

Decision Making Theory

Week 12 – Project Management

Project Management



**Program Evaluation
and Review Technique
(PERT)**



**Critical Path Method
(CPM)**

PERT and CPM

- Network techniques
- Developed in 1950's
 - CPM by DuPont for chemical plants (1957)
 - PERT by Booz, Allen & Hamilton with the U.S. Navy, for Polaris missile (1958)
- Consider precedence relationships and interdependencies
- Each uses a different estimate of activity times

PERT/CPM

1.

- Define the project and all of its significant activities or tasks.

2.

- Develop the relationships among the activities. Decide which activities must precede others.

3.

- Draw the network connecting all of the activities.

4.

- Assign time and/or cost estimates to each activity.

5.

- Compute the longest time path through the network; this is called the critical path.

6.

- Use the network to help plan, schedule, monitor, and control the project.

Questions PERT & CPM Can Answer

1. When will the entire project be completed?
2. What are the critical activities or tasks in the project?
3. Which are the noncritical activities?
4. What is the probability the project will be completed by a specific date?

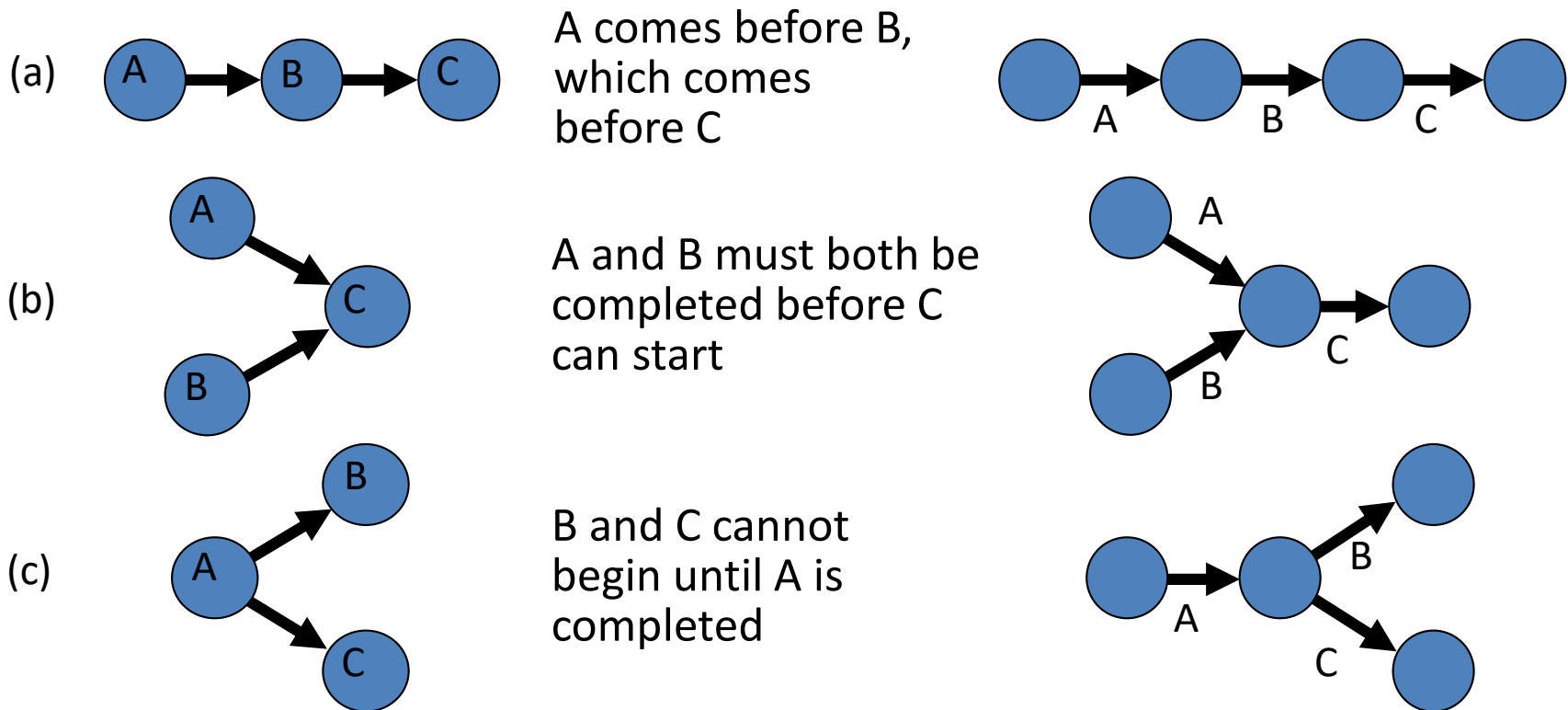
Questions PERT & CPM

Can Answer

5. Is the project on schedule, behind schedule, or ahead of schedule?
6. Is the money spent equal to, less than, or greater than the budget?
7. Are there enough resources available to finish the project on time?
8. If the project must be finished in a shorter time, what is the way to accomplish this at least cost?

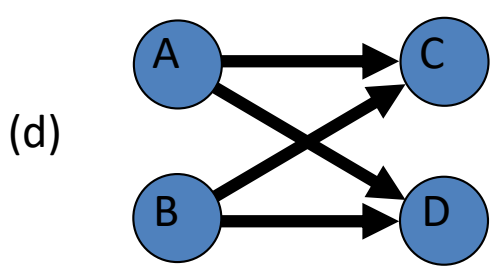
A Comparison of AON and AOA Network Conventions

Activity on Node (AON)	Activity Meaning	Activity on Arrow (AOA)
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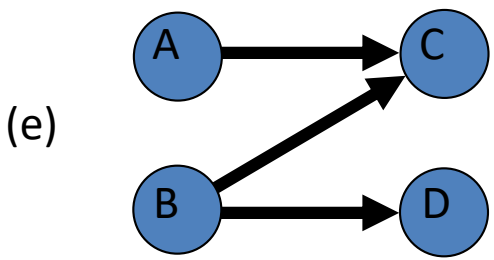
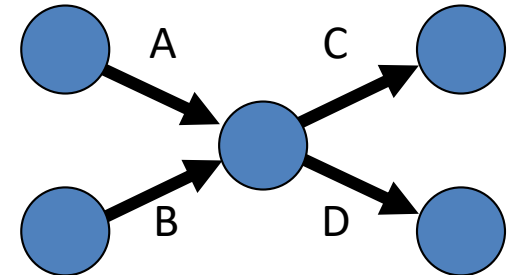


A Comparison of AON and AOA Network Conventions

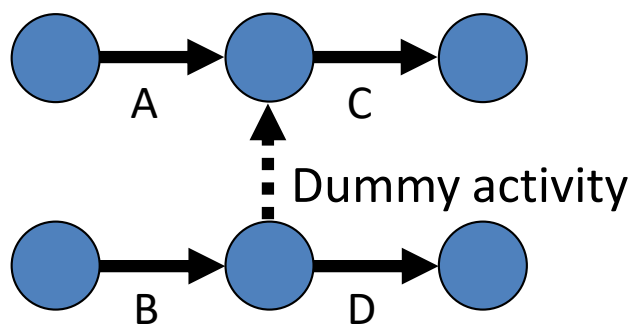
Activity on Node (AON)	Activity Meaning	Activity on Arrow (AOA)
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C and D cannot begin until both A and B are completed



C cannot begin until both A and B are completed; D cannot begin until B is completed. A dummy activity is introduced in AOA



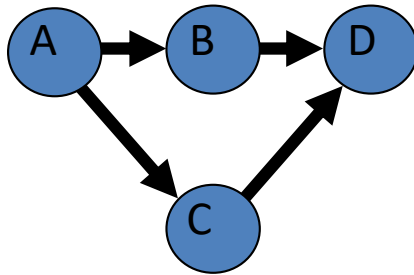
A Comparison of AON and AOA Network Conventions

Activity on Node (AON)

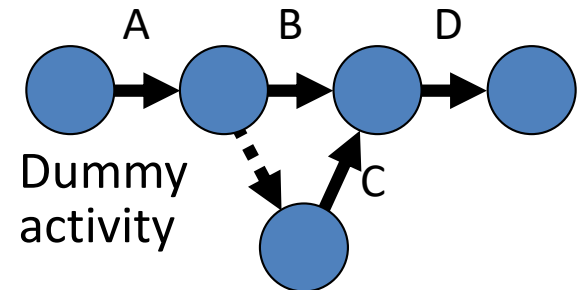
Activity Meaning

Activity on Arrow (AOA)

(f)



B and C cannot begin until A is completed. D cannot begin until both B and C are completed. A dummy activity is again introduced in AOA.

