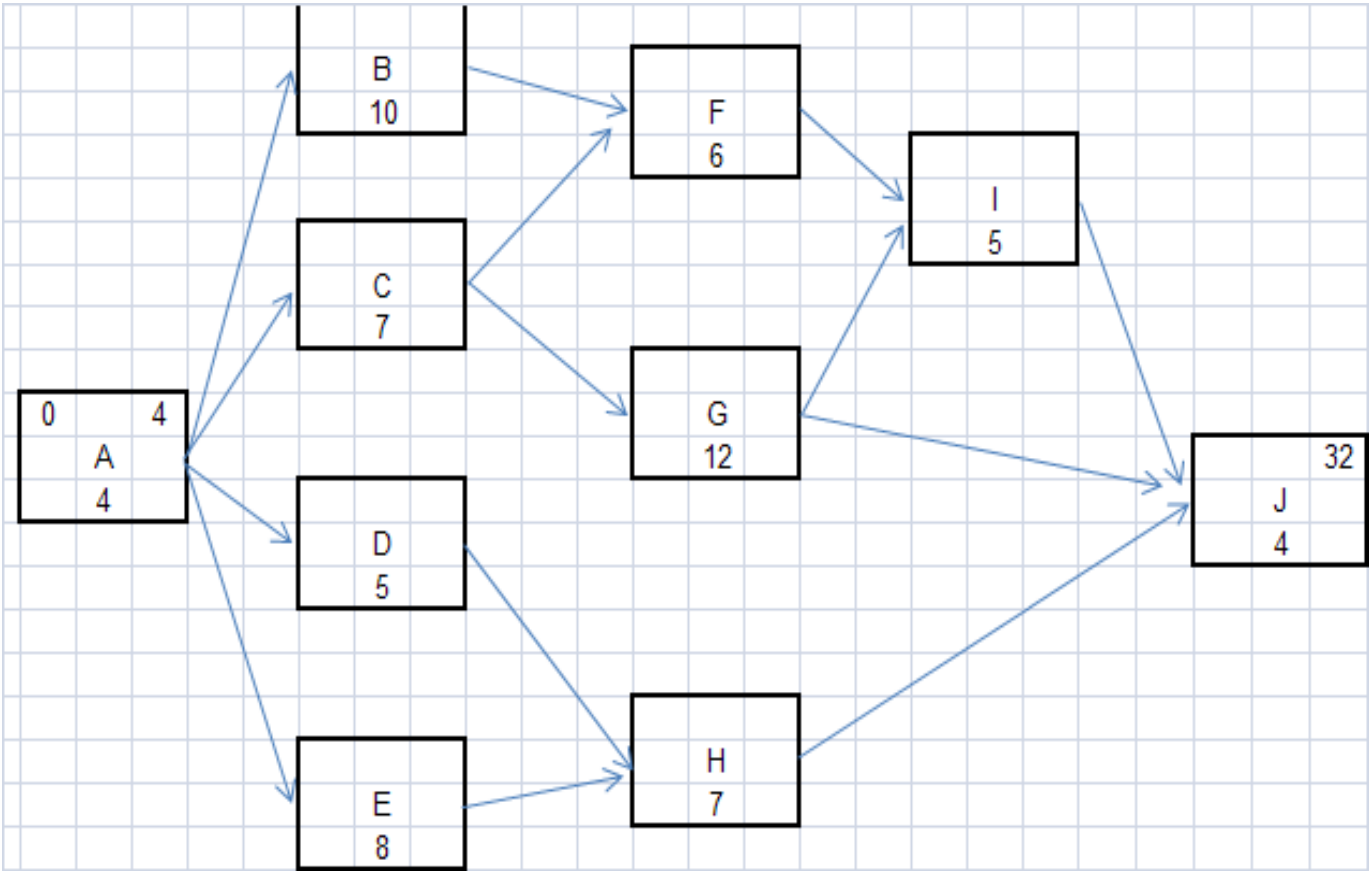
Question:

- How much can C be late before the PROJECT IS LATE?

- **In Class Exercise #1**

Complete the forward and backward passes on the following network:

What is the critical path?



Which tasks have free slack and total slack and how much?

