School of Business

Department of Management Information Systems

BMIS360: *Operations Management*

Chapter 3 | Part 1

Project Management

Spring 2023 - 2024

Learning Objectives

- Project Management concepts
- PERT & CP
- Project variance of activity times
- Crash a project

Outline

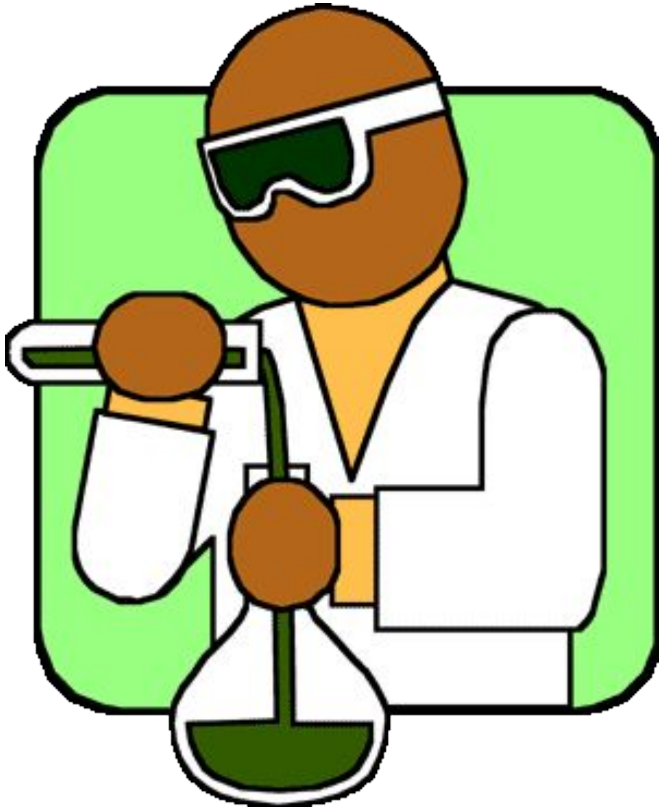
- Create a work breakdown structure
- Draw AON networks
- Complete both forward and backward passes for a project
- Determine a critical path
- Calculate the variance of activity times
- Crash a project

Project Characteristics

- Single unit
- Many related activities
- Difficult production planning and inventory control
- General purpose equipment
- High labor skills

Examples of Projects

- Building Construction



- Research Project

Management of Projects

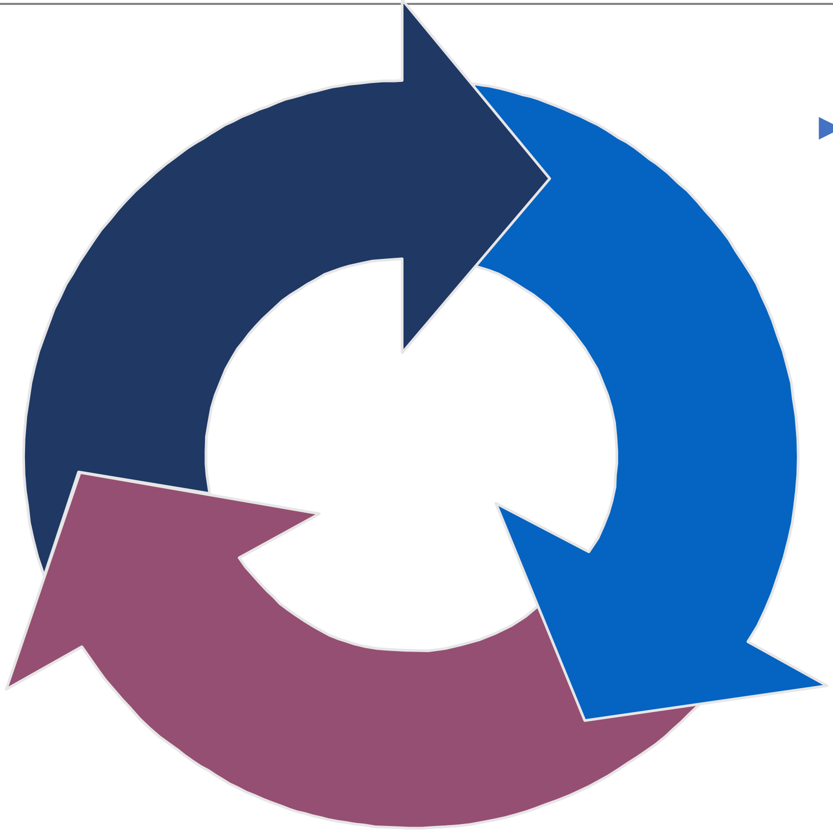
PLANNING - GOAL SETTING, DEFINING THE PROJECT, TEAM ORGANIZATION

SCHEDULING - RELATE PEOPLE, MONEY, AND SUPPLIES TO SPECIFIC ACTIVITIES AND ACTIVITIES TO EACH OTHER

CONTROLLING - MONITOR RESOURCES, COSTS, QUALITY, AND BUDGETS; REVISE PLANS AND SHIFT RESOURCES TO MEET TIME AND COST DEMANDS

Project Management Activities

- ***Planning***
  - Objectives
  - Resources
  - Work break-down structure
  - Organization
- ***Scheduling***
  - Project activities
  - Start & end times
  - Network
- ***Controlling***
  - Monitor, compare, revise, action