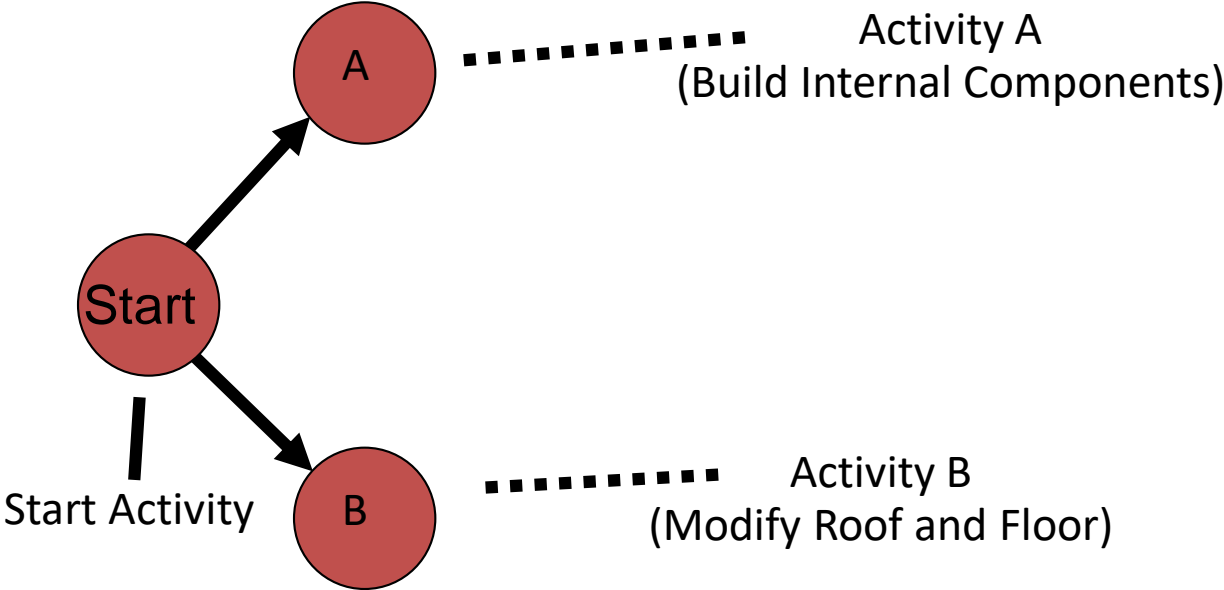


AON Example

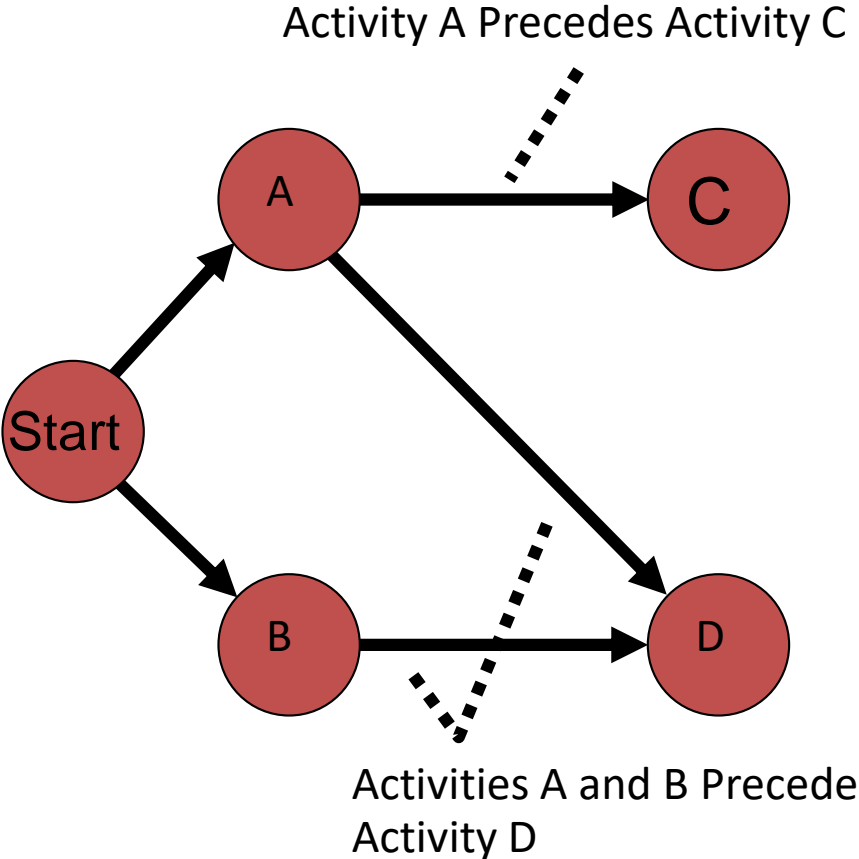
Milwaukee Paper Manufacturing's Activities and Predecessors

<i>Activity</i>	<i>Description</i>	<i>Immediate Predecessors</i>
<i>A</i>	<i>Build internal components</i>	<i>—</i>
<i>B</i>	<i>Modify roof and floor</i>	<i>—</i>
<i>C</i>	<i>Construct collection stack</i>	<i>A</i>
<i>D</i>	<i>Pour concrete and install frame</i>	<i>A, B</i>
<i>E</i>	<i>Build high-temperature burner</i>	<i>C</i>
<i>F</i>	<i>Install pollution control system</i>	<i>C</i>
<i>G</i>	<i>Install air pollution device</i>	<i>D, E</i>
<i>H</i>	<i>Inspect and test</i>	<i>F, G</i>

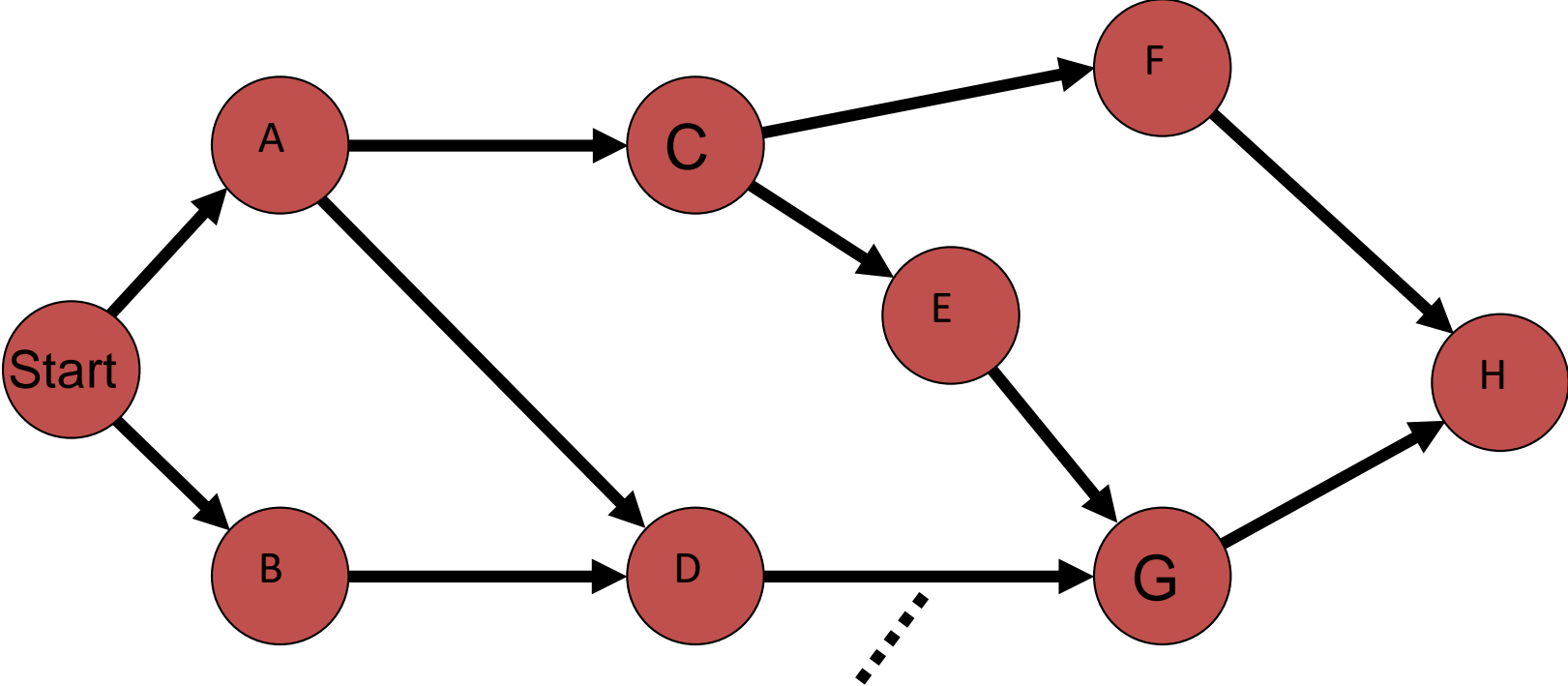
AON Network for Milwaukee Paper



AON Network for Milwaukee Paper



AON Network for Milwaukee Paper



Arrows Show Precedence Relationships

Figure 3.8

Determining the Project Schedule

Perform a Critical Path Analysis

- ☑ The critical path is the longest path through the network
- ☑ The critical path is the shortest time in which the project can be completed
- ☑ Any delay in critical path activities delays the project
- ☑ Critical path activities have no slack time

Determining the Project Schedule

Perform a Critical Path Analysis

Activity	Description	Time (weeks)
A	Build internal components	2
B	Modify roof and floor	3
C	Construct collection stack	2
D	Pour concrete and install frame	4
E	Build high-temperature burner	4
F	Install pollution control system	3
G	Install air pollution device	5
H	Inspect and test	2
Total Time (weeks)		25

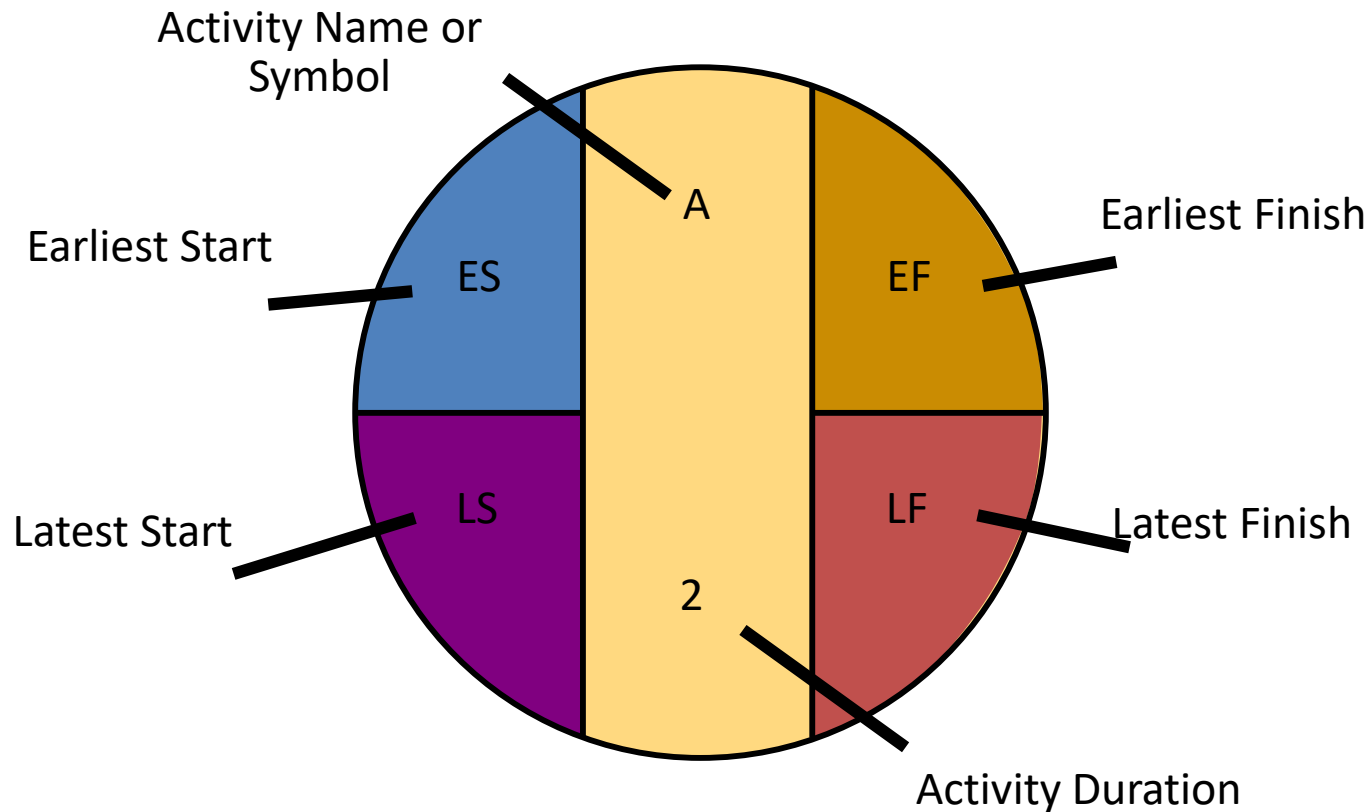
Determining the Project Schedule

Perform a Critical Path Analysis

- Earliest start (ES) = earliest time at which an activity can start, assuming all predecessors have been completed
- Earliest finish (EF) = earliest time at which an activity can be finished
- Latest start (LS) = latest time at which an activity can start so as to not delay the completion time of the entire project
- Latest finish (LF) = latest time by which an activity has to be finished so as to not delay the completion time of the entire project

Determining the Project Schedule

Perform a Critical Path Analysis



Forward Pass

Begin at starting event and work forward

Earliest Start Time Rule:

- ☑ If an activity has only a single immediate predecessor, its ES equals the EF of the predecessor
- ☑ If an activity has multiple immediate predecessors, its ES is the maximum of all the EF values of its predecessors

$$ES = \text{Max} \{EF \text{ of all immediate predecessors}\}$$

Forward Pass

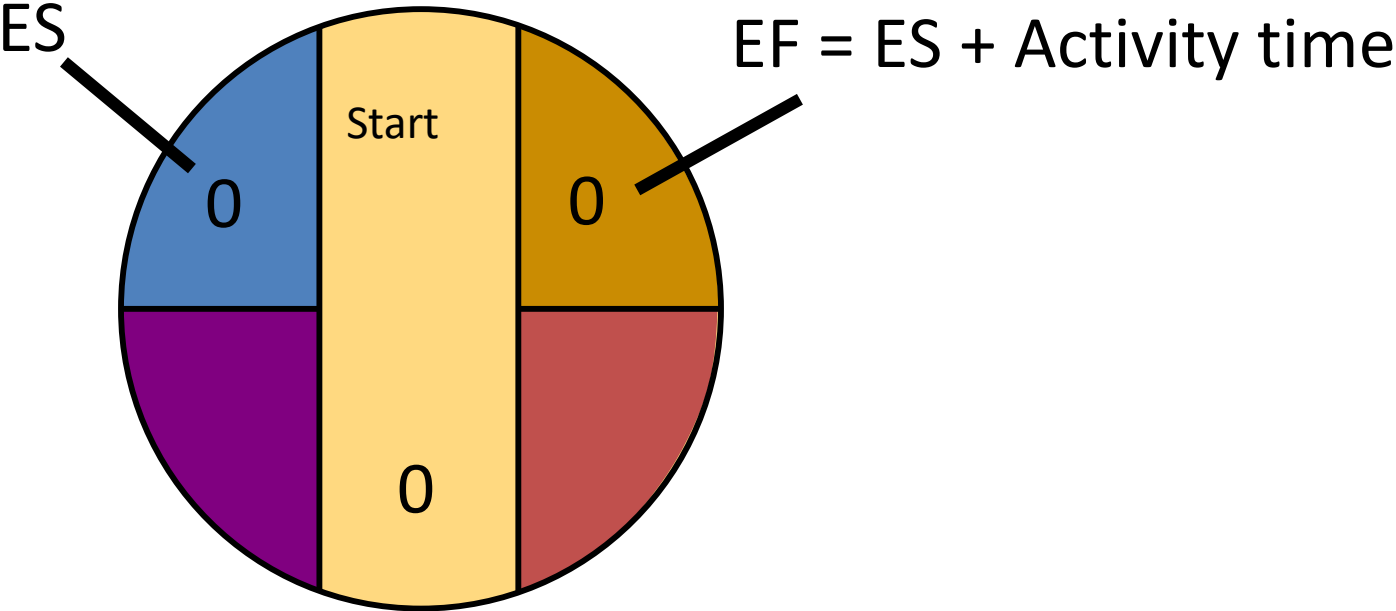
Begin at starting event and work forward

Earliest Finish Time Rule:

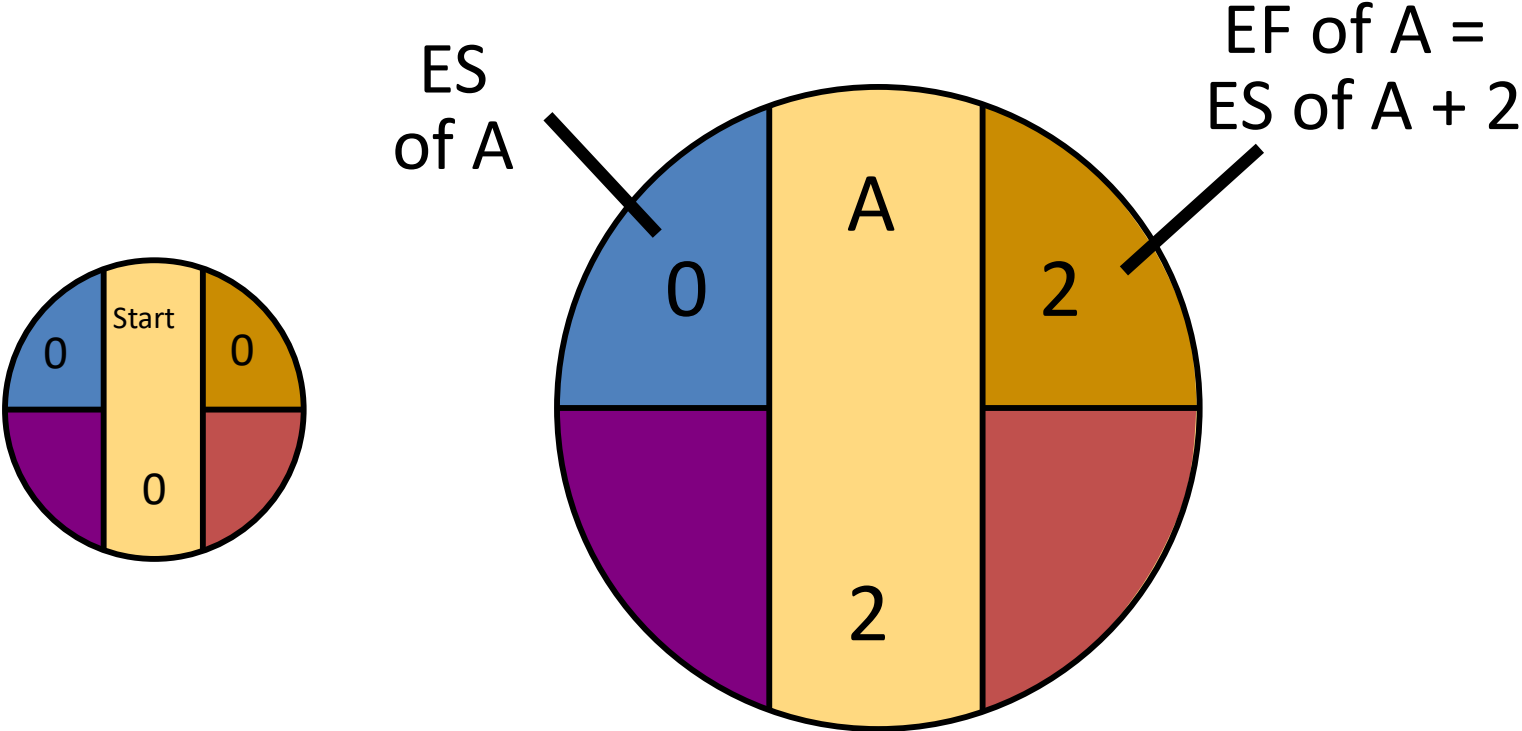
- ☑ The earliest finish time (EF) of an activity is the sum of its earliest start time (ES) and its activity time