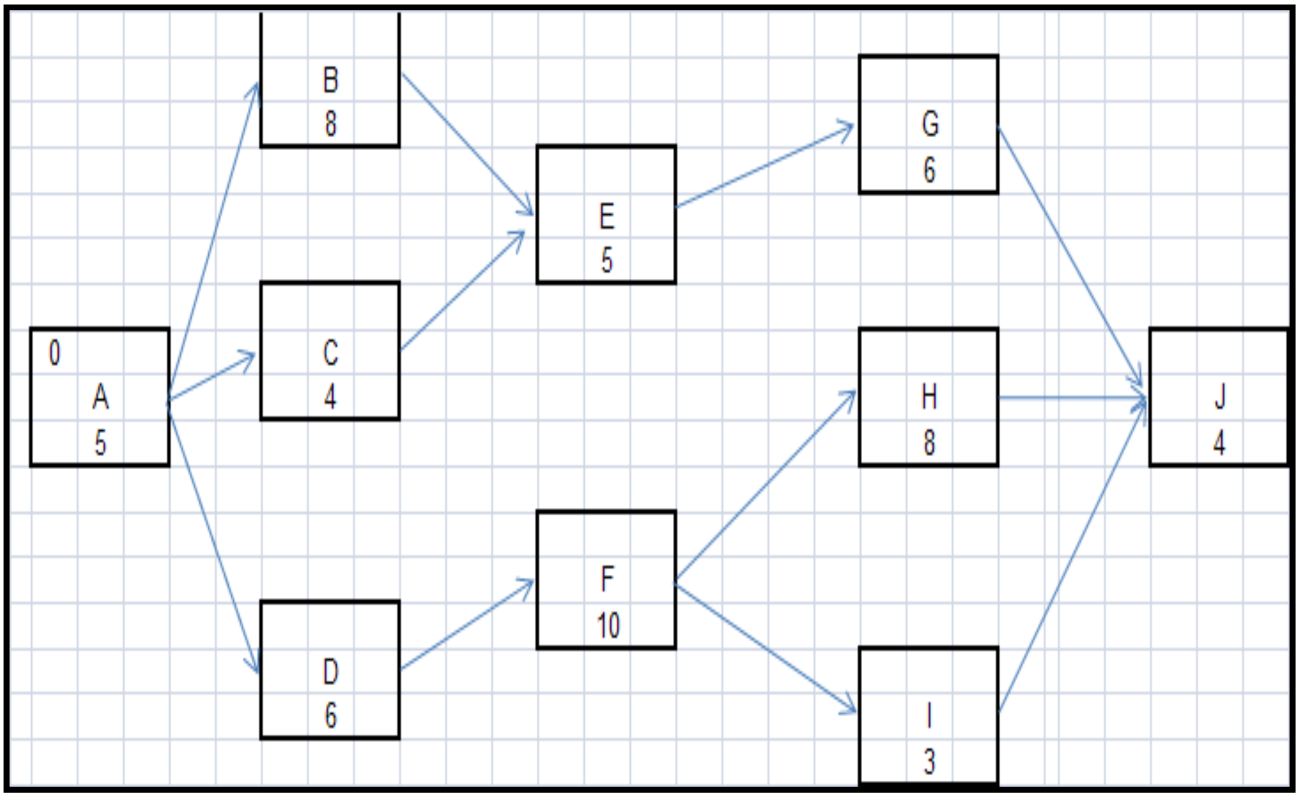
Answer to previous page

- C can be late three (3) time periods and the project will still finish on time.
- **WHY?**
  - C can be late one day and push up next to Task F.
  - F can be late two more days if C pushes two more days on F. So, not a problem.
- **Conclusion:**
  - C has Total Slack = Task C (free slack) and Task F (free slack)
  - I.e., this is the total amount of free slack it has to work with along its sub-path from C-F-G before any more lateness would make the project late.

On Your Own After Class

Complete the forward and backward passes on the following network:

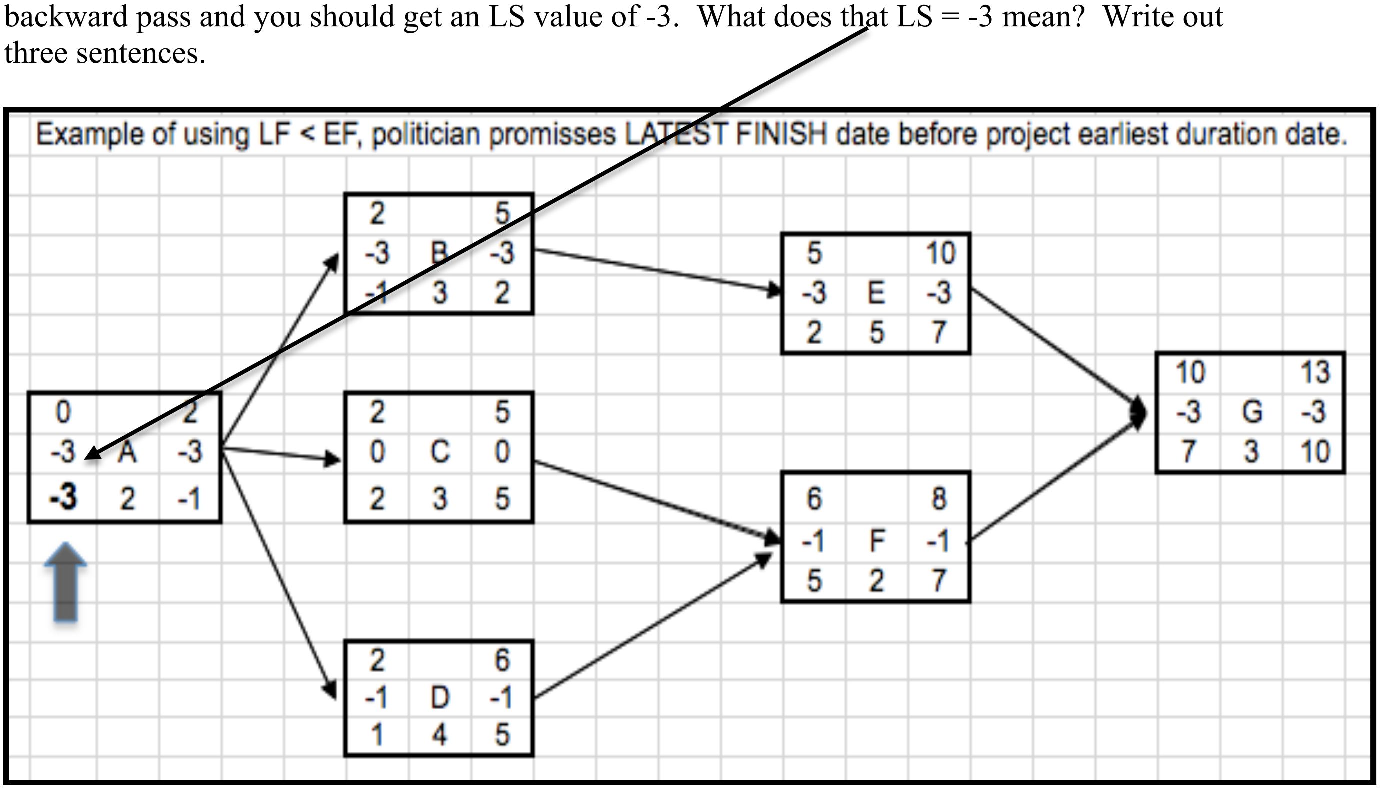
What is the critical path?



Which tasks have free slack and total slack and how much?

On Your Own:

Change the latest finish date in the network above (also, next page) to be 10. Now, work the backward pass and you should get an LS value of -3. What does that LS = -3 mean? Write out three sentences.