Project Planning, Scheduling, and Controlling

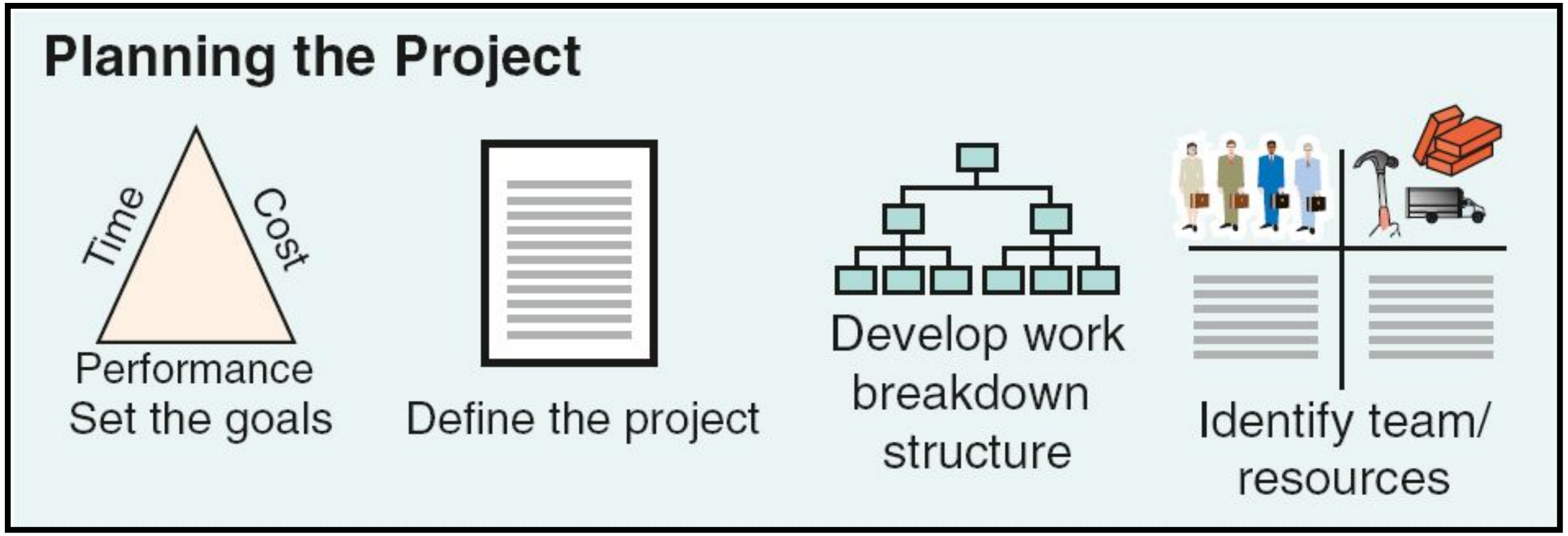


Figure 3.1

Project Planning, Scheduling, and Controlling

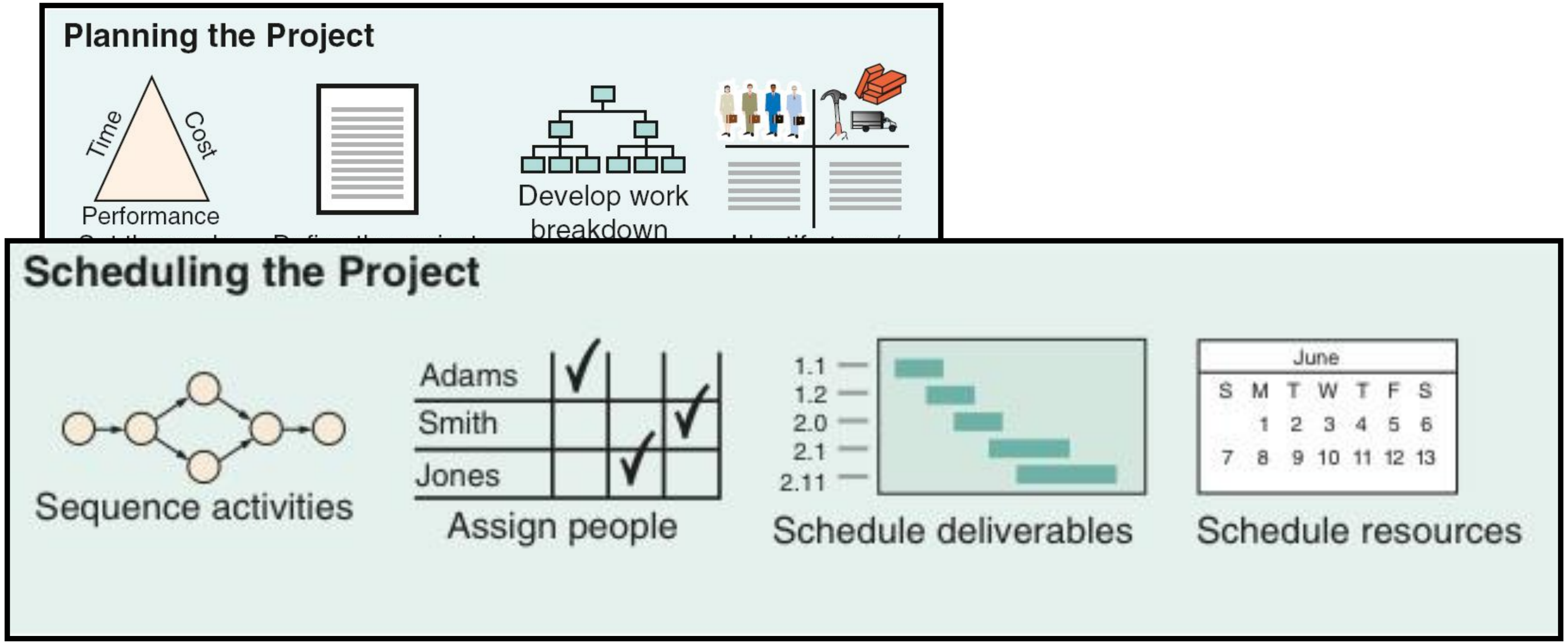


Figure 3.1

Project Planning, Scheduling, and Controlling

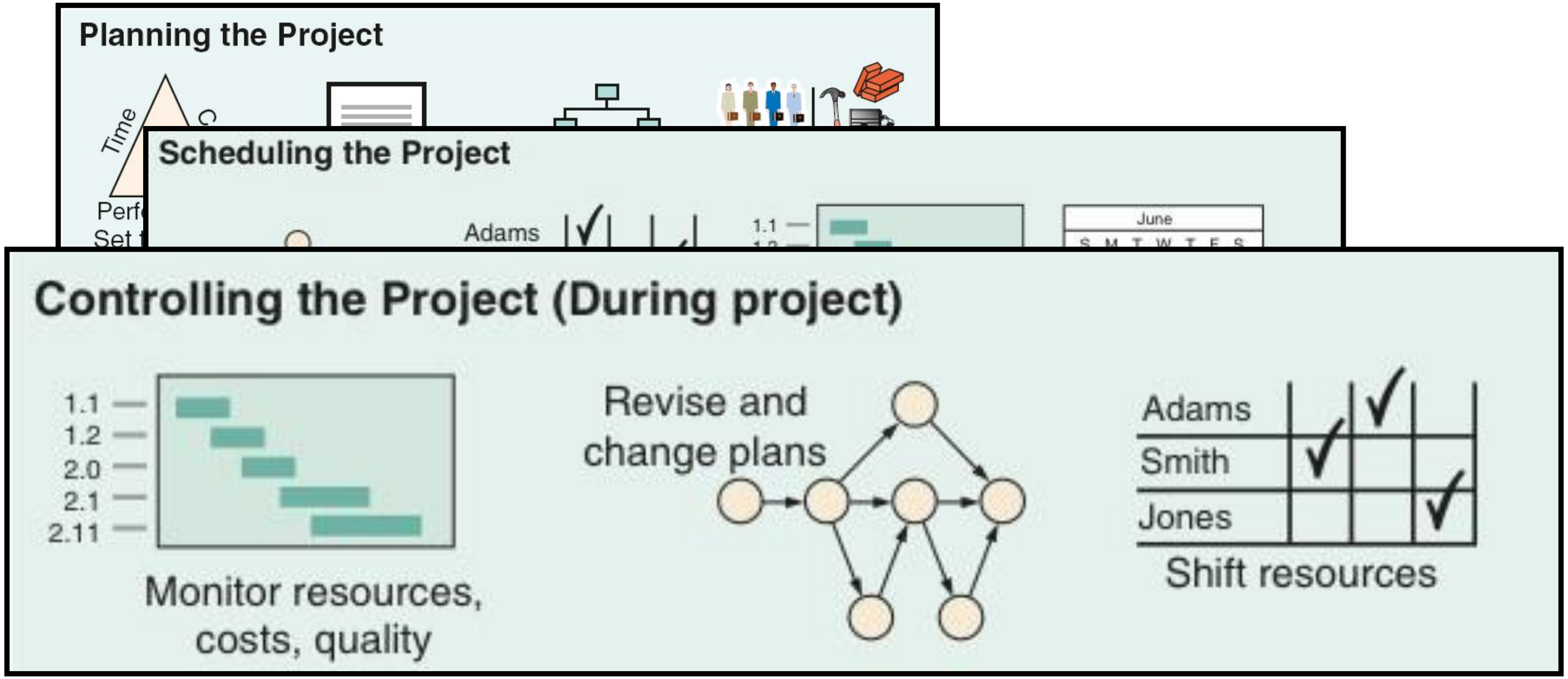


Figure 3.1

Project Planning, Scheduling, and Controlling

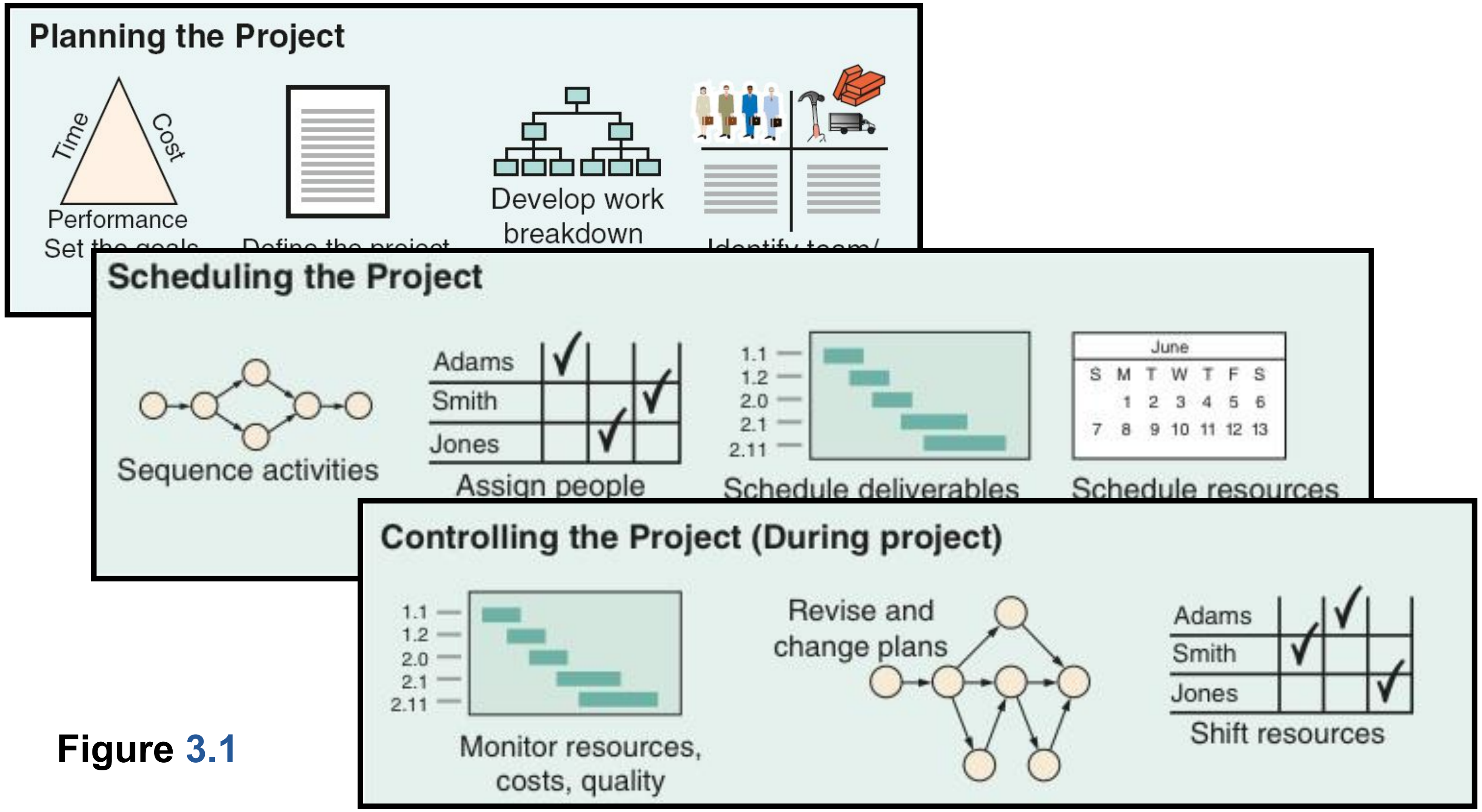
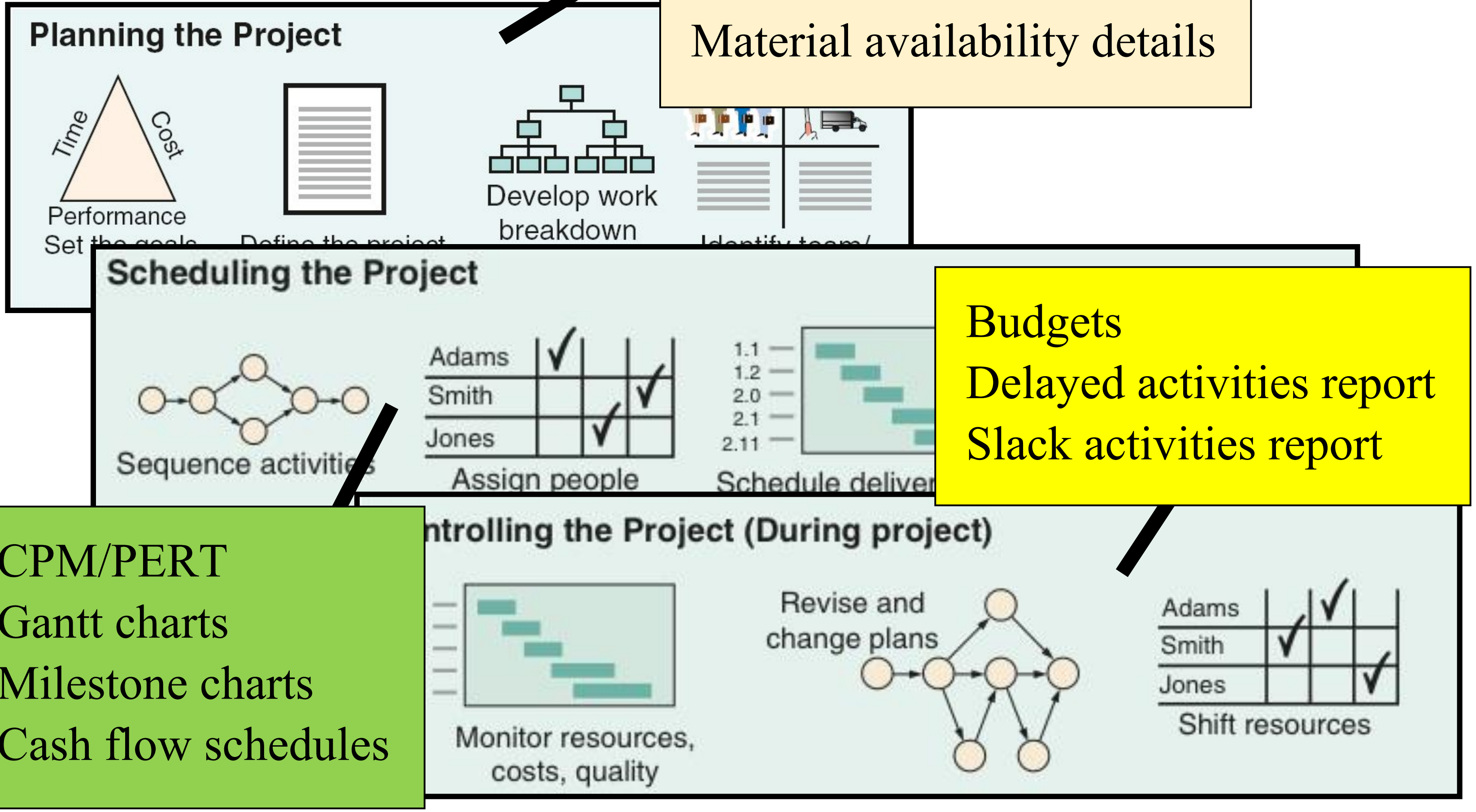


Figure 3.1

Project Planning, Sched olling

Time/cost estimates
Budgets
Engineering diagrams
Cash flow charts
Material availability details



Budgets
Delayed activities report
Slack activities report

CPM/PERT
Gantt charts
Milestone charts
Cash flow schedules

Project Planning

- Establishing objectives
- 01
- Defining project
- 02
- Creating work breakdown structure
- 03
- Determining resources
- 04
- Forming organization
- 05

A Sample Project Organization

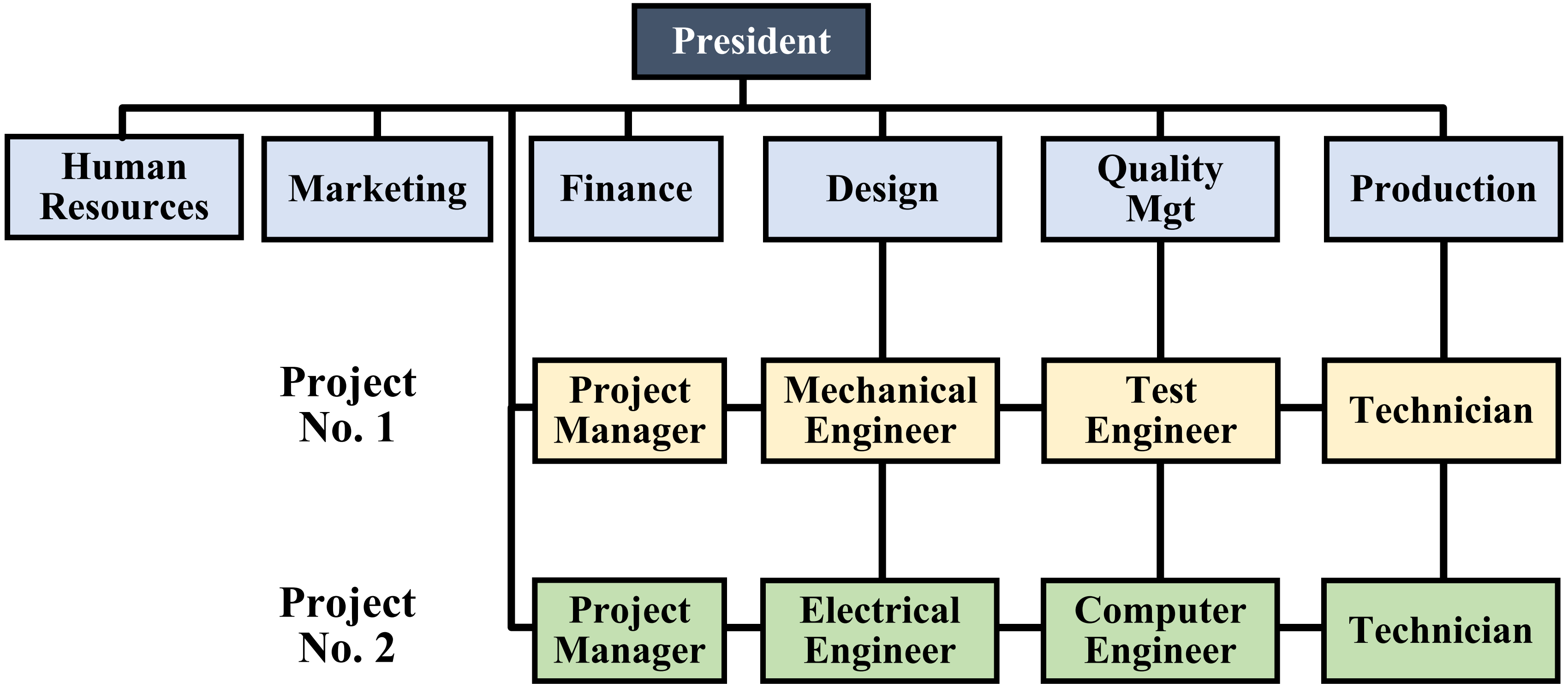


Figure 3.2

The Role of the Project Manager

Project managers should be:

- Good coaches
- Good communicators
- Able to organize activities from a variety of disciplines

Responsible for making sure that:

1. All necessary activities are finished in order and on time
2. The project comes in within budget
3. The project meets quality goals
4. The people assigned to the project receive motivation, direction, and information

Work Breakdown Structure

Level

1. Project
    2. Major tasks in the project
        3. Subtasks in the major tasks
            4. Activities (or "work packages") to be completed

Work Breakdown Structure

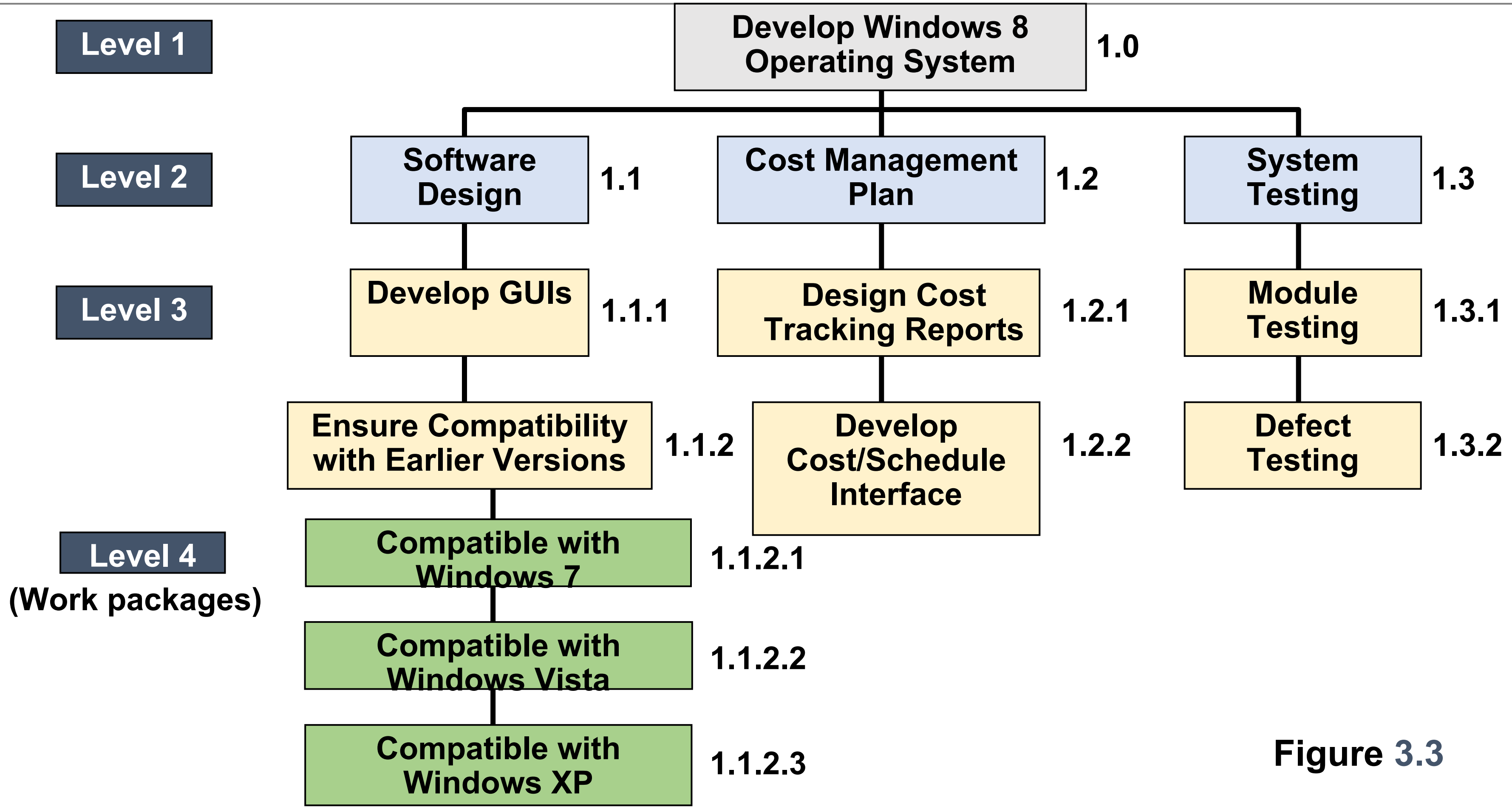


Figure 3.3

Project Scheduling

1. Identifying precedence relationships
2. Sequencing activities
3. Determining activity times & costs
4. Estimating material & worker requirements
5. Determining critical activities

Purpose of Project Scheduling

- Shows the relationship of each activity to others and to the whole project
- Identifies the precedence relationships among activities
- Encourages the setting of realistic time and cost estimates for each activity
- Helps make better use of people, money, and material resources by identifying critical bottlenecks in the project

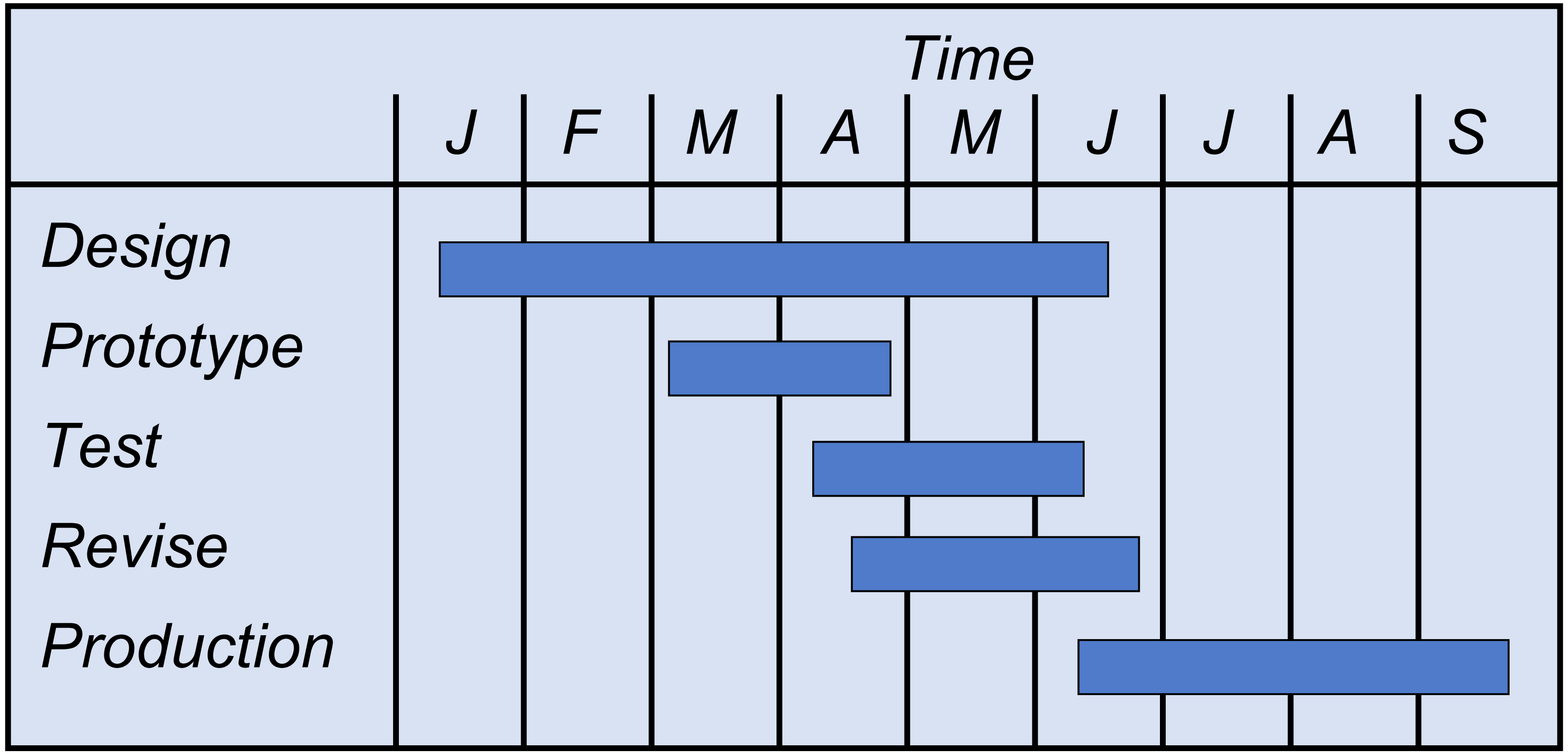
Scheduling Techniques

- ❖Ensure that all activities are planned for
- ❖Their order of performance is accounted for
- ❖The activity time estimates are recorded
- ❖The overall project time is developed

Project Management Techniques

A. Gantt chart
B. Critical Path Method (CPM)
C. Program Evaluation and Review Technique (PERT)

A Sample Gantt Chart



Project Control Report

- Detailed cost breakdowns for each task
- Total program labor curves
- Cost distribution tables
- Functional cost and hour summaries
- Raw materials and expenditure forecasts
- Variance reports
- Time analysis reports
- Work status reports

PERT & 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

Six Steps PERT & CPM

1. Define the project and prepare the work breakdown structure

2. Develop relationships among the activities - decide which activities must precede and which must follow others

3. Draw the network connecting all of the activities

Six Steps PERT & CPM

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

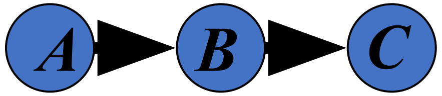
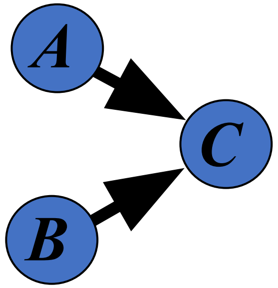
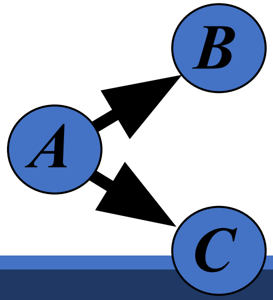
Questions PERT & CPM Can Answer

- *When will the entire project be completed?*
- *What are the critical activities or tasks in the project?*
- *Which are the noncritical activities?*
- *What is the probability the project will be completed by a specific date?*

Questions PERT & CPM Can Answer

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

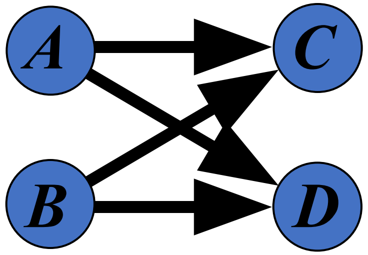
AON Network Conventions

	Activity on Node (AON)	Activity Meaning
(a)		A comes before B, which comes before C
(b)		A and B must both be completed before C can start
(c)		B and C cannot begin until A is completed

AON Network Conventions

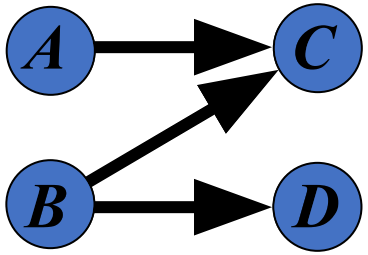
Activity on Node (AON)	*Activity Meaning*