$$EF = ES + \text{Activity time}$$

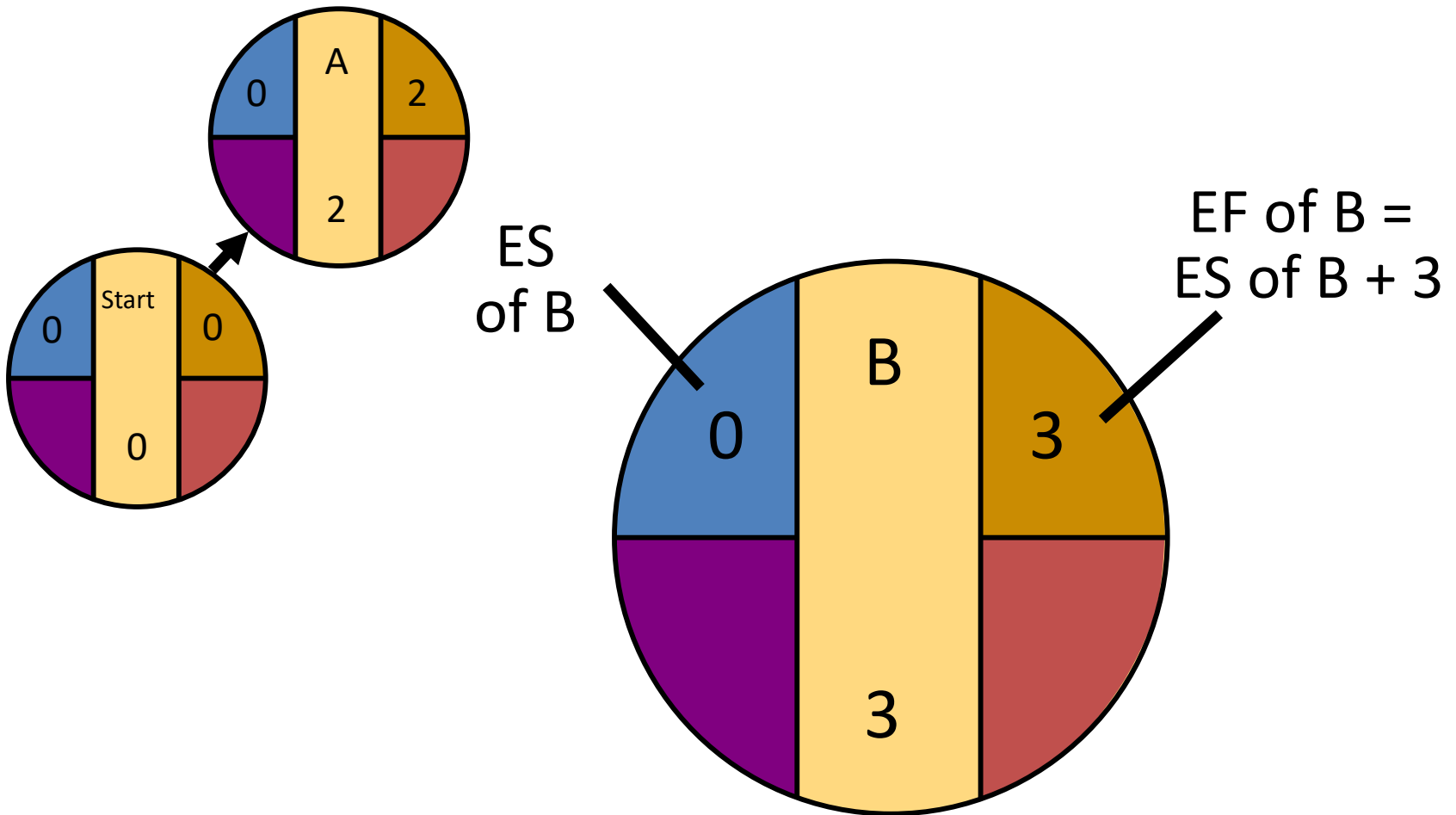
ES/EF Network for Milwaukee Paper



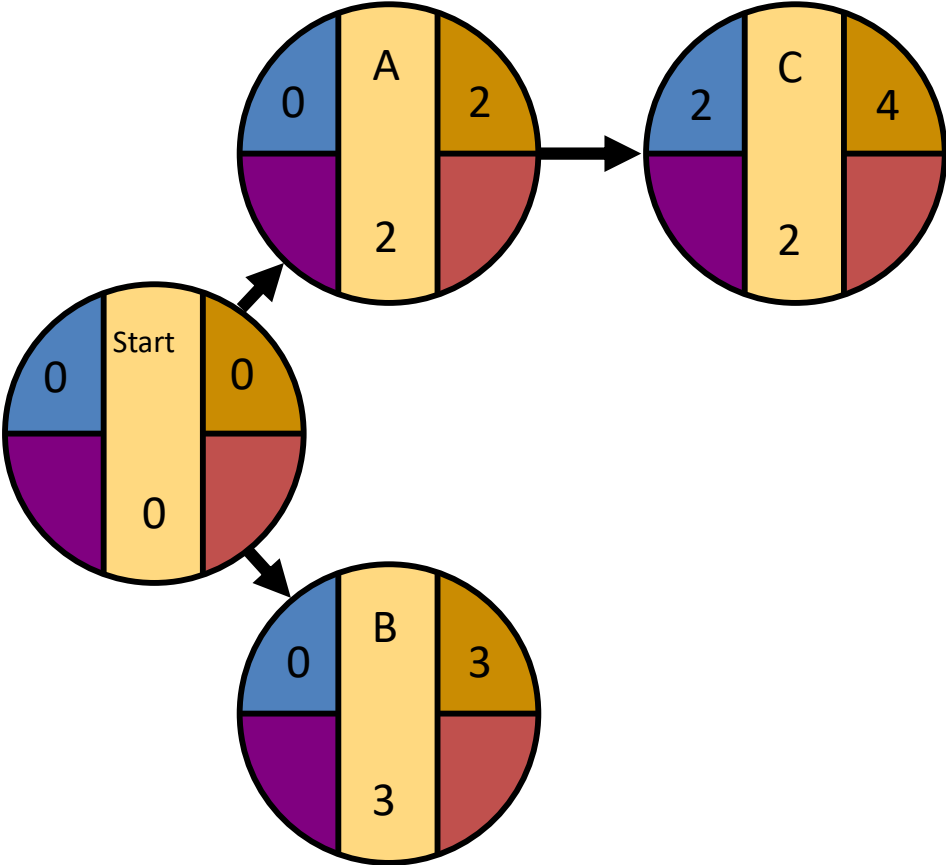
ES/EF Network for Milwaukee Paper



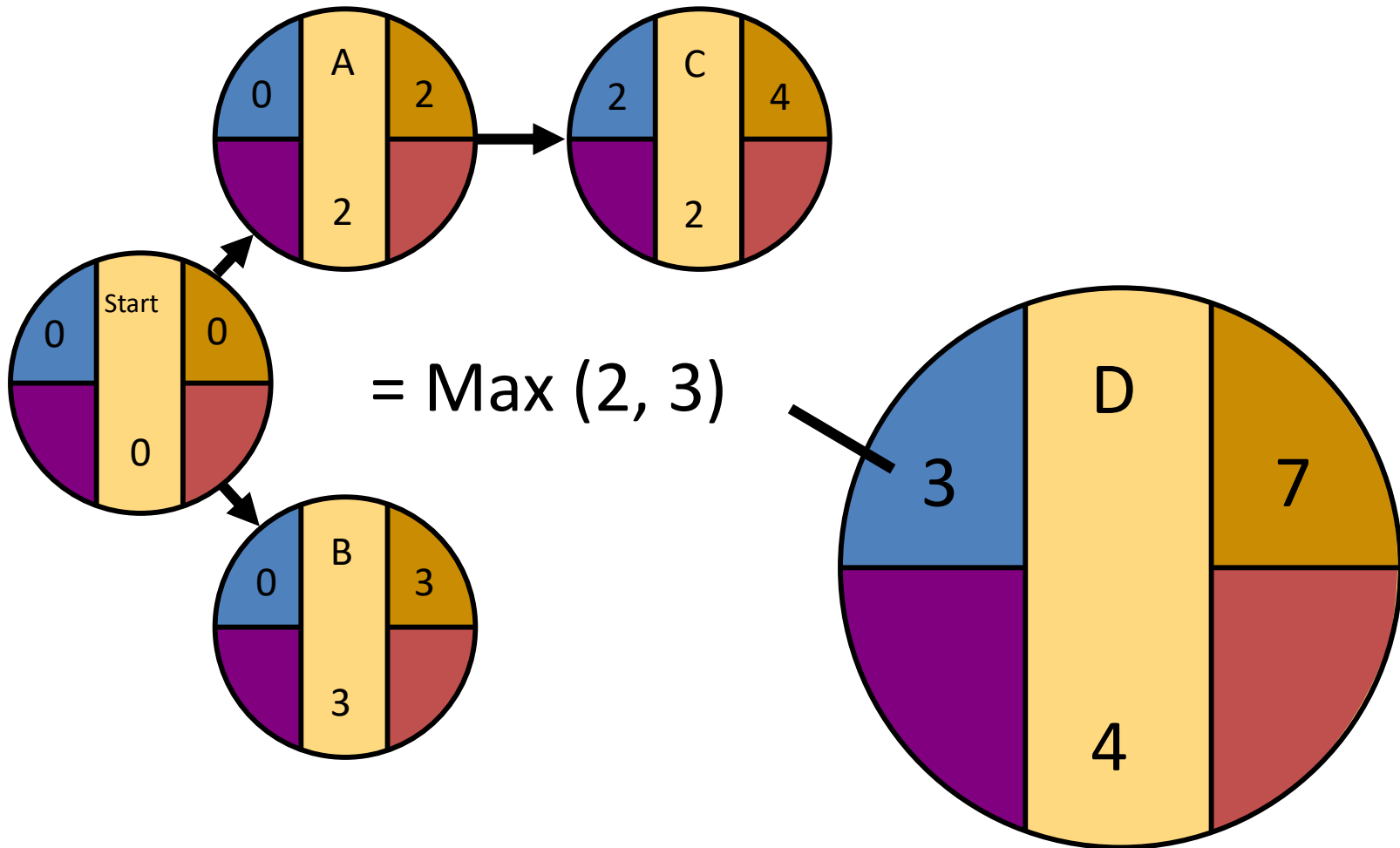
ES/EF Network for Milwaukee Paper



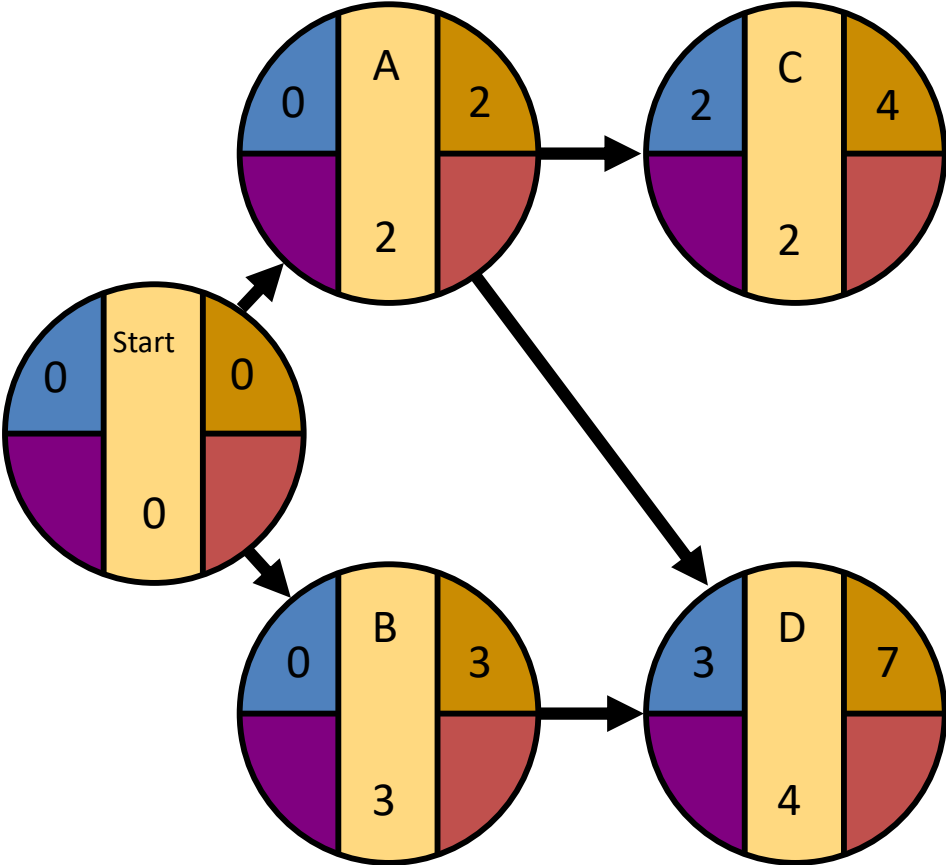
ES/EF Network for Milwaukee Paper



ES/EF Network for Milwaukee Paper



ES/EF Network for Milwaukee Paper



ES/EF Network for Milwaukee Paper

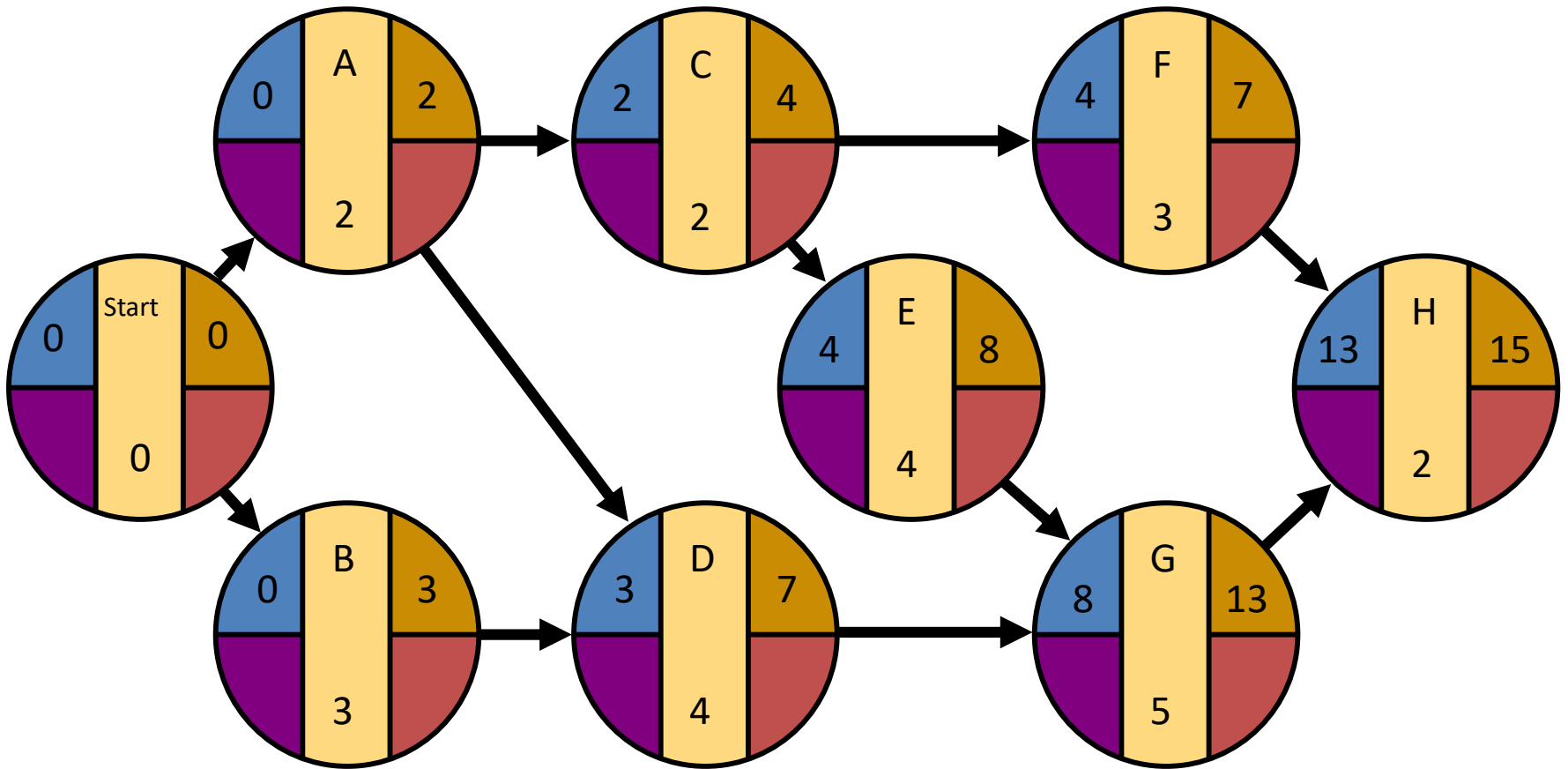


Figure 3.11

Backward Pass

Begin with the last event and work backwards

Latest Finish Time Rule:

- ☑ If an activity is an immediate predecessor for just a single activity, its LF equals the LS of the activity that immediately follows it
- ☑ If an activity is an immediate predecessor to more than one activity, its LF is the minimum of all LS values of all activities that immediately follow it

$LF = \text{Min} \{LS \text{ of all immediate following activities}\}$

Backward Pass

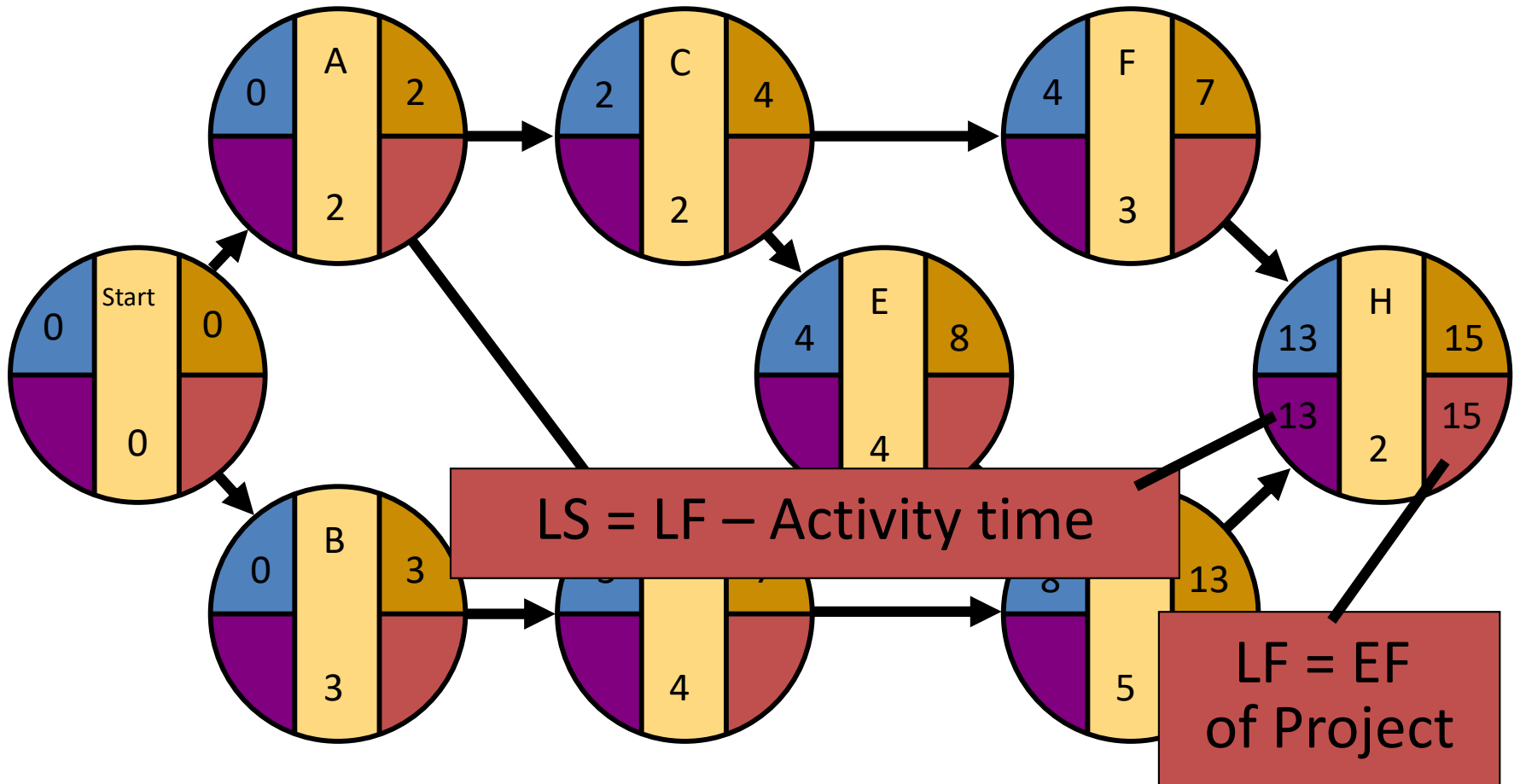
Begin with the last event and work backwards

Latest Start Time Rule:

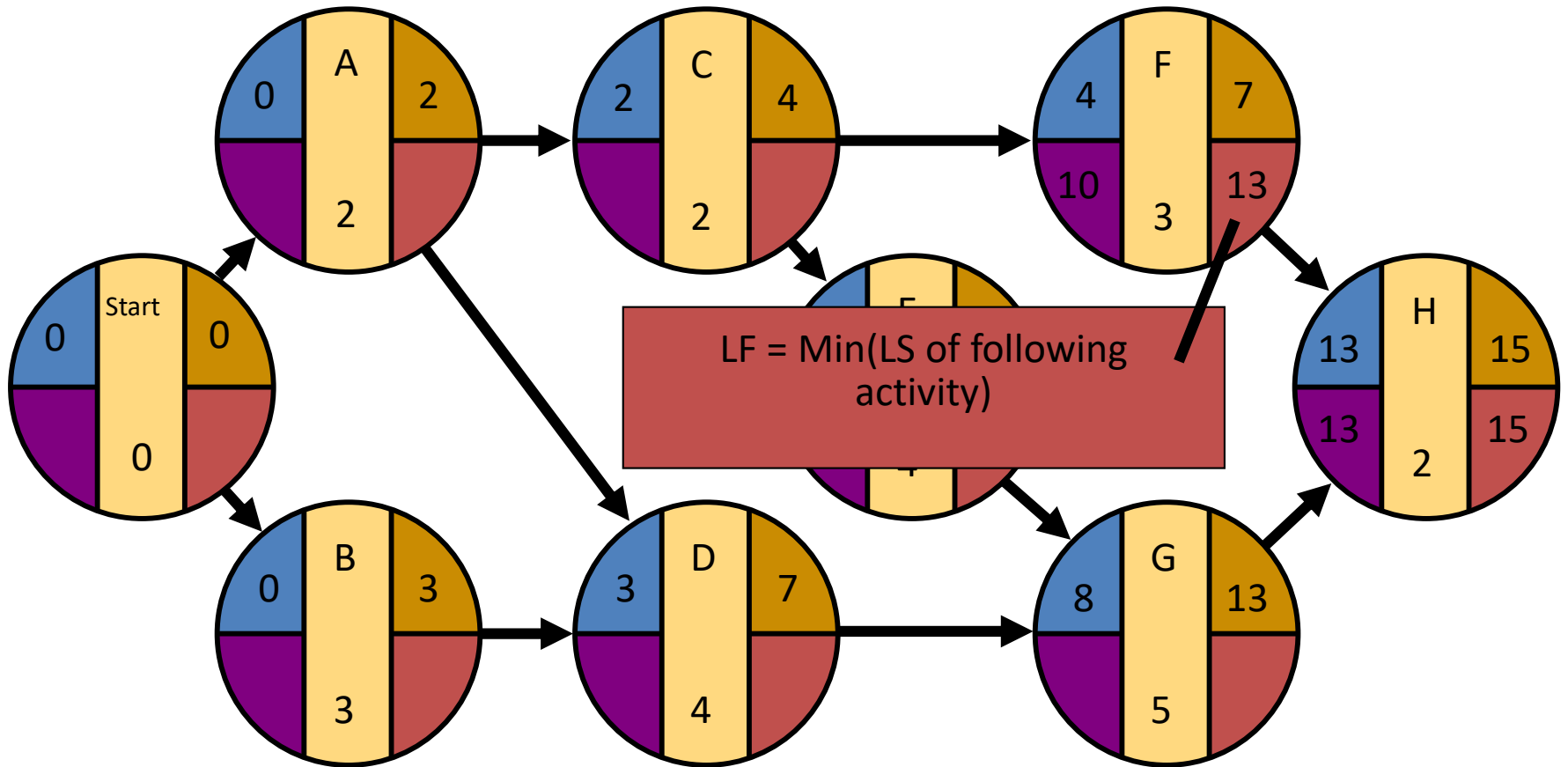
- ☑ The latest start time (LS) of an activity is the difference of its latest finish time (LF) and its activity time