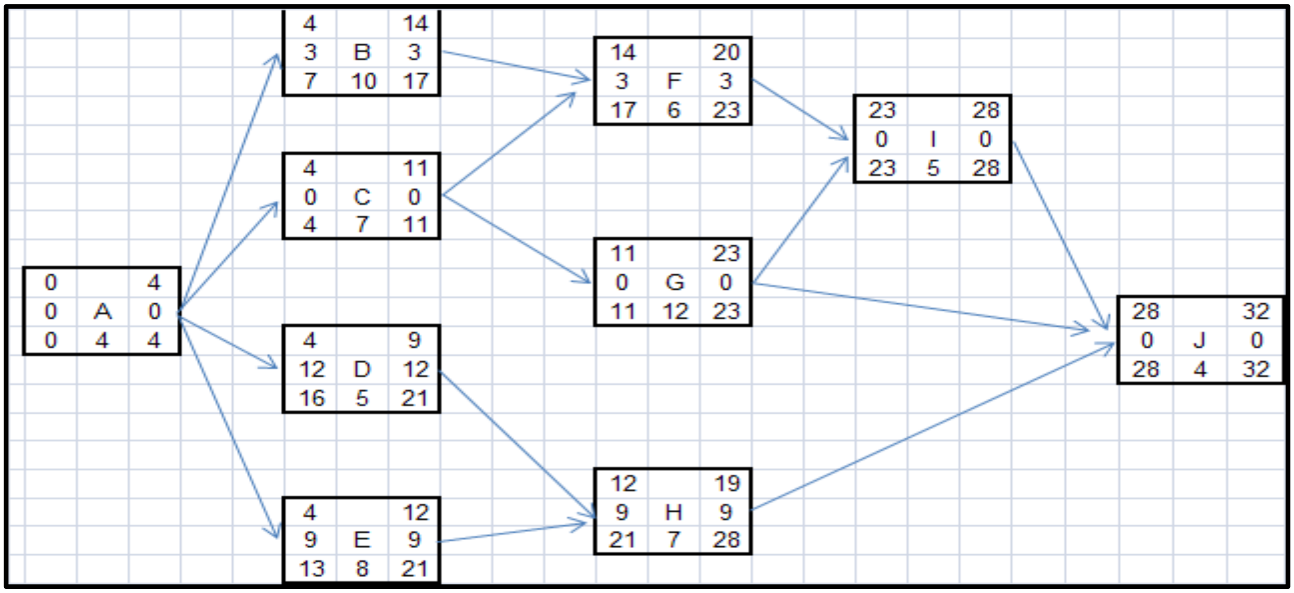


Here is a possible perspective.

By setting the LF to be 10, the politician or the software company management is saying that they want this project out on the market or ready for the public (highway project, bridge project, etc.) on a certain date, regardless of what the project people say is the project technical finish date and duration (13 time periods). So, you, the project manager work the backward pass and come up with the -3 for the LS and this informs you that you need to start the project three days earlier. I notice, also, that the critical path is no longer identified as the path with total slack = 0. It is the path with the LEAST slack, i.e., in this case, the LEAST SLACK is -3 along A – B- E G.

Notice the slack values along the various paths. Do they make sense to you? The “-1” means that this task should have started ONLY one day earlier. WHY? Notice that task F, for example, finished on period 8 and task G starts at period 10. That is two days that task F could be late (free slack), so task F only really has to start one day earlier.