(d)



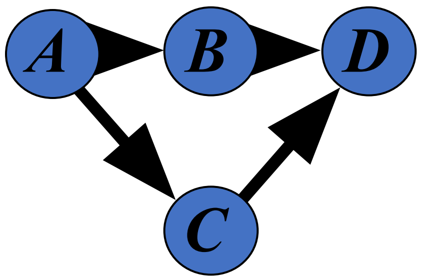
C and D cannot begin until both A and B are completed

(e)



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

AON Network Conventions

Activity on Node (AON)	*Activity Meaning*
(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

Table 3.1	Milwaukee Paper Manufacturing's Activities and Predecessors	
ACTIVITY	DESCRIPTION	IMMEDIATE PREDECESSORS
A	Build internal components	—
B	Modify roof and floor	—
C	Construct collection stack	A
D	Pour concrete and install frame	A, B
E	Build high-temperature burner	C
F	Install pollution control system	C
G	Install air pollution device	D, E
H	Inspect and test	F, G

AON Network for Milwaukee Paper

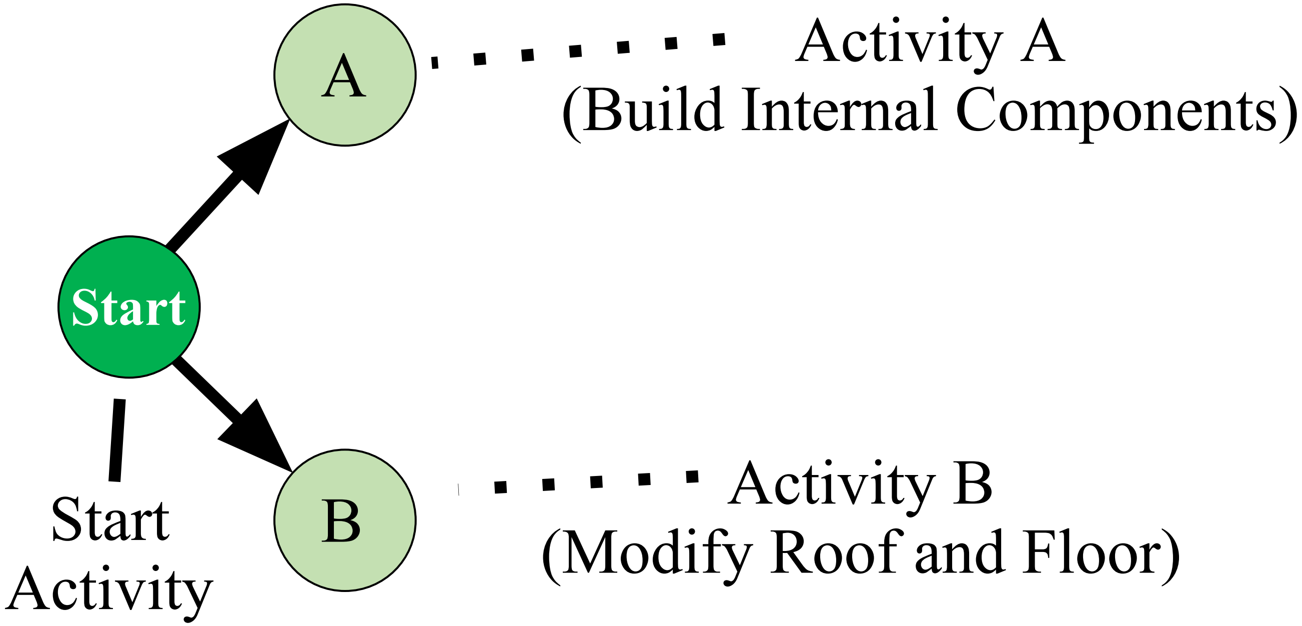


Figure 3.5

AON Network for Milwaukee Paper

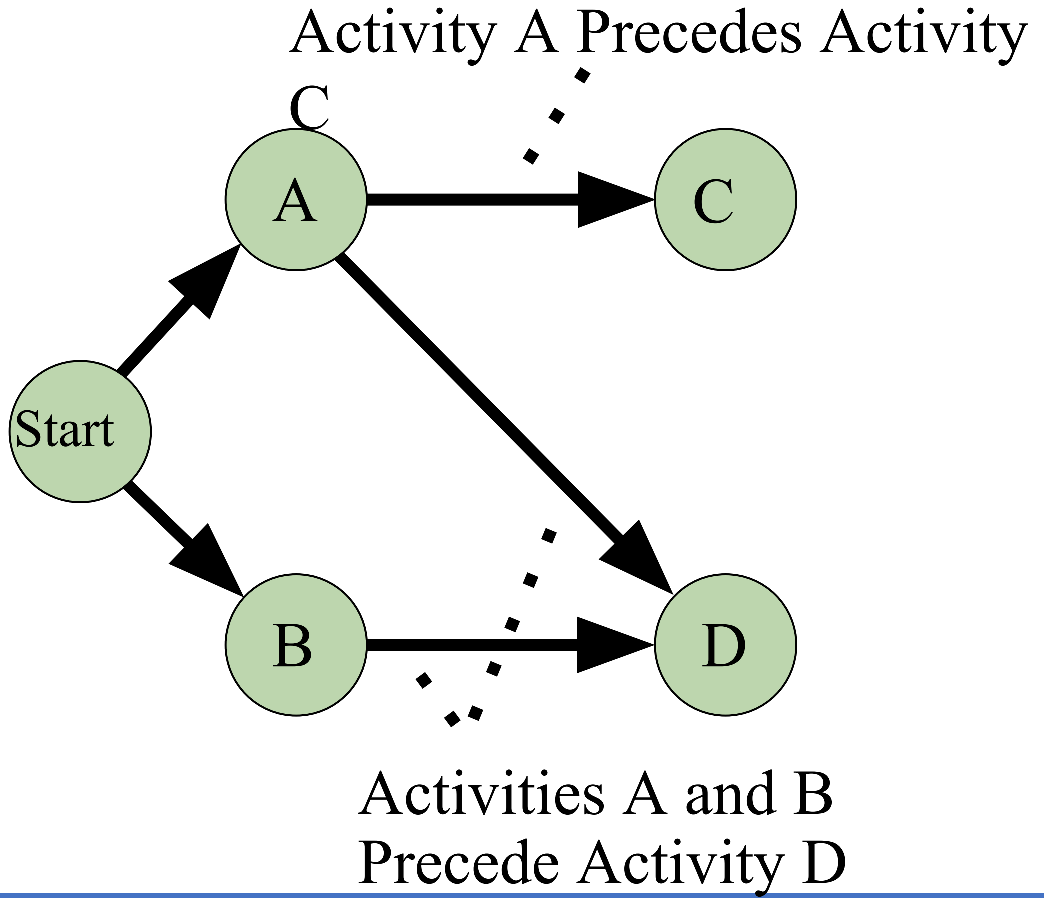
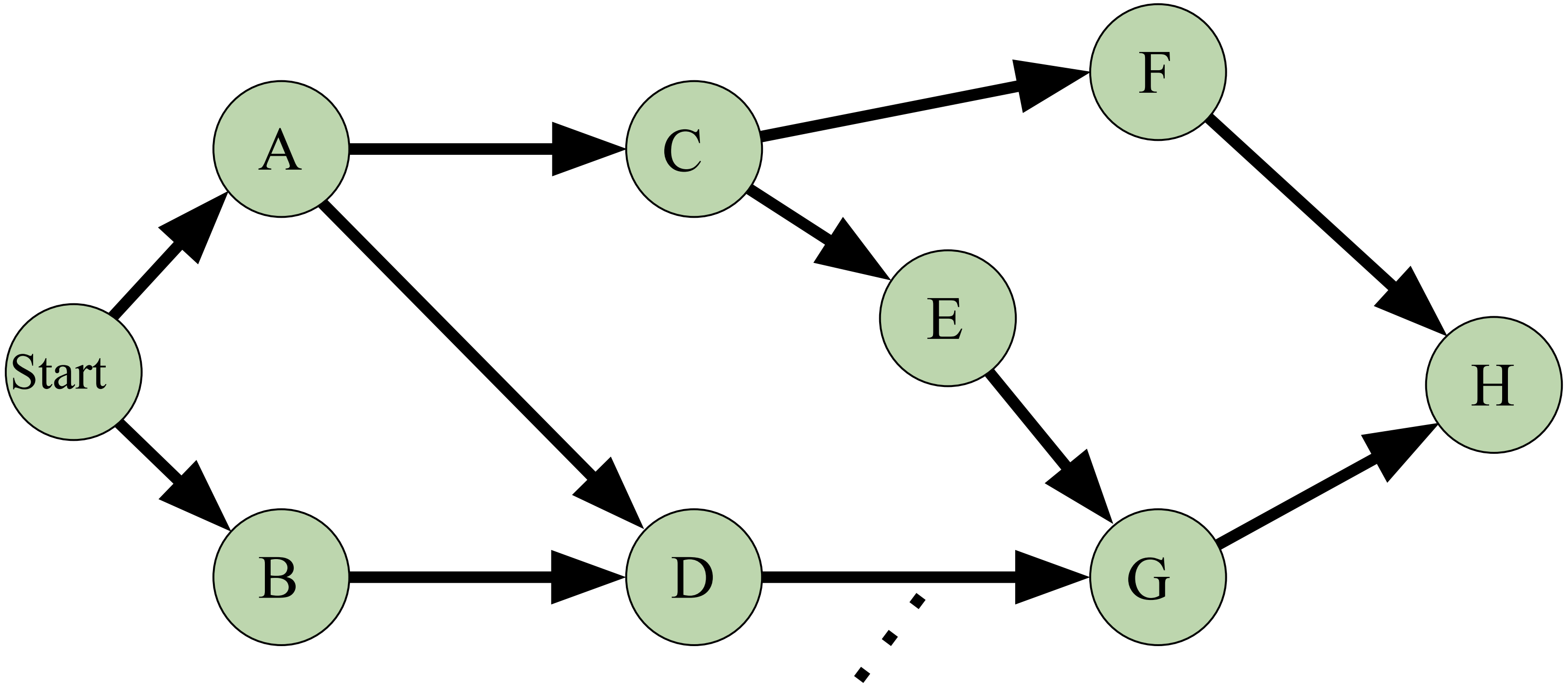


Figure 3.6

AON Network for Milwaukee Paper



Arrows Show Precedence Relationships

Figure 3.7

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

Table 3.2	Time Estimates for Milwaukee Paper Manufacturing	
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

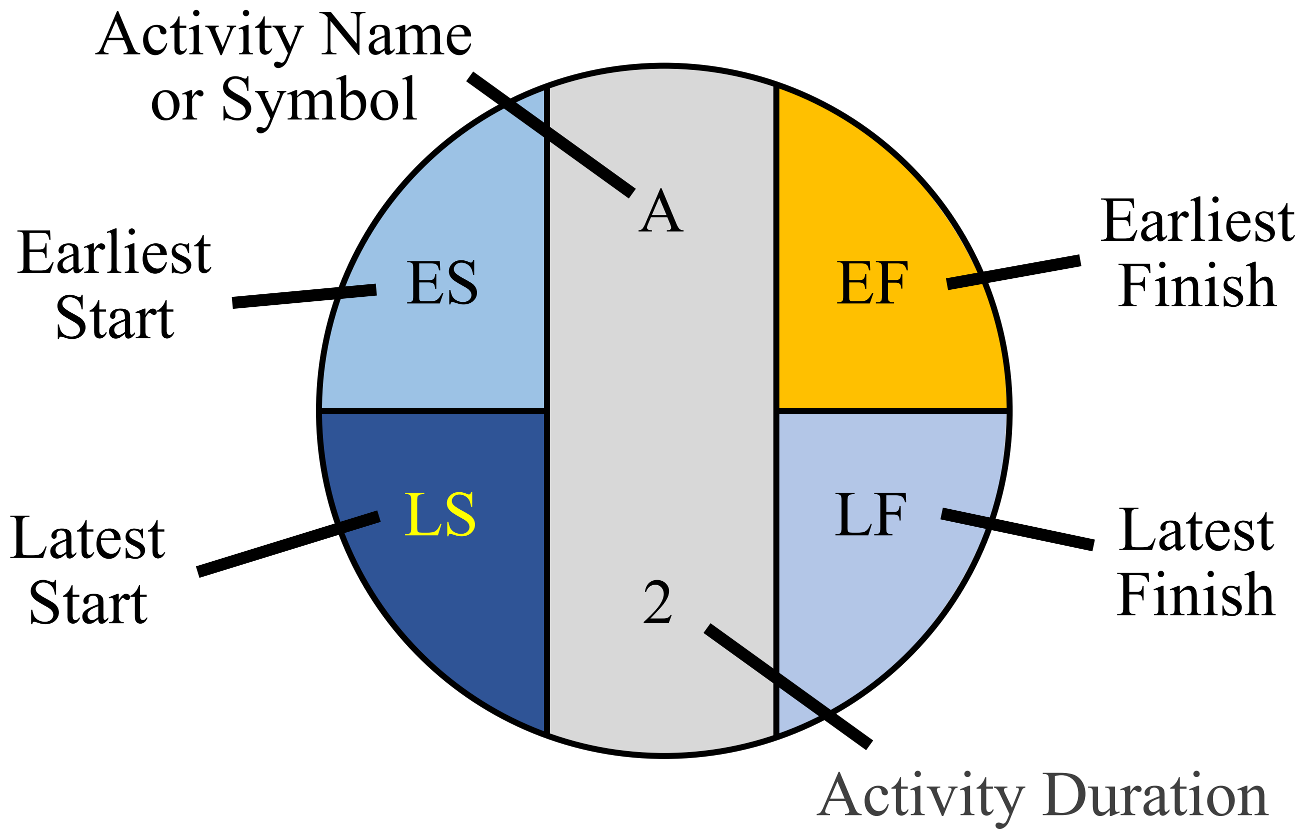
Perform a Critical Path Analysis:

- ***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

Activity Format

Figure 3.9



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 = Max {EF of all immediate predecessors}***

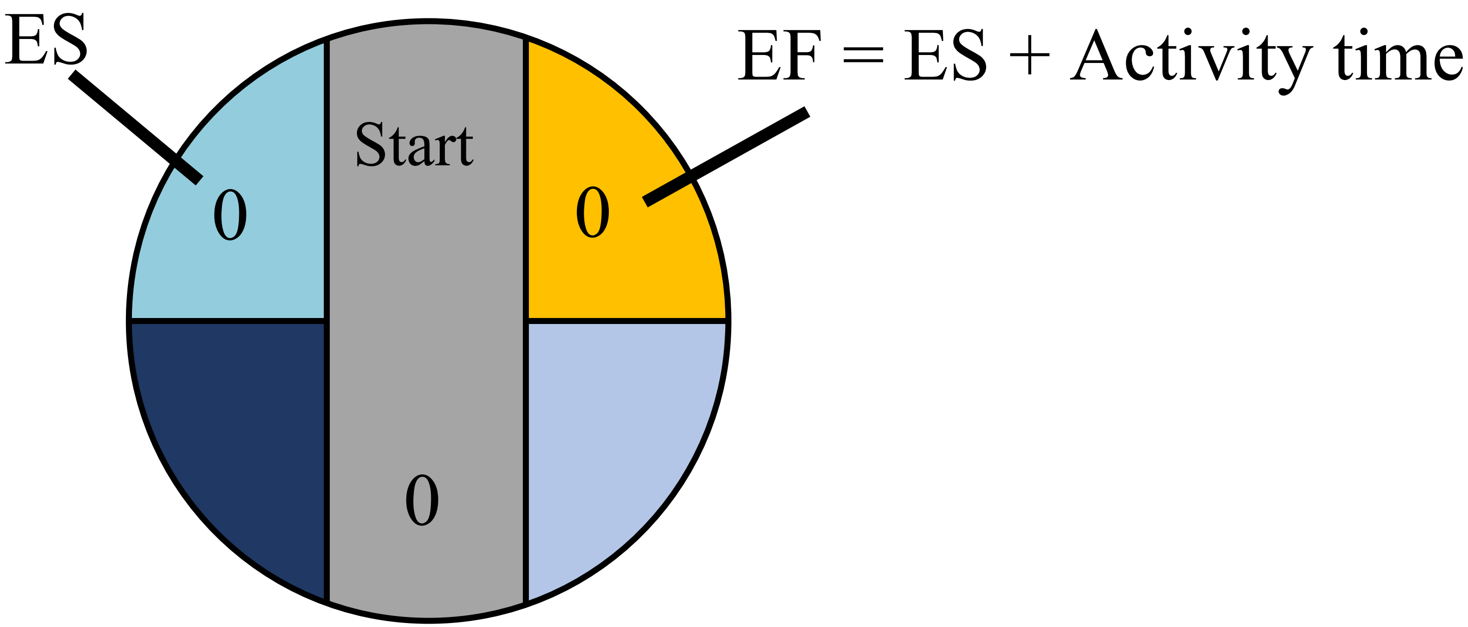
Forward Pass

Begin at starting event and work forward

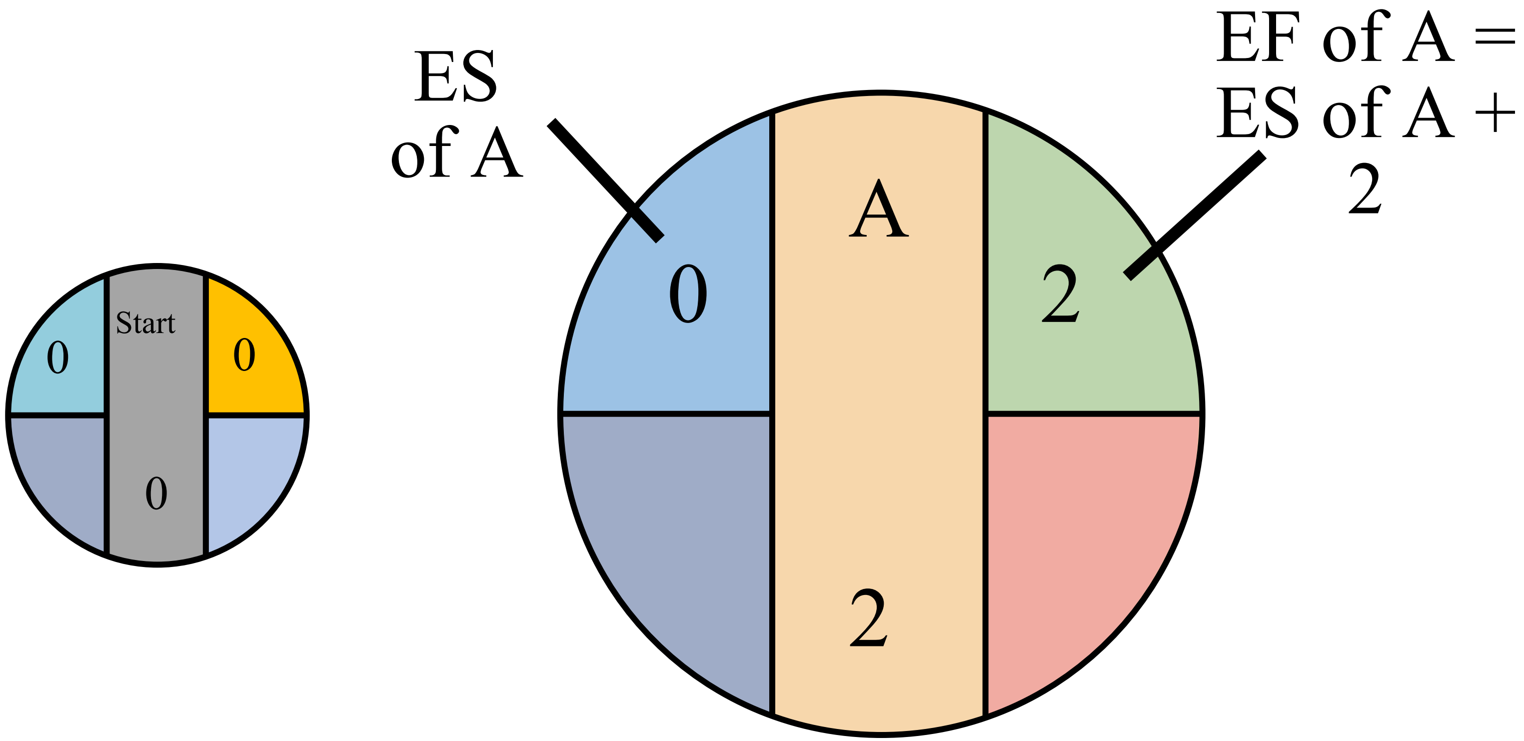
Earliest Finish Time Rule:

- The earliest finish time (EF) of an activity is the sum of its earliest start time (ES) and its activity time
  - ***EF = ES + Activity time***