$$LS = LF - \text{Activity time}$$

LS/LF Times for Milwaukee Paper

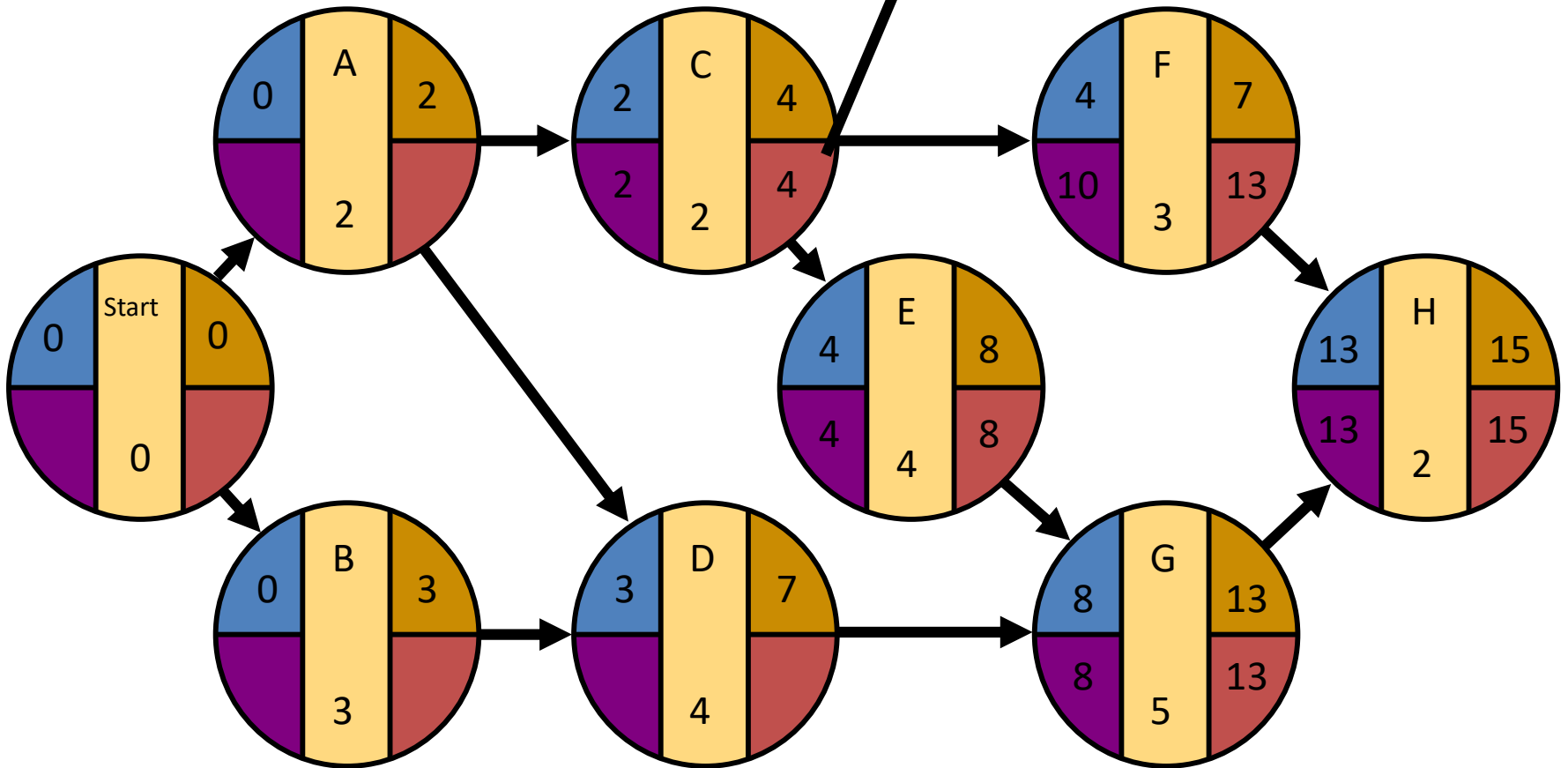


LS/LF Times for Milwaukee Paper

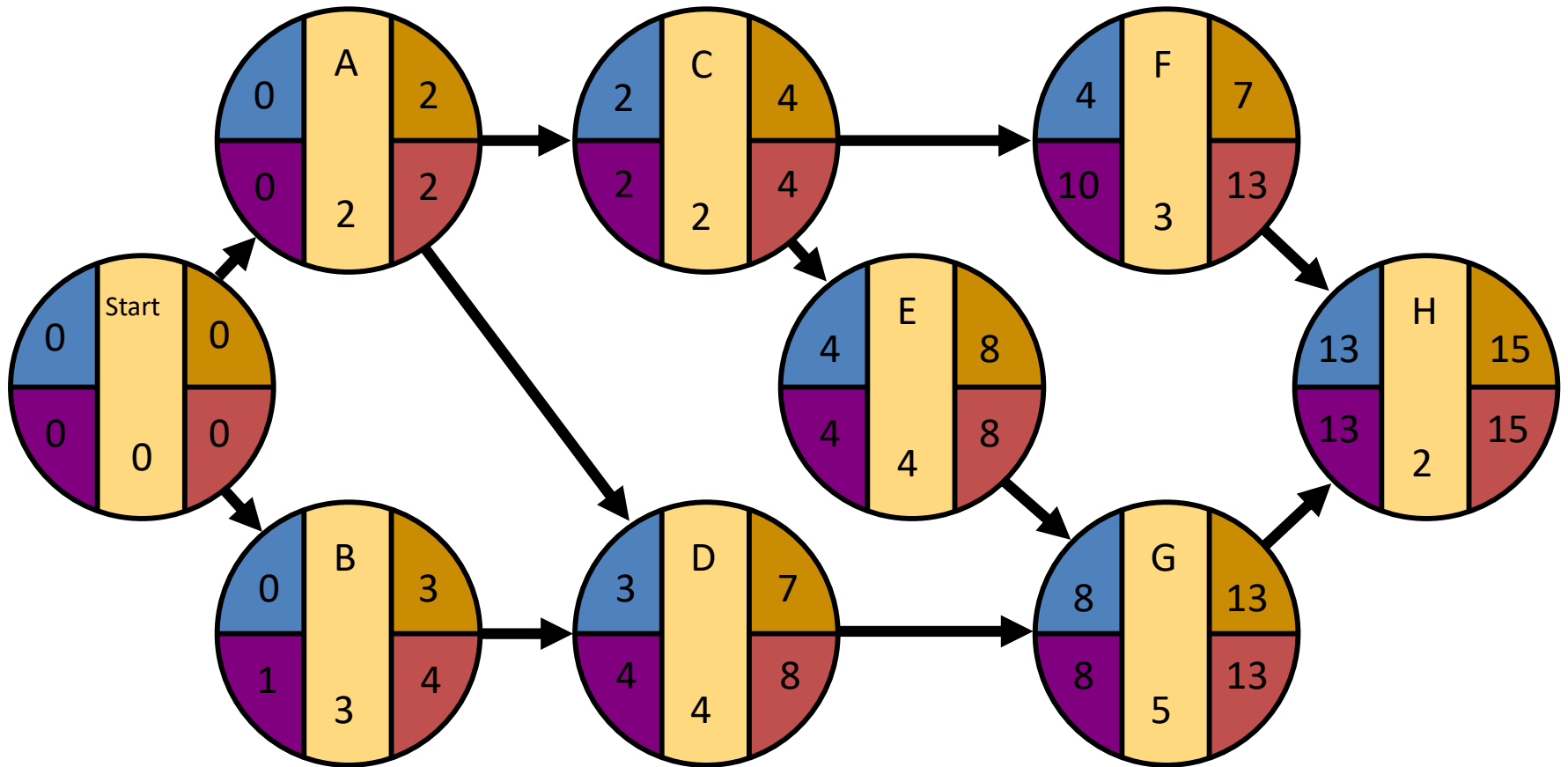


LS/LF Times for

M $LF = \text{Min}(4, 10)$



LS/LF Times for Milwaukee Paper



Computing Slack Time

After computing the ES, EF, LS, and LF times for all activities, compute the slack or free time for each activity

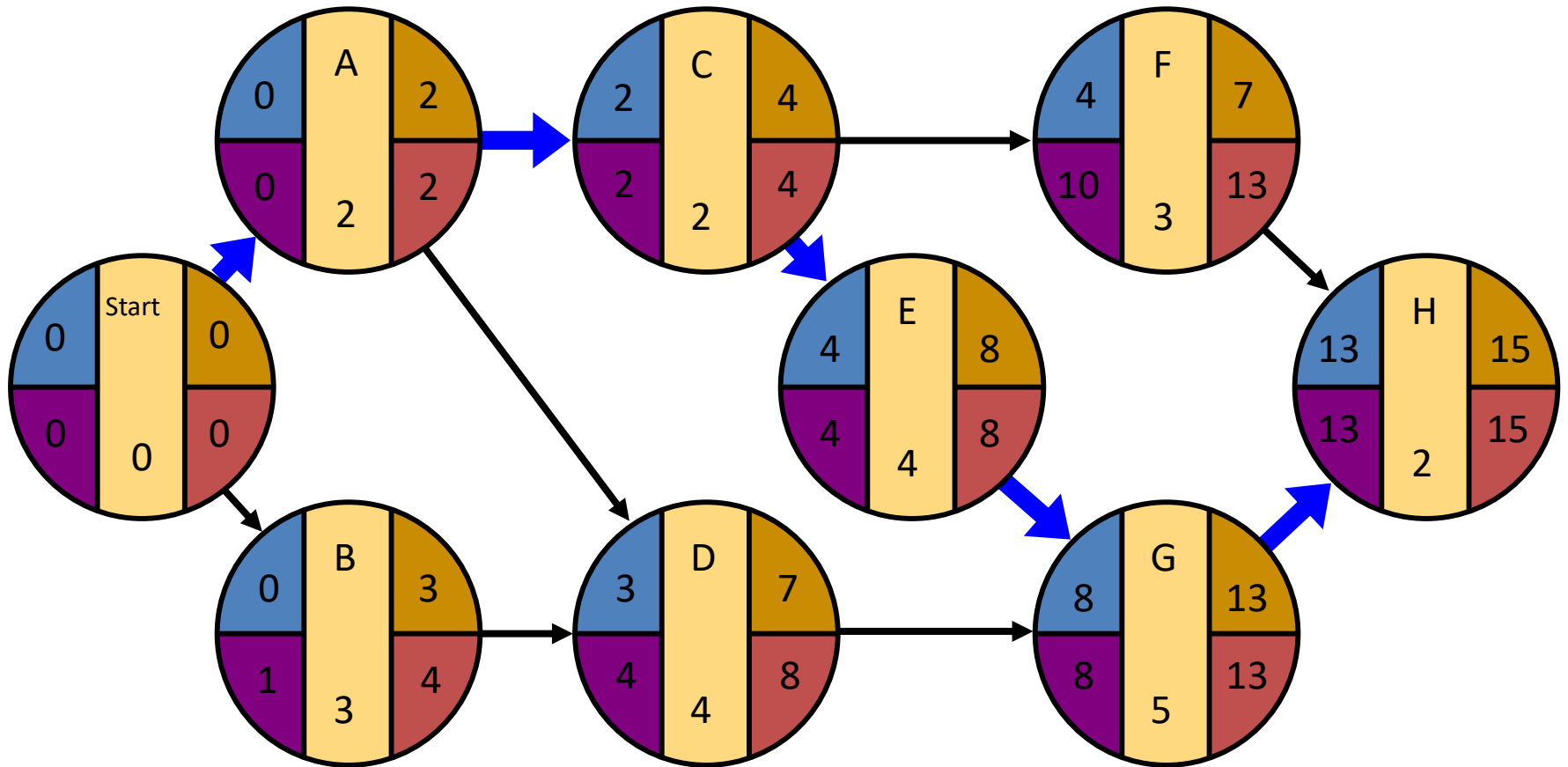
- ☑ Slack is the length of time an activity can be delayed without delaying the entire project

$$\text{Slack} = \text{LS} - \text{ES} \quad \text{or} \quad \text{Slack} = \text{LF} - \text{EF}$$