Solution to In-Class Exercise #1

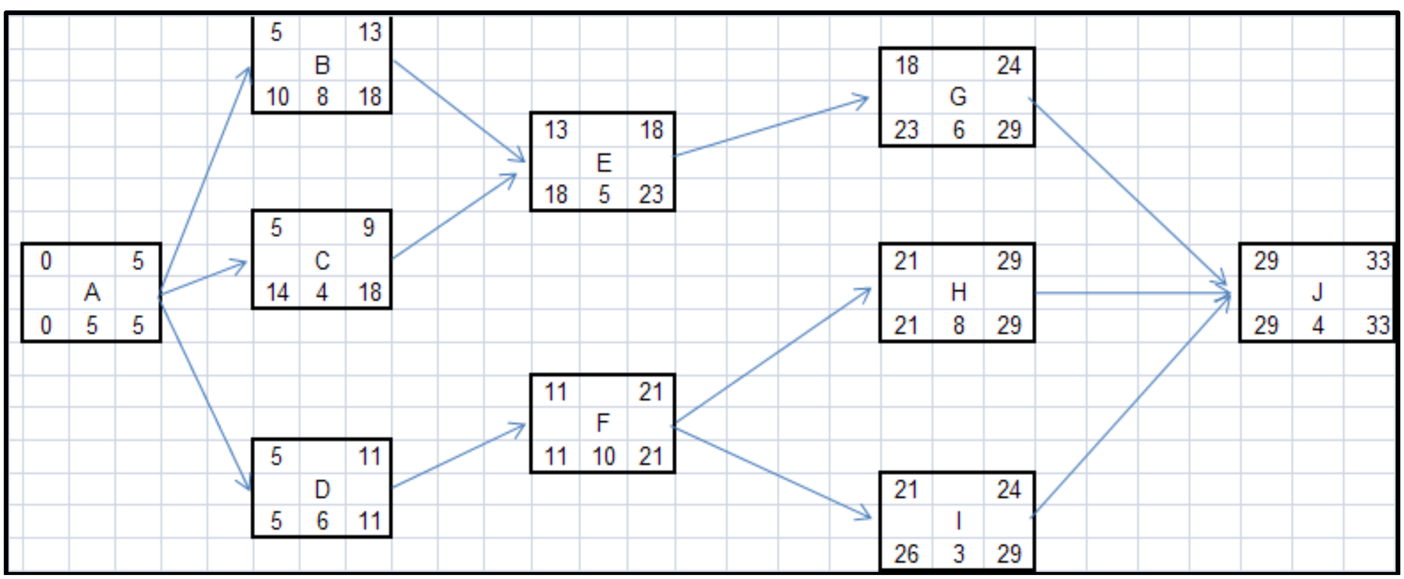


Tasks with Free Slack and Total Slack

Task>>	A	B	C*	D	E	F	G	H	I	J
FS	0	0	0	3	0	3	0	9	0	NA
TS	0	3	0	12	9	3	0	9	0	NA

*A critical task (such as Task C) ALWAYS has FS=0 and TS (or SLK) = 0.

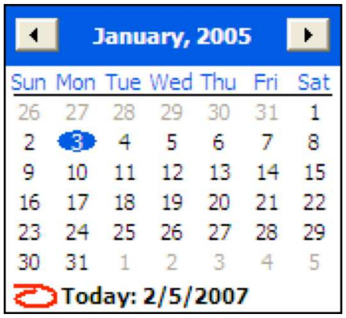
Solution: On Your Own After Class

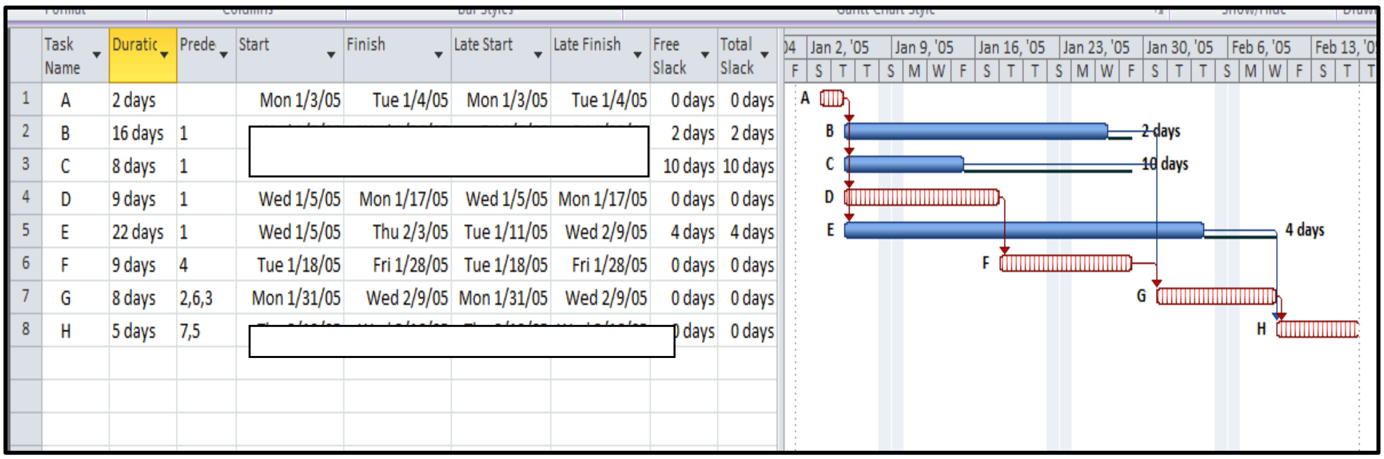


Tasks with Free Slack and Total Slack

Task>>	A	B	C	D	E	F	G	H	I	J
FS	0	0	4	0	0	0	5	0	5	NA
TS	0	5	9	0	5	0	5	0	5	NA

Calendar Problems





	Task Name	Duration	Predecessors	Start	Finish	Late Start	Late Finish	Free Slack	Total Slack
1	A	2 days		Mon 1/3/05	Tue 1/4/05	Mon 1/3/05	Tue 1/4/05	0 days	0 days
2	B	16 days	1					2 days	2 days
3	C	8 days	1					10 days	10 days
4	D	9 days	1	Wed 1/5/05	Mon 1/17/05	Wed 1/5/05	Mon 1/17/05	0 days	0 days
5	E	22 days	1	Wed 1/5/05	Thu 2/3/05	Tue 1/11/05	Wed 2/9/05	4 days	4 days
6	F	9 days	4	Tue 1/18/05	Fri 1/28/05	Tue 1/18/05	Fri 1/28/05	0 days	0 days
7	G	8 days	2,6,3	Mon 1/31/05	Wed 2/9/05	Mon 1/31/05	Wed 2/9/05	0 days	0 days
8	H	5 days	7,5					0 days	0 days