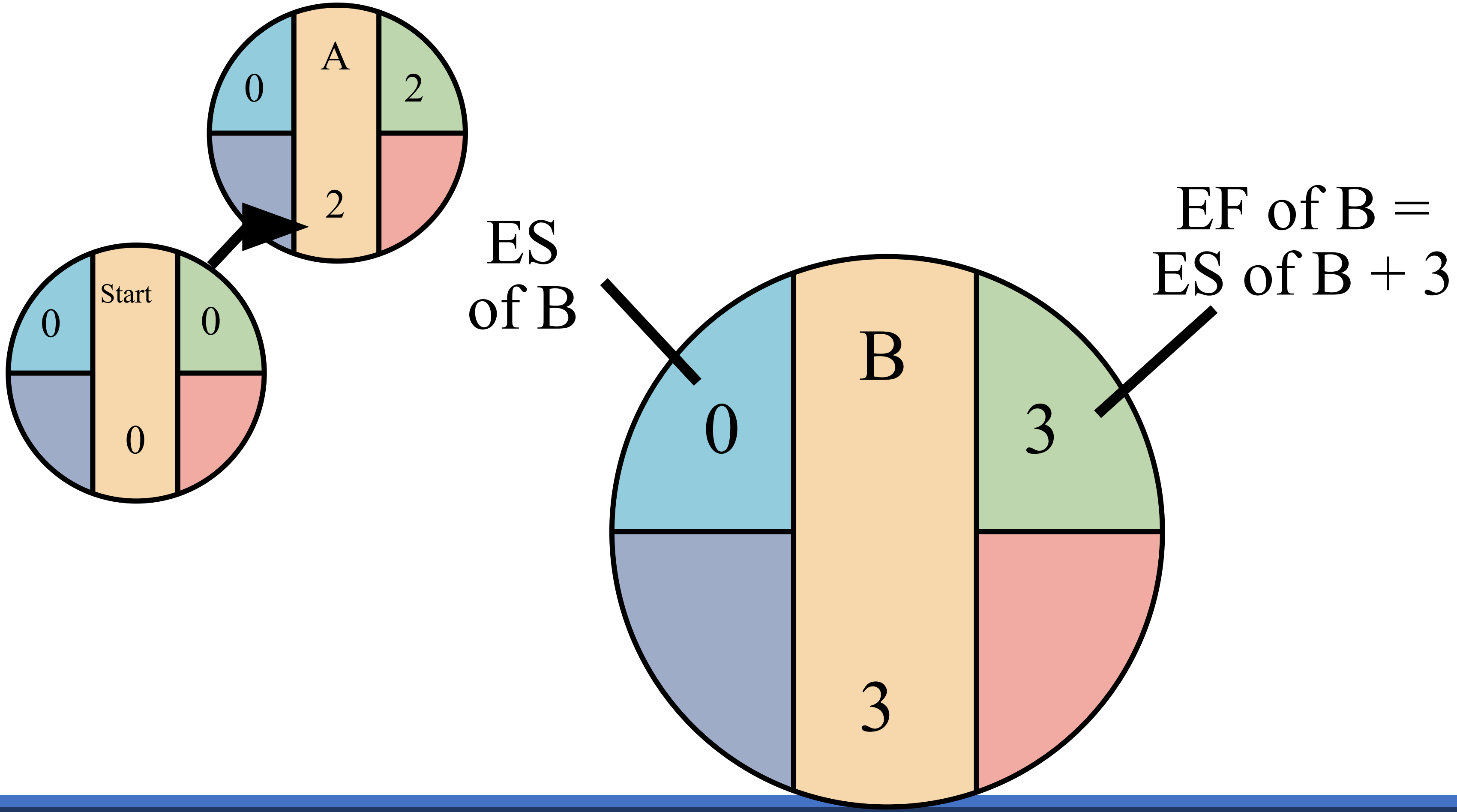
ES/EF Network for Milwaukee Paper



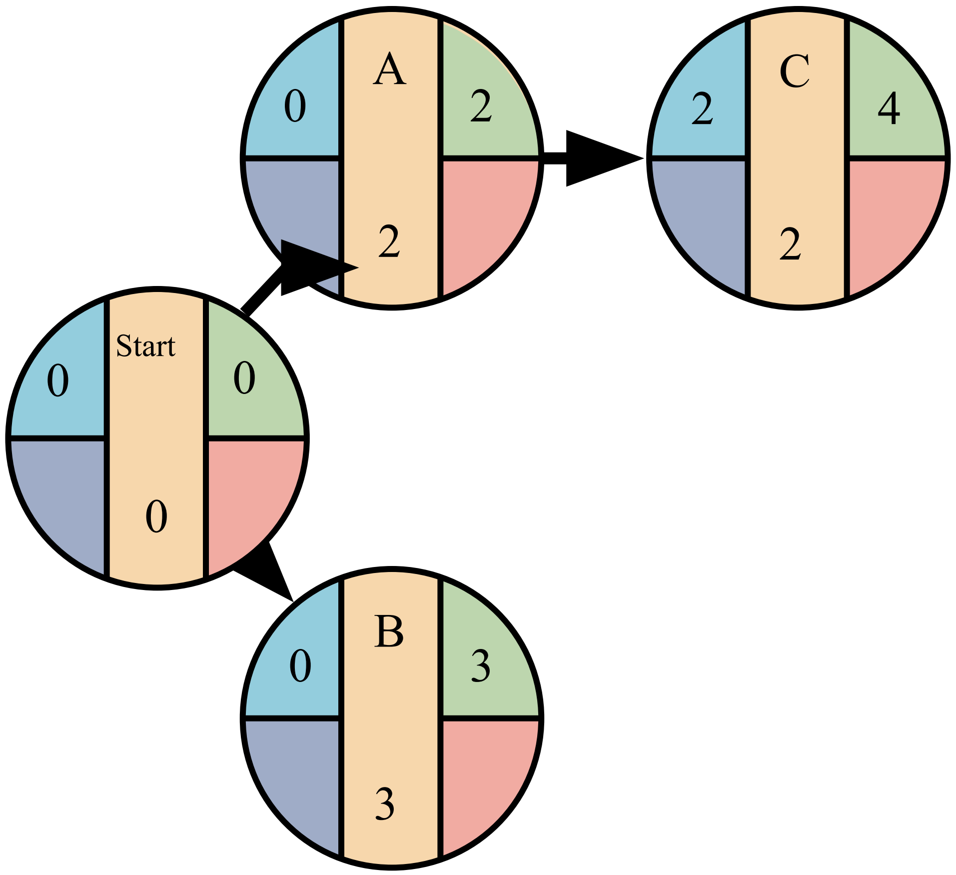
ES/EF Network for Milwaukee Paper



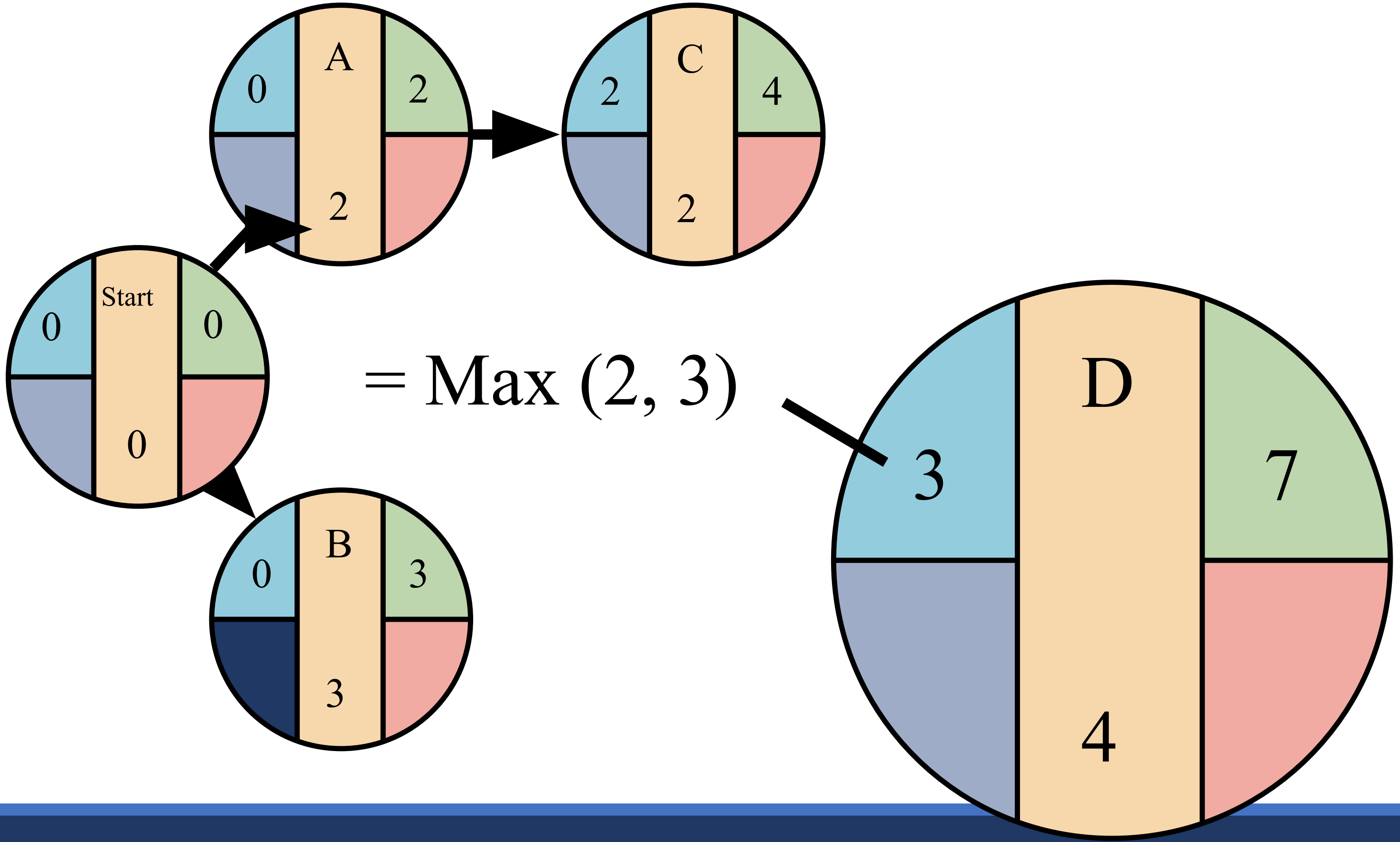
ES/EF Network for Milwaukee Paper



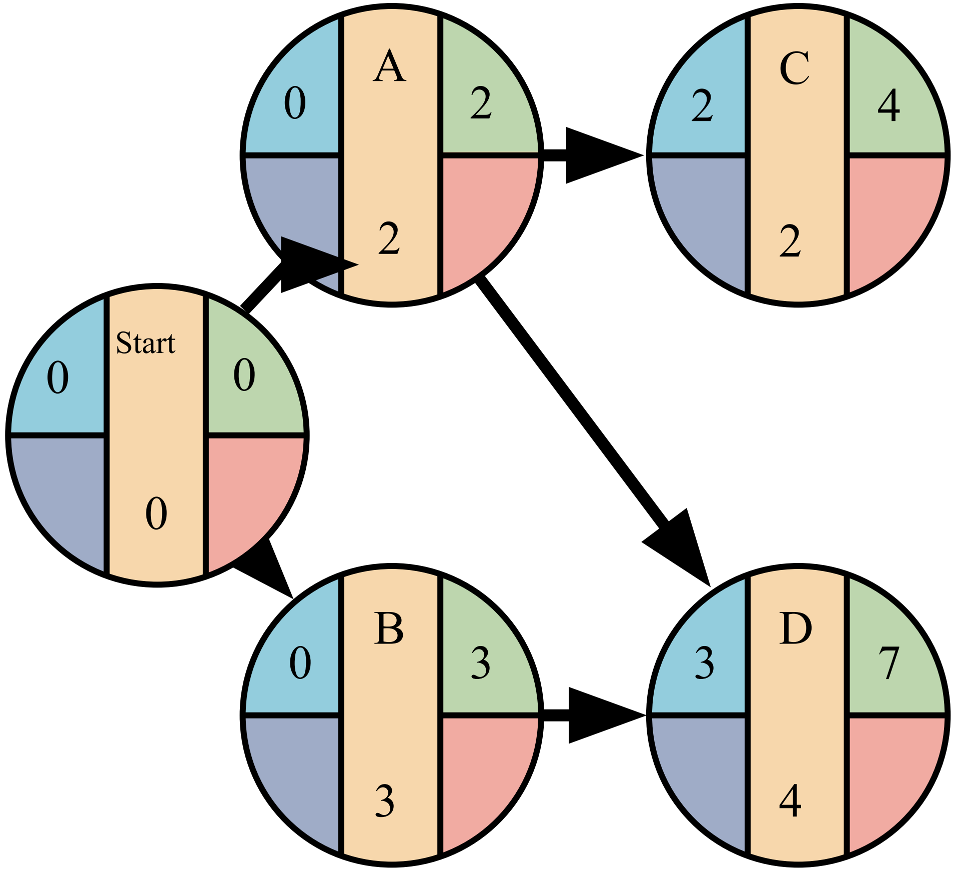
ES/EF Network for Milwaukee Paper



ES/EF Network for Milwaukee Paper



ES/EF Network for Milwaukee Paper