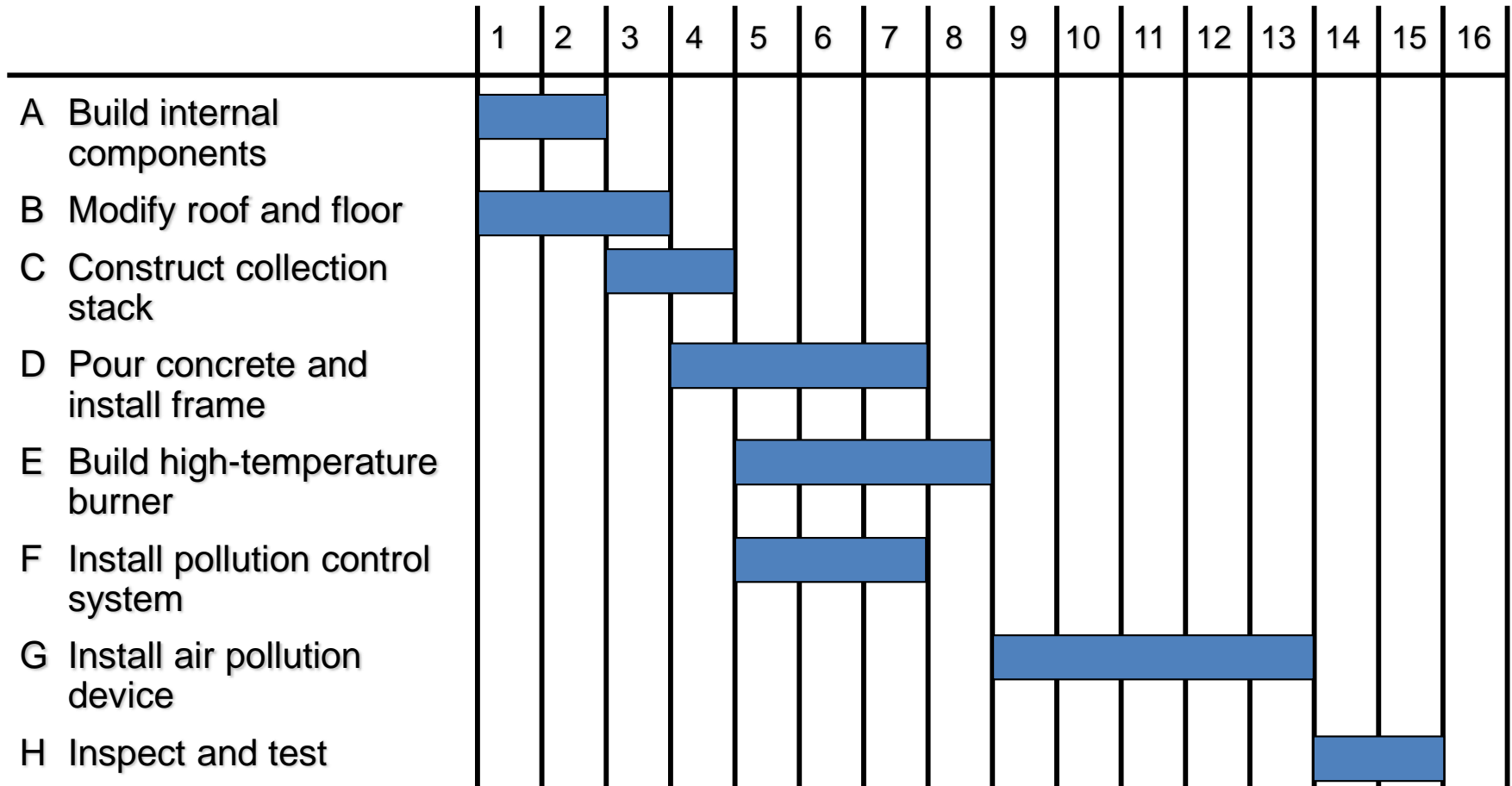
Computing Slack Time

Activity	Earliest Start ES	Earliest Finish EF	Latest Start LS	Latest Finish LF	Slack LS – ES	On Critical Path
A	0	2	0	2	0	Yes
B	0	3	1	4	1	No
C	2	4	2	4	0	Yes
D	3	7	4	8	1	No
E	4	8	4	8	0	Yes
F	4	7	10	13	6	No
G	8	13	8	13	0	Yes
H	13	15	13	15	0	Yes

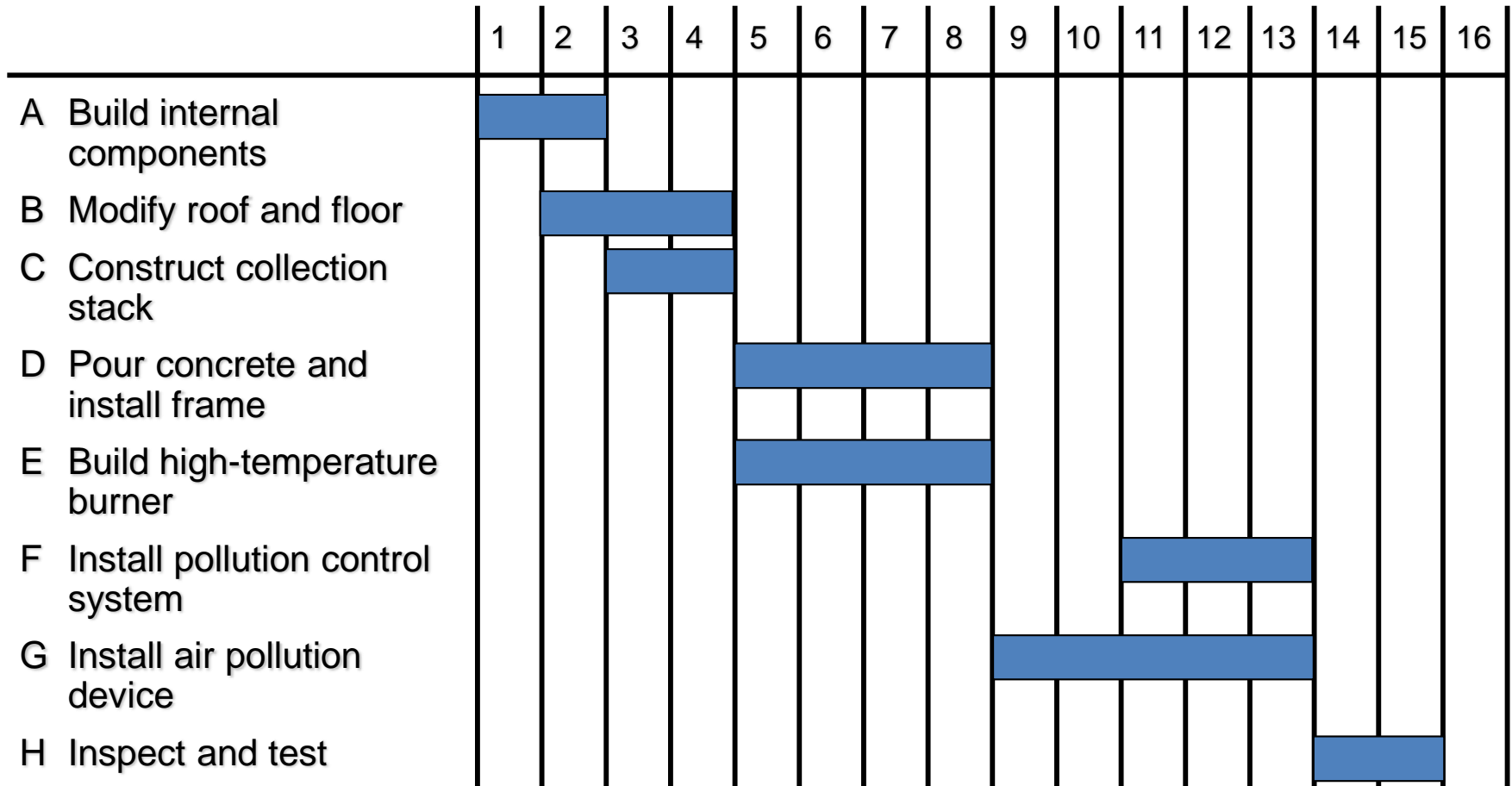
Critical Path for Milwaukee Paper



ES – EF Gantt Chart for Milwaukee Paper



LS – LF Gantt Chart for Milwaukee Paper



Variability in Activity Times

- CPM assumes we know a fixed time estimate for each activity and there is no variability in activity times
- PERT uses a probability distribution for activity times to allow for variability

Variability in Activity Times

- Three time estimates are required
 - Optimistic time (a)
 - if everything goes according to plan
 - Pessimistic time (b)
 - assuming very unfavorable conditions
 - Most likely time (m)
 - most realistic estimate

Variability in Activity Times

- Estimate follows beta distribution

Expected time:

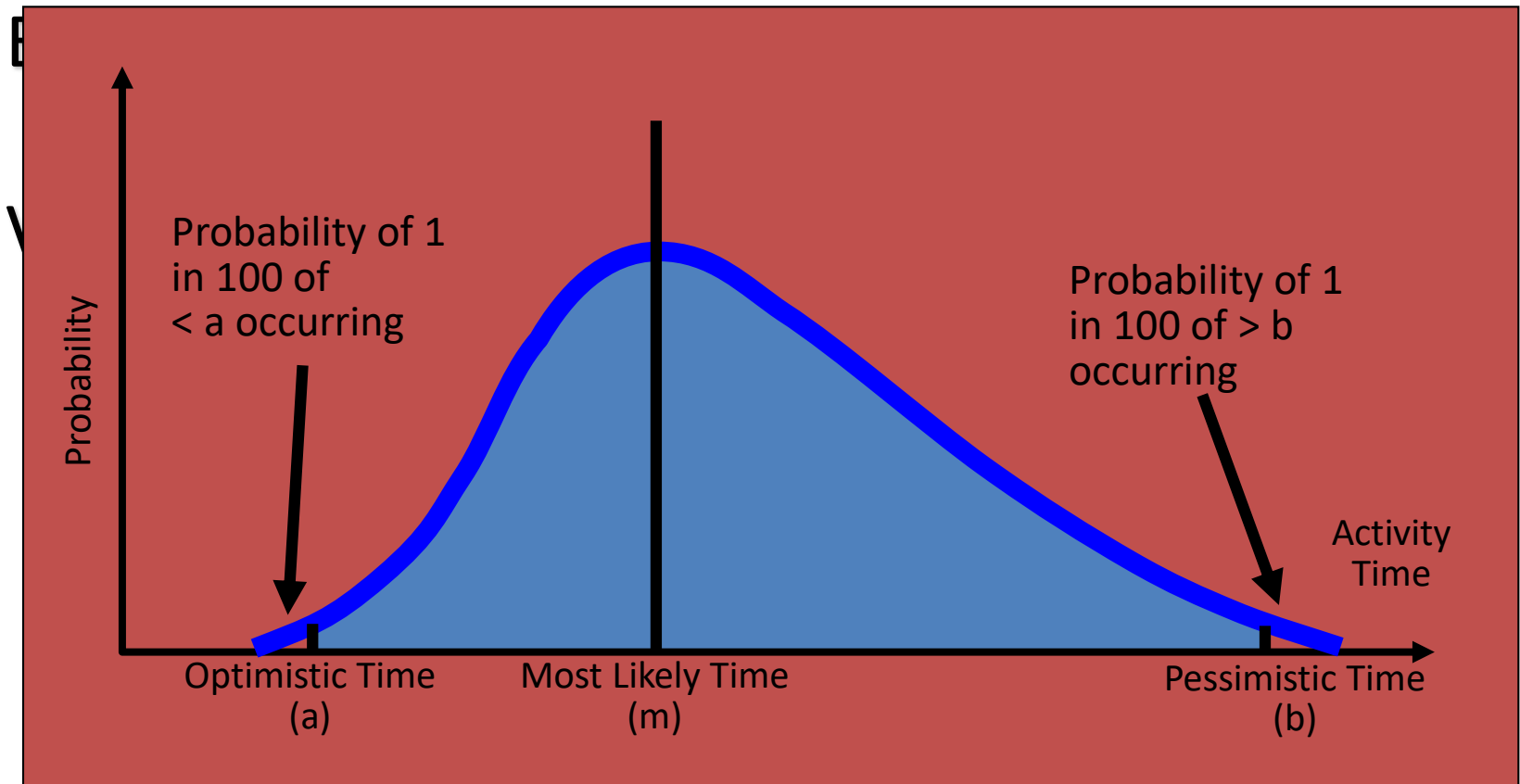
$$t = (a + 4m + b)/6$$

Variance of times:

$$v = [(b - a)/6]^2$$

Variability in Activity Times

- Estimate follows beta distribution



Computing Variance

Activity	Optimistic a	Most Likely m	Pessimistic b	Expected Time $t = (a + 4m + b)/6$	Variance $[(b - a)/6]^2$
A	1	2	3	2	.11
B	2	3	4	3	.11
C	1	2	3	2	.11
D	2	4	6	4	.44
E	1	4	7	4	1.00
F	1	2	9	3	1.78
G	3	4	11	5	1.78
H	1	2	3	2	.11

Table 3.4

Trade-Offs And Project Crashing

It is not uncommon to face the following situations:

- The project is behind schedule
- The completion time has been moved forward

Shortening the duration of the project is called project crashing

Factors to Consider When Crashing A Project

- The amount by which an activity is crashed is, in fact, permissible
- Taken together, the shortened activity durations will enable us to finish the project by the due date
- The total cost of crashing is as small as possible

Steps in Project Crashing

1. Compute the crash cost per time period. If crash costs are linear over time:

$$\text{Crash cost per period} = \frac{(\text{Crash cost} - \text{Normal cost})}{(\text{Normal time} - \text{Crash time})}$$

2. Using current activity times, find the critical path and identify the critical activities

Steps in Project Crashing

- If there is only one critical path, then select the activity on this critical path that (a) can still be crashed, and (b) has the smallest crash cost per period. If there is more than one critical path, then select one activity from each critical path such that (a) each selected activity can still be crashed, and (b) the total crash cost of all selected activities is the smallest. Note that the same activity may be common to more than one critical path.