The early start date and time for Task 1 is 8 am, Monday, January 3, 2005.

Rather Easy

1. What is the early start date and time for task #2? ________________________
   Next day after finish of Task #1. Think Forward Pass.
2. What is the early finish date and time for Task #3? ___________________________
   Finish date of Task #1 + during of Task #3. Think Forward Pass again.
3. What is the early start date and time for Task #8? _________________________
   Subtract duration of Task #8 from finish (LF = EF, because critical task). Backward Pass.

Slightly more difficult

4. What is the latest finish date and time for Task #2? _____________________________
   Add the Total Slack to the EF. Remember, TS = LF – EF.
5. What is the latest start date and time for Task #7? ___________________________
   Critical Task (NO slack): BW Pass: 1 day before ES(Tsk #8). FW Pass: 1 day after EF(Tsk #8).

More difficult

6. If Task #5 were shortened by 2 days,
   a. What would be the free slack for Task #5? ________________________
      Visualize that Task #5 will become shorter (solid blue bar), Slack line will get longer, > 4 days.
   b. What would be the latest finish time and date for Task #5? ______________

ANSWERS

Rather Easy

1. What is the early start date and time for task #2? ___Wed, Jan 5 at 8 a.m.____
   Task 2 starts immediately the next day at 8 am after Task 1 finishes. This is a simple finish-start linkage.

2. What is the early finish date and time for Task #3? ____Friday, Jan 14 at 5 pm_____
End of task bar is the EF. Recall that EF = ES + Dur. The ES for Task #3 is same as for Task #2. A duration of 8 days (task #3) will be starting on Wednesday (1/5) and finishing Friday the next week (1/14), i.e., W-F, M-F.

3. What is the early start date and time for Task #8? __Thurs, Feb 10 at 8 am___
Recall that ES = EF – Dur. So work back in time from the finish of Task 8 using the duration. Task 8 finishes Wed (2/16) at 5pm, so going back 5 days duration makes Wed-T-Mom, F-Thr (2/10).

Slightly more difficult

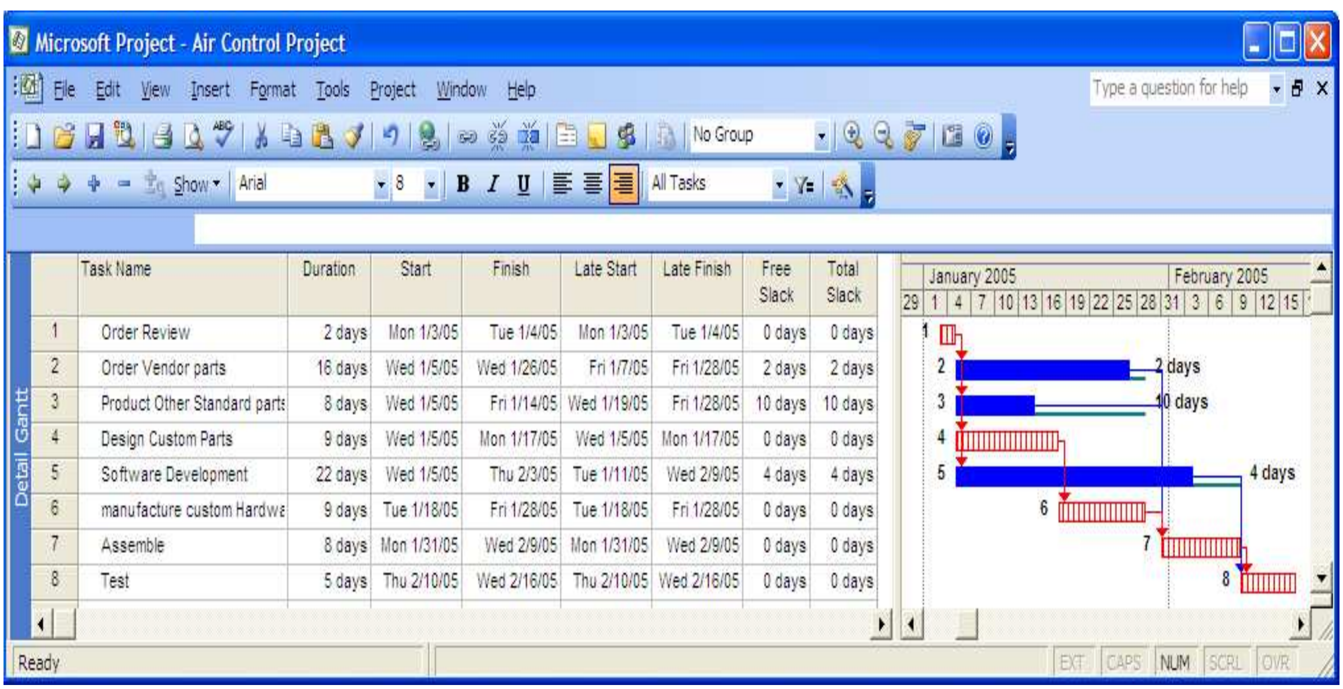
4. What is the latest finish date and time for Task #2? ____Fri, Jan 28 at 5 pm____
   LF is the EF plus the Total Slack, i.e., LF = EF + TS. From the Gant chart, you can see FS=2 for Task 2, but also this is the TS=2 because the Blue bar leads directly into a critical task (#7). So LF = EF + TS. Also, the LF = ES + Dur + TS.