ES/EF Network for Milwaukee Paper

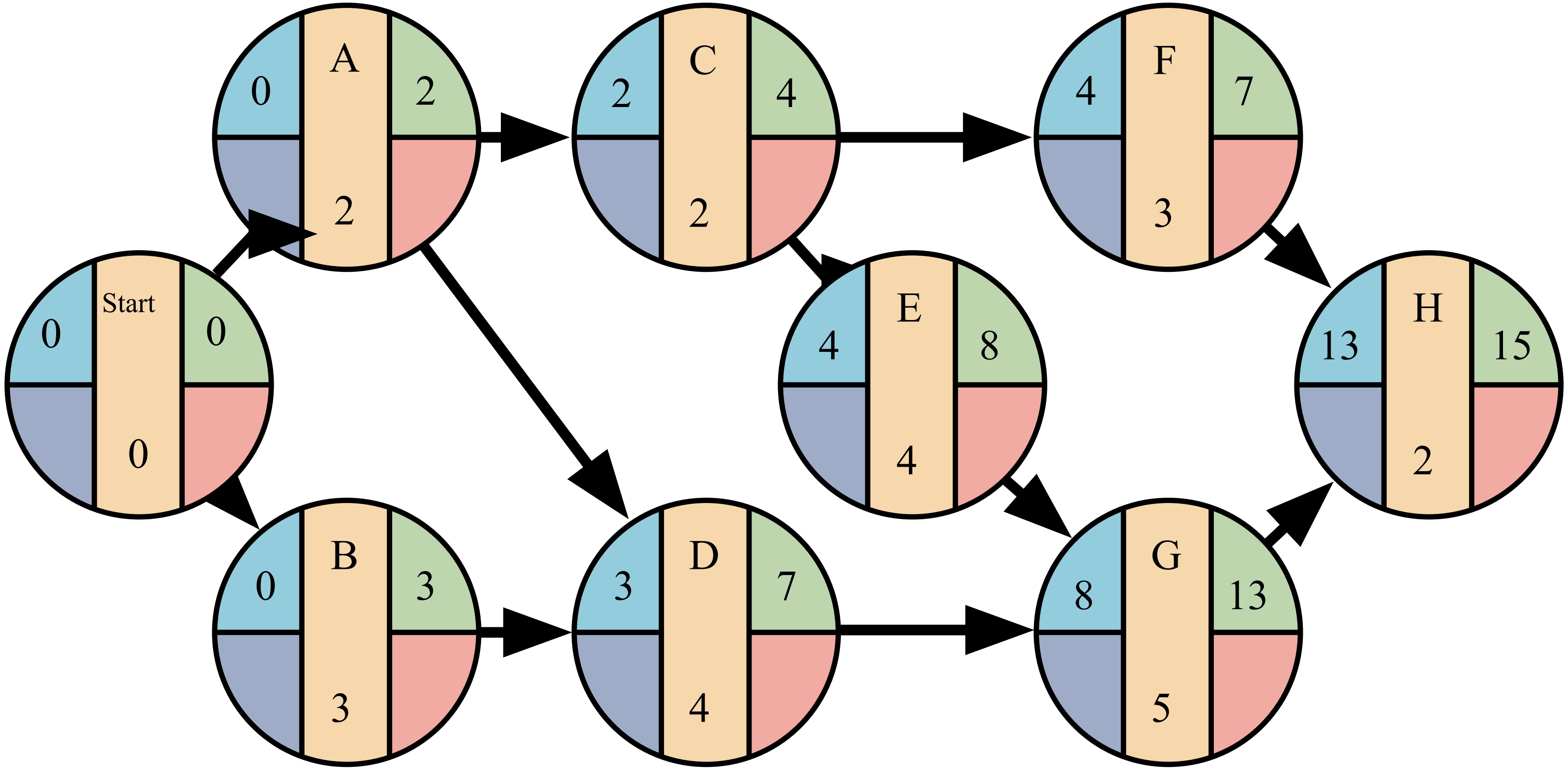


Figure 3.10

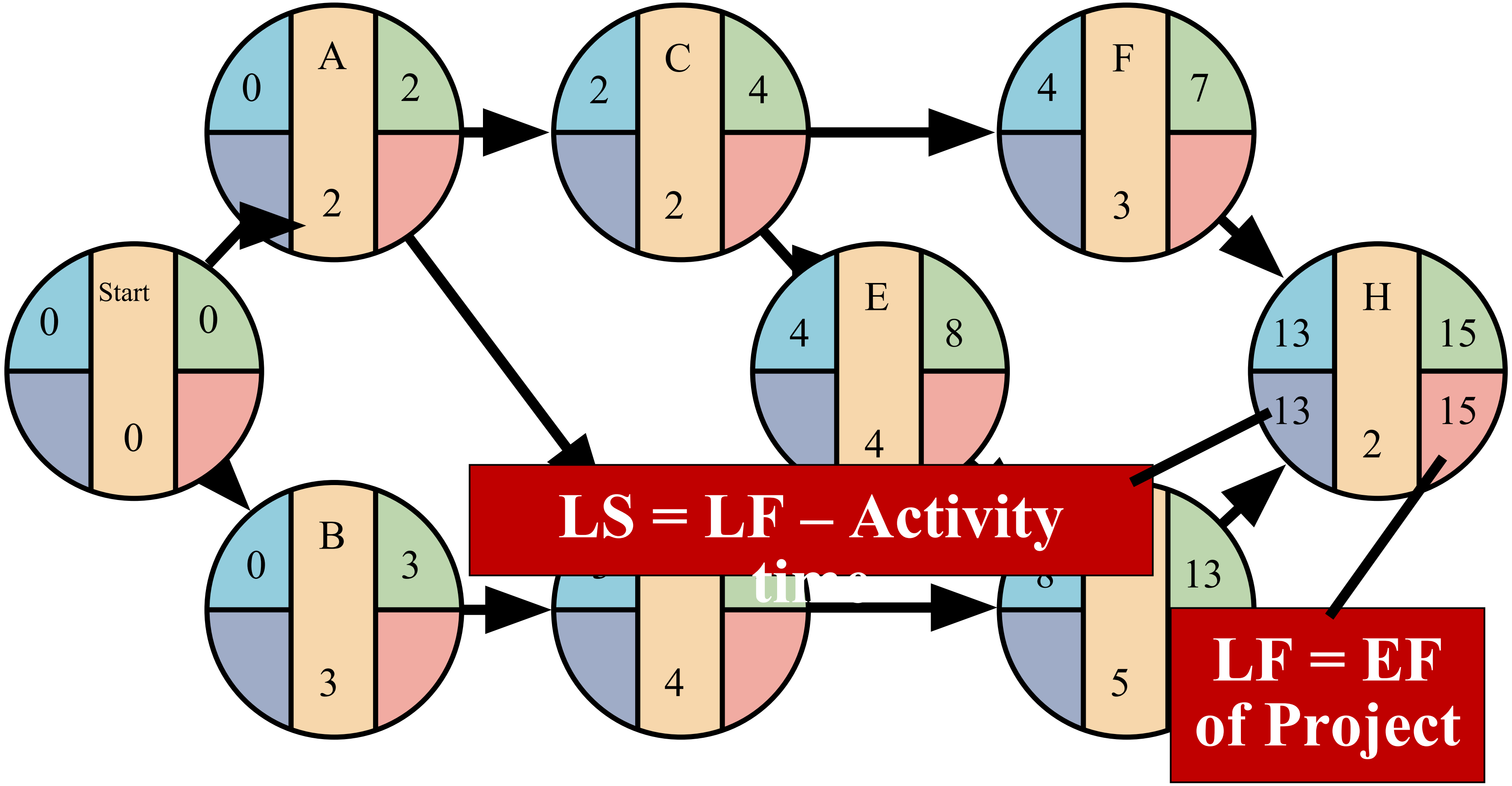
Backward Pass

Begin with the last event and work backwards

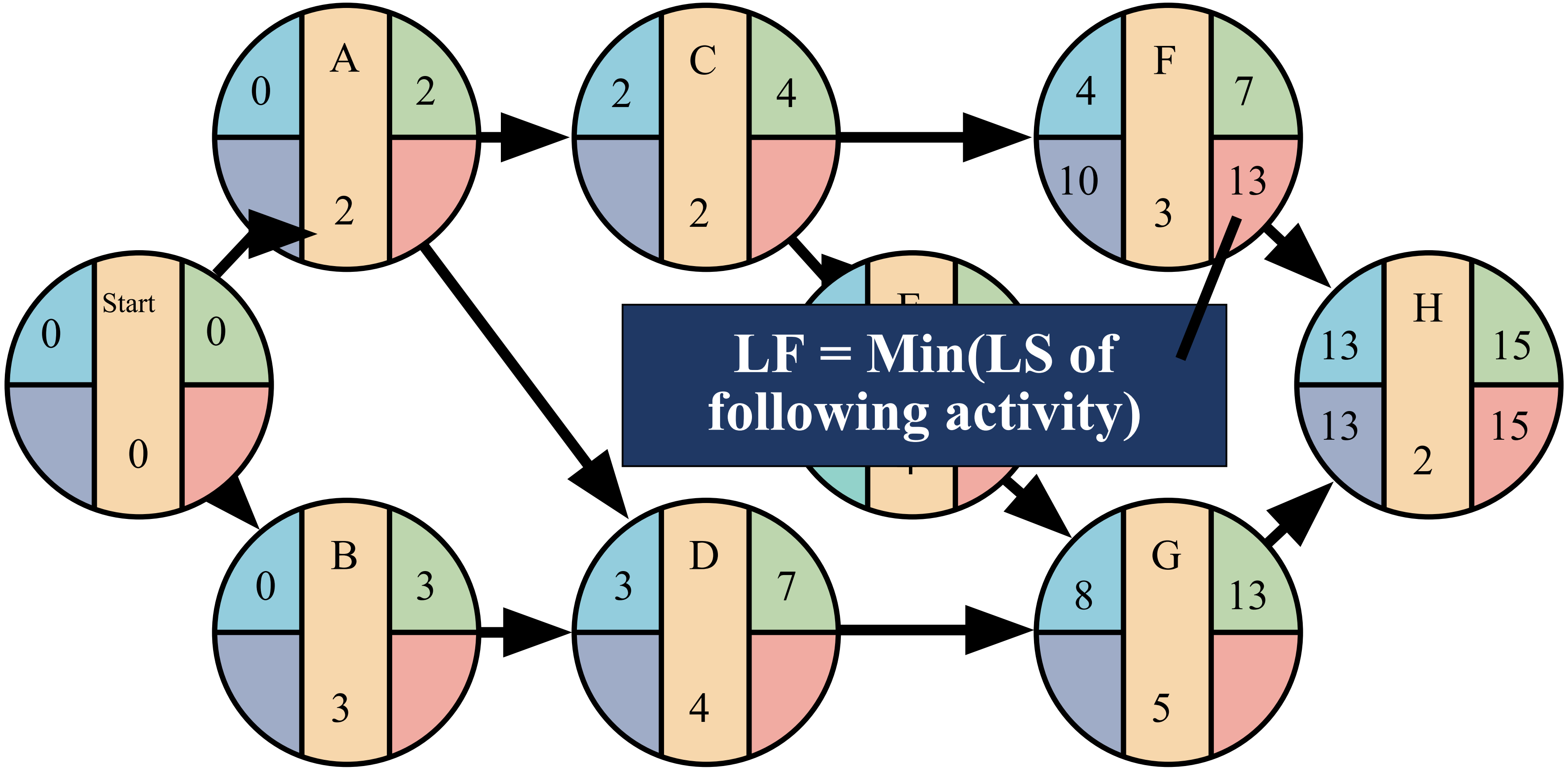
Latest Start Time Rule:

- The latest start time (LS) of an activity is the difference of its latest finish time (LF) and its activity time
  - ***LS = LF – Activity time***