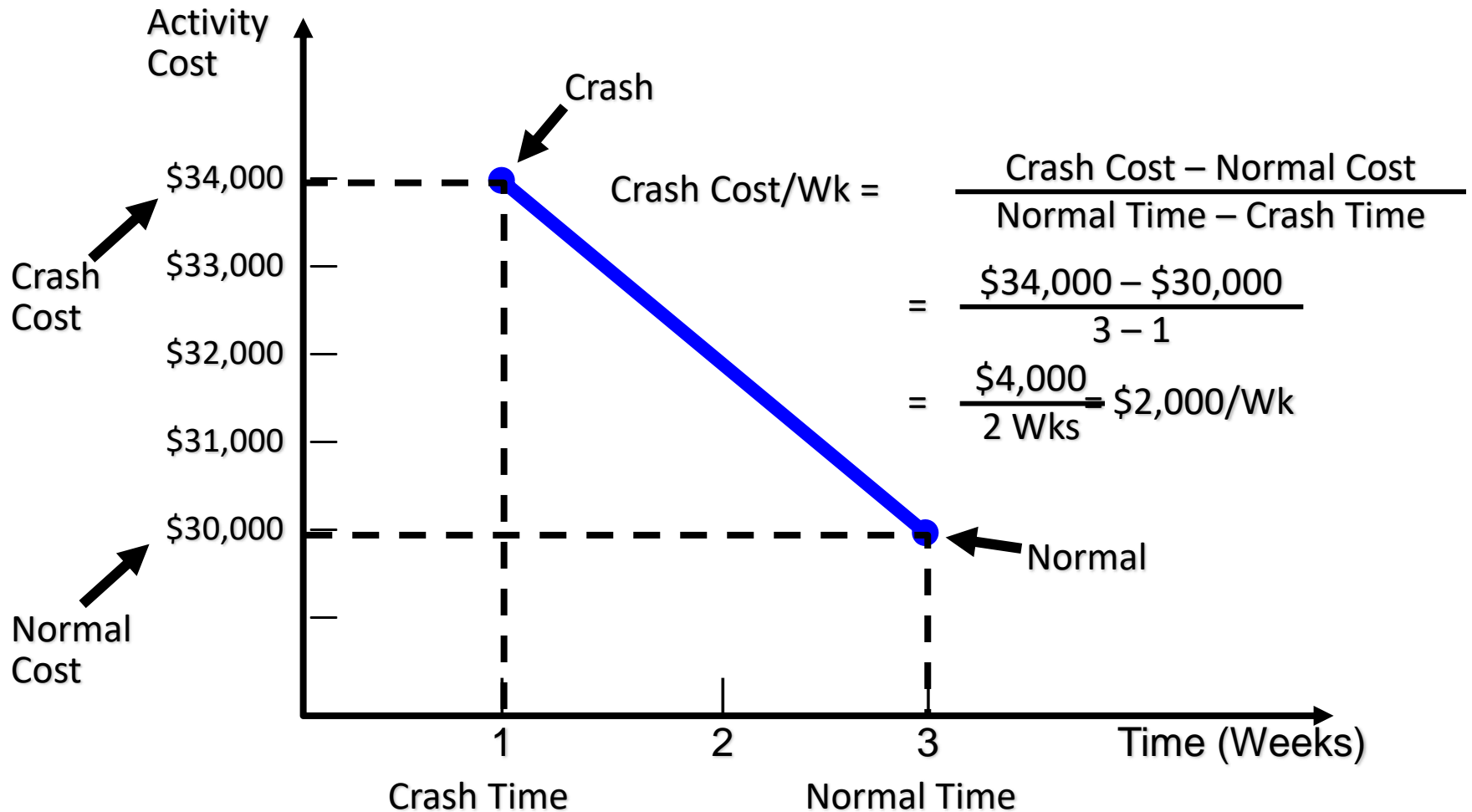
Steps in Project Crashing

- Update all activity times. If the desired due date has been reached, stop. If not, return to Step 2.

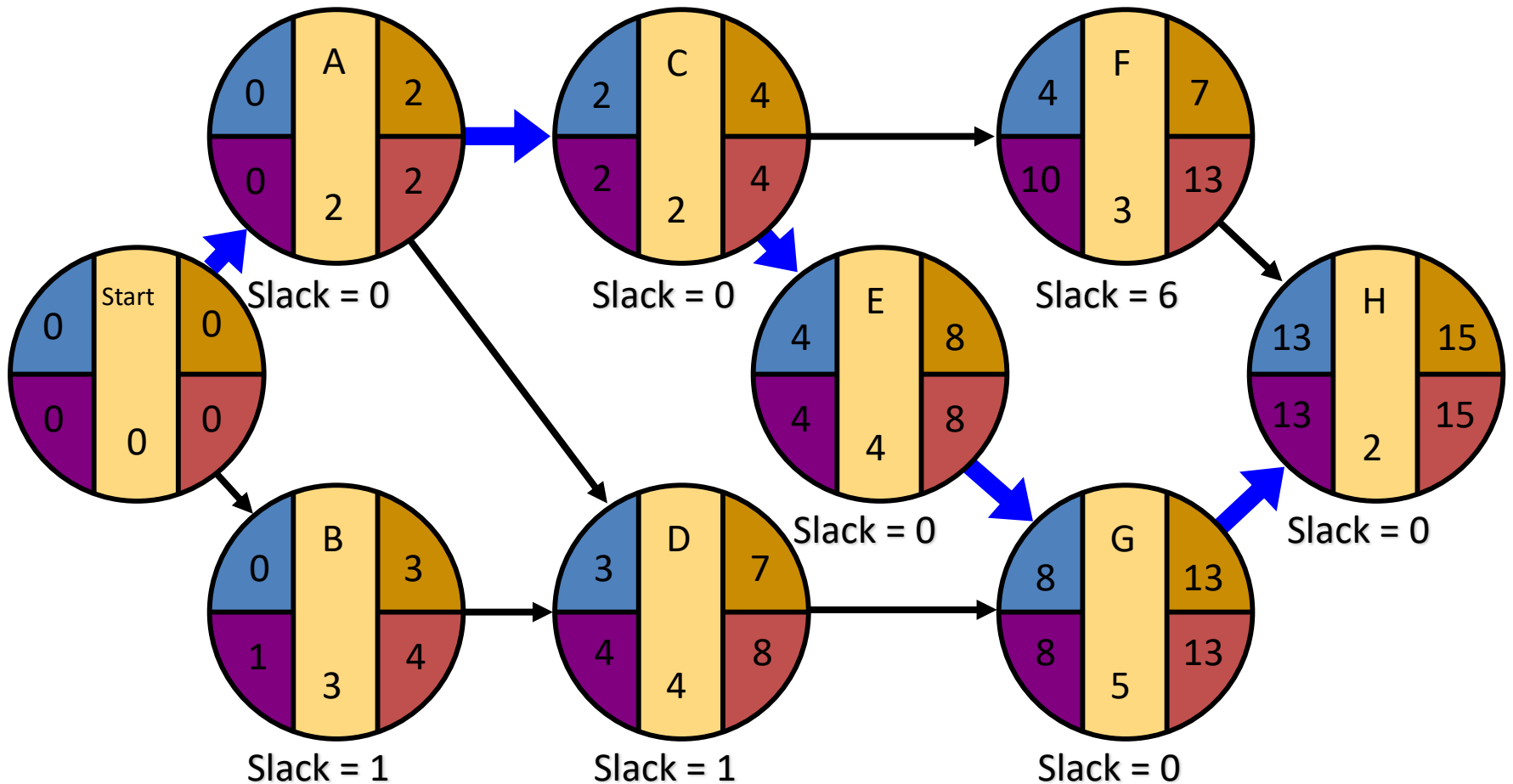
Crashing The Project

Activity	Time (Wks)		Cost (\$)		Crash Cost Per Wk (\$)	Critical Path?
	Normal	Crash	Normal	Crash		
A	2	1	22,000	22,750	750	Yes
B	3	1	30,000	34,000	2,000	No
C	2	1	26,000	27,000	1,000	Yes
D	4	2	48,000	49,000	1,000	No
E	4	2	56,000	58,000	1,000	Yes
F	3	2	30,000	30,500	500	No
G	5	2	80,000	84,500	1,500	Yes
H	2	1	16,000	19,000	3,000	Yes

Crash and Normal Times and Costs for Activity B



Critical Path And Slack Times For Milwaukee Paper



Advantages of PERT/CPM

- Especially useful when scheduling and controlling large projects
- Straightforward concept and not mathematically complex
- Graphical networks help highlight relationships among project activities
- Critical path and slack time analyses help pinpoint activities that need to be closely watched

Advantages of PERT/CPM

- Project documentation and graphics point out who is responsible for various activities
- Applicable to a wide variety of projects
- Useful in monitoring not only schedules but costs as well

Limitations of PERT/CPM

- Project activities have to be clearly defined, independent, and stable in their relationships
- Precedence relationships must be specified and networked together
- Time estimates tend to be subjective and are subject to fudging by managers
- There is an inherent danger of too much emphasis being placed on the longest, or critical, path

EXERCISE

12.12

Sid Davidson is the personnel director of Babson and Willcount, a company that specializes in consulting and research. One of the training programs that Sid is considering for the middle-level managers of Babson and Willcount is leadership training. Sid has listed a number of activities that must be completed before a training program of this nature could be conducted. The activities and immediate predecessors appear in the following table:

12.12

ACTIVITY	IMMEDIATE PREDECESSORS	TIME (DAYS)
A	--	2
B	--	5
C	--	1
D	B	10
E	A, D	3
F	C	6
G	E, F	8

12.12

- a. Develop a network for this problem?
- b. Determine the total project completion time and the critical path?

12.16

Monohan Machinery specializes in developing weed-harvesting equipment that is used to clear small lakes of weeds. George Monohan, president of Monohan Machinery, is convinced that harvesting weeds is far better than using chemicals to kill weeds. Chemicals cause pollution, and the weeds seem to grow faster after chemicals have been used. George is contemplating the construction of a machine that would harvest weeds on narrow rivers and waterways. The activities that are necessary to build one of these experimental weed-harvesting machines are listed in the following table. Construct a network for these activities.

12.16

ACTIVITIES	IMMEDIATE PREDECESSORS	TIME (WEEKS)
A	--	6
B	--	5
C	A	3
D	A	2
E	B	4
F	B	6
G	C, E	10
H	D, F	7

12.30

The Scott Corey accounting firm is installing a new computer system. Several things must be done to make sure the system works properly before all the accounts are put into the new system. The following table provides information about this project. How long will it take to install the system? What is the critical path?

2

ACTIVITY	IMMEDIATE PREDECESSOR	TIME (WEEKS)
A	--	3
B	--	4
C	A	6
D	B	2
E	A	5
F	C	2
G	D,E	4
H	F,G	5

THANK YOU