5. What is the latest start date and time for Task #7? _____Mon, Jan 31, 8 am_____
   Notice that Task #7 is RED, hence it is a critical task. Now it is easy. Critical tasks have no slack. Therefore the LF = EF and the LS = ES.

More difficult

6. If Task #5 were shortened by 2 days, what would be the latest finish time and date for Task #5?

   NO CHANGE: Wed , Feb 9, 5pm
   The idea here is that shortening a task does not change its late date. The BLUE bar would become shorter by 2 days and increase the FS from 4 to 6 days. It would just gives more flexibility to the task, i.e., now people working on Task #5 have more time to work on something else.



	Task Name	Duration	Start	Finish	Late Start	Late Finish	Free Slack	Total Slack
1	Order Review	2 days	Mon 1/3/05	Tue 1/4/05	Mon 1/3/05	Tue 1/4/05	0 days	0 days
2	Order Vendor parts	16 days	Wed 1/5/05	Wed 1/26/05	Fri 1/7/05	Fri 1/28/05	2 days	2 days
3	Product Other Standard parts	8 days	Wed 1/5/05	Fri 1/14/05	Wed 1/19/05	Fri 1/28/05	10 days	10 days
4	Design Custom Parts	9 days	Wed 1/5/05	Mon 1/17/05	Wed 1/5/05	Mon 1/17/05	0 days	0 days
5	Software Development	22 days	Wed 1/5/05	Thu 2/3/05	Tue 1/11/05	Wed 2/9/05	4 days	4 days
6	manufacture custom Hardwa	9 days	Tue 1/18/05	Fri 1/28/05	Tue 1/18/05	Fri 1/28/05	0 days	0 days
7	Assemble	8 days	Mon 1/31/05	Wed 2/9/05	Mon 1/31/05	Wed 2/9/05	0 days	0 days
8	Test	5 days	Thu 2/10/05	Wed 2/16/05	Thu 2/10/05	Wed 2/16/05	0 days	0 days

ANSWERS TO SLACK ANALYSIS QUESTIONS

Answers to Slack Analysis when LF = EF:

C has ____1_____ days of Free Slack (before next task is late) **One day difference between C and F.**

C has ____3_____ days of Total Slack (before project is late) **FS = 1 (C – D) and FS = 2 (F – G)**

D has ____0_____ days of Free Slack (before next task is late) **No free time between D and F.**

D has ____2_____ days of Total Slack (before project is late) **FS = 0 (D - F) and FS = 2 (F – G)**

F has ____2_____ days of Free Slack (before next task is late) **Two days difference between F and G**

F has _____2______ days of Total Slack (before project is late) Sub-path is F-G, hence TS = FS = 2.