LS/LF - Times for Milwaukee Paper

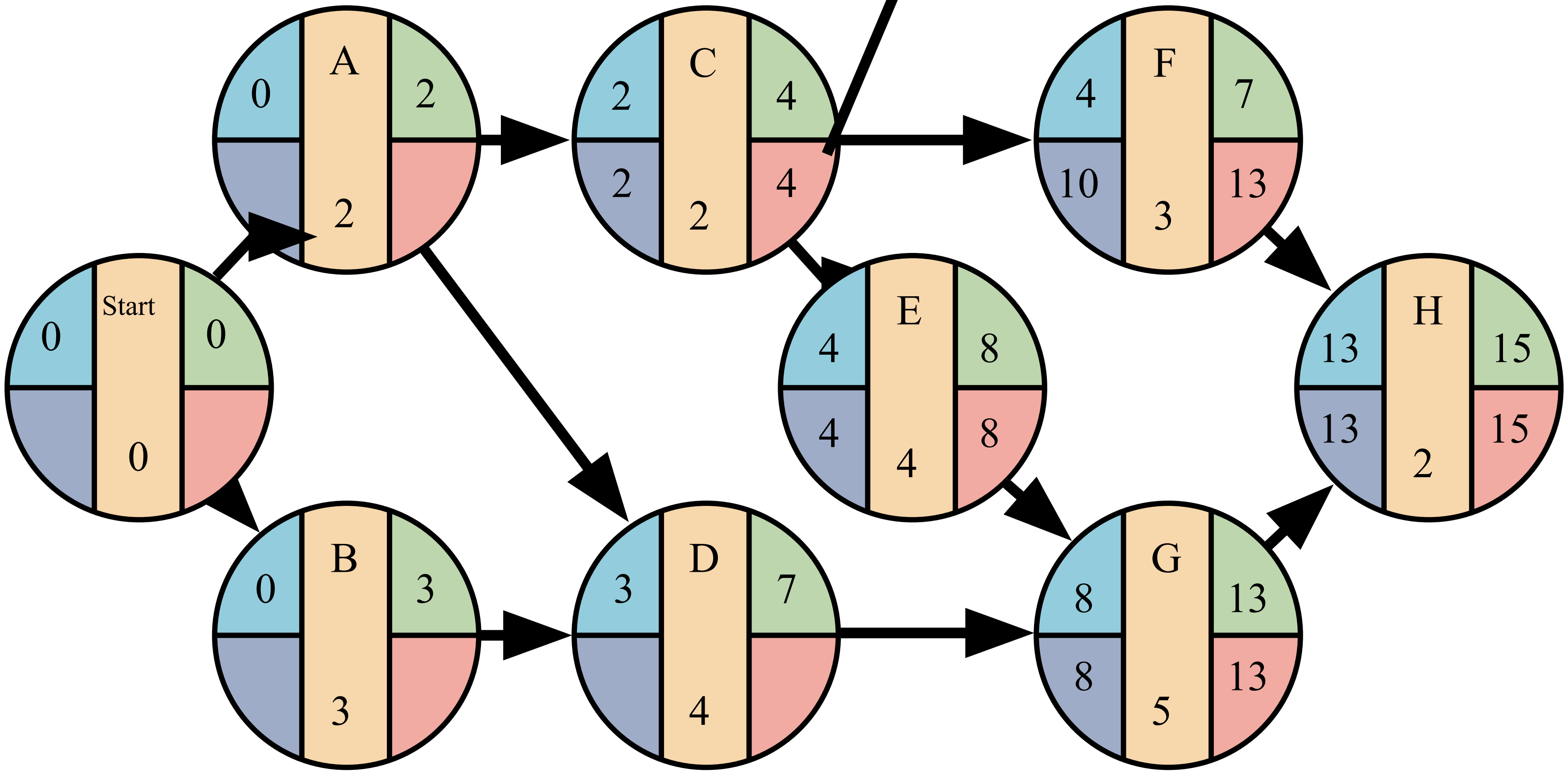


LS/LF - Times for Milwaukee Paper

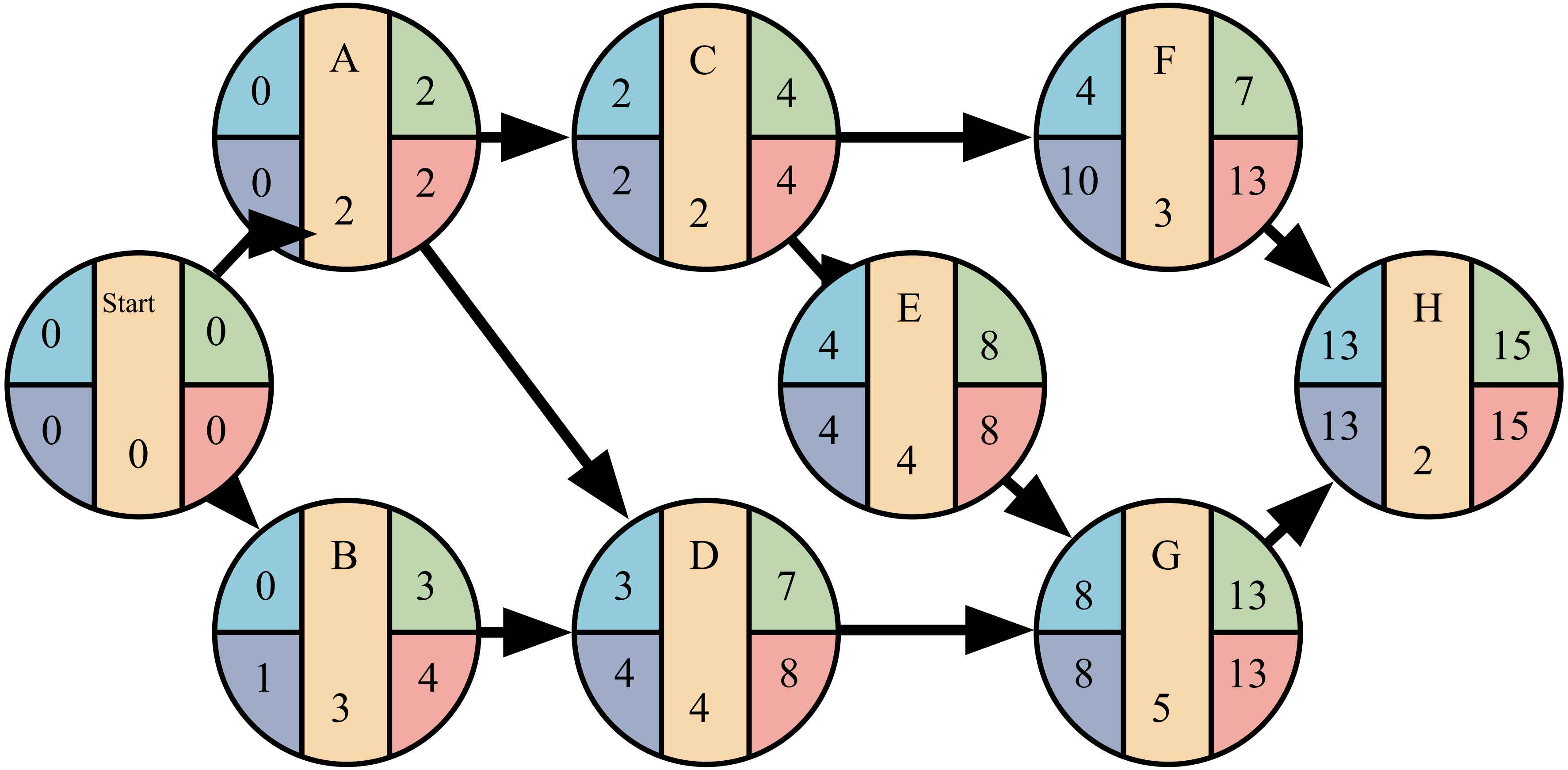


LS/LF - Times for Milwaukee Paper

LF = 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.

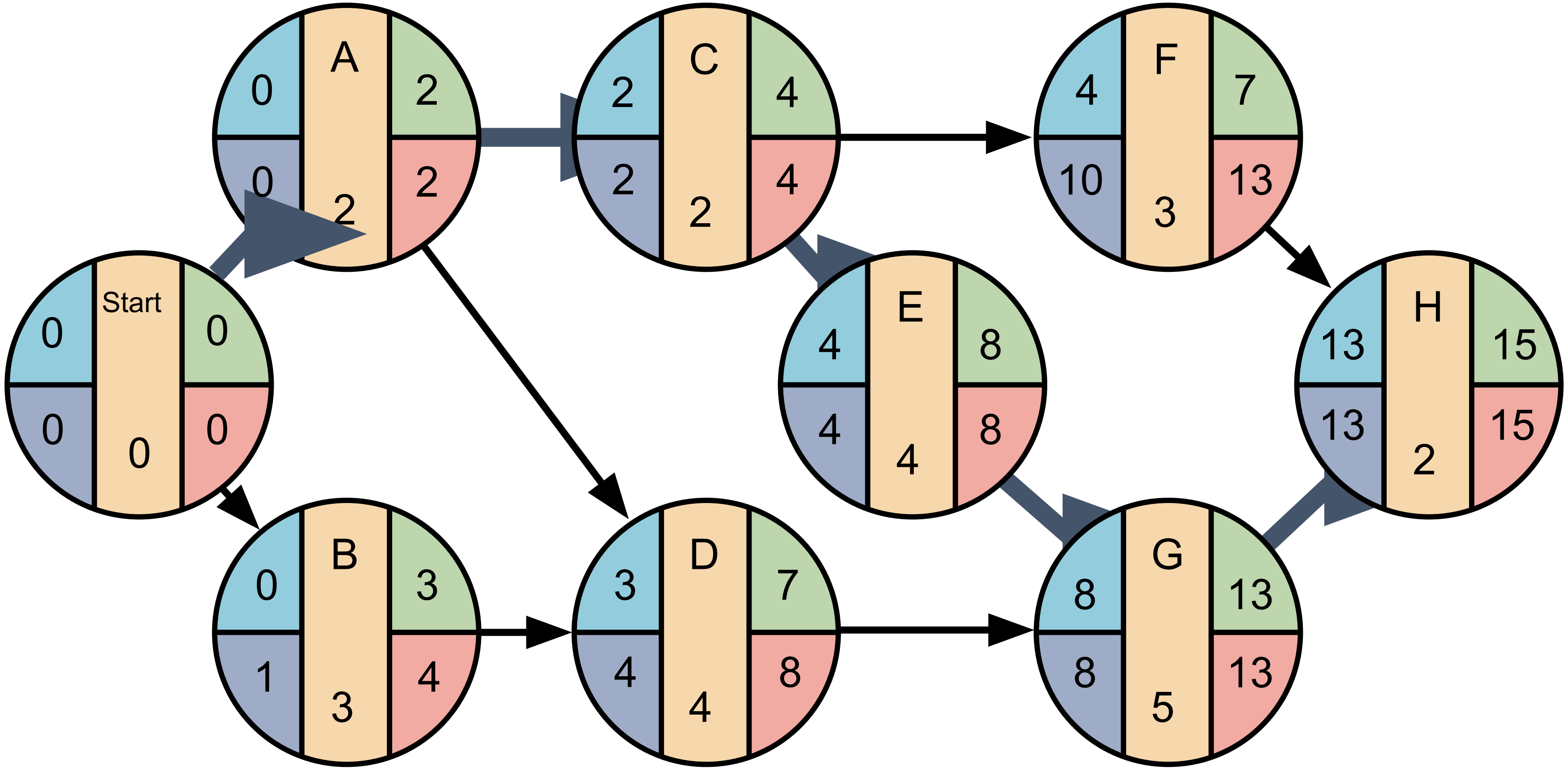
Slack = LS – ES or Slack = LF – EF

Computing Slack Time

TABLE 3.3 Milwaukee Paper's Schedule and Slack Times

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



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:

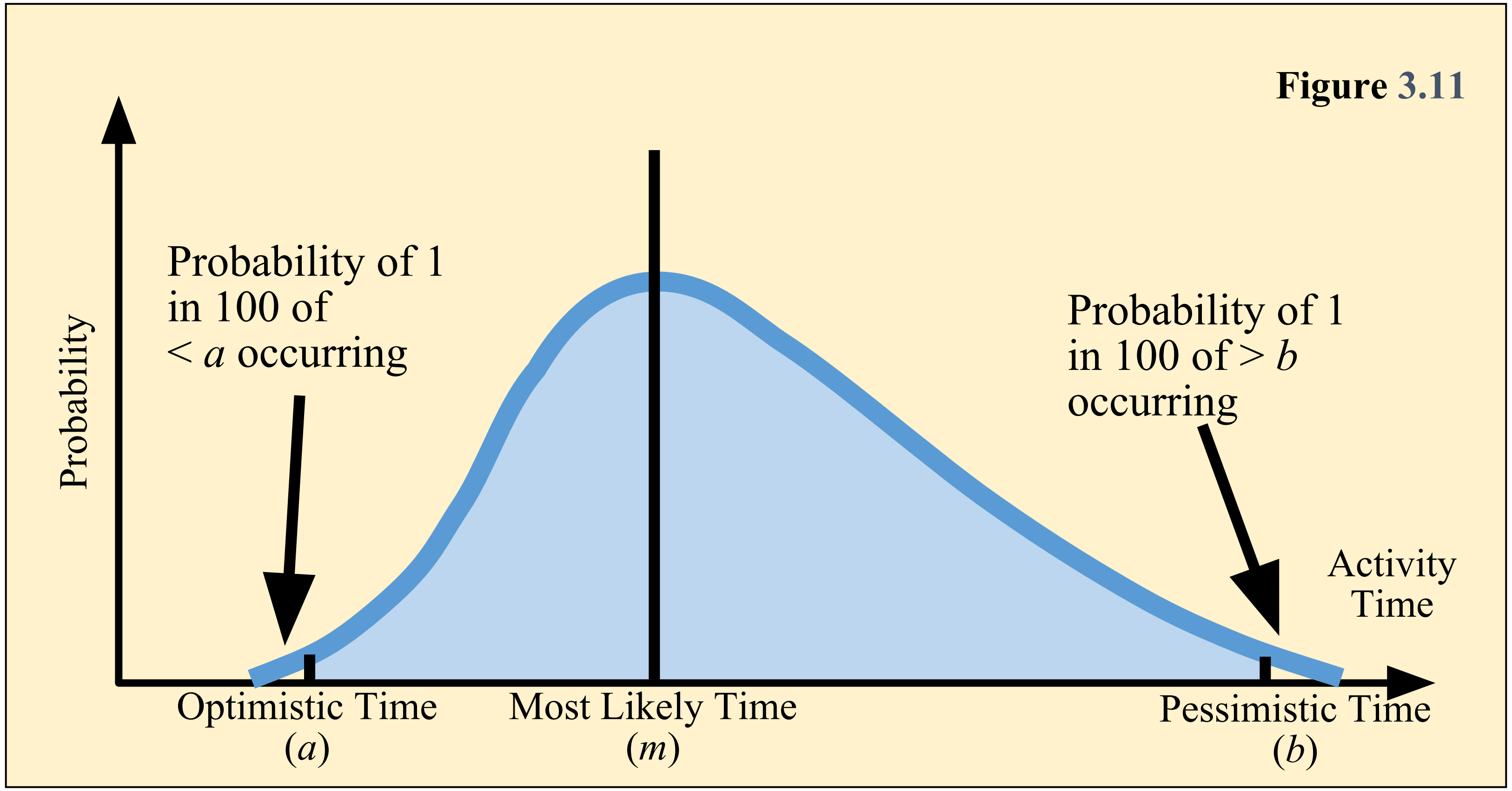
$$t = (a + 4m + b)/6$$

Variance of times:

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

Variability in Activity Times

Estimate follows beta distribution



Computing Variance

TABLE 3.4	Time Estimates (in weeks) for Milwaukee Paper's Project				
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

Critical Path : A – C – E – G – H

Probability of Project Completion

Project variance is computed by summing the variances of critical activities

$$s_p^2 = \textit{Project variance}$$

$$= \sum(\text{variances of activities on critical path})$$

Probability of Project Completion

Project variance is computed by

Project variance

$$s^2_p = .11 + .11 + 1.00 + 1.78 + .11 = 3.11$$

Project standard deviation

$$s_p = \sqrt{\text{Project variance}}$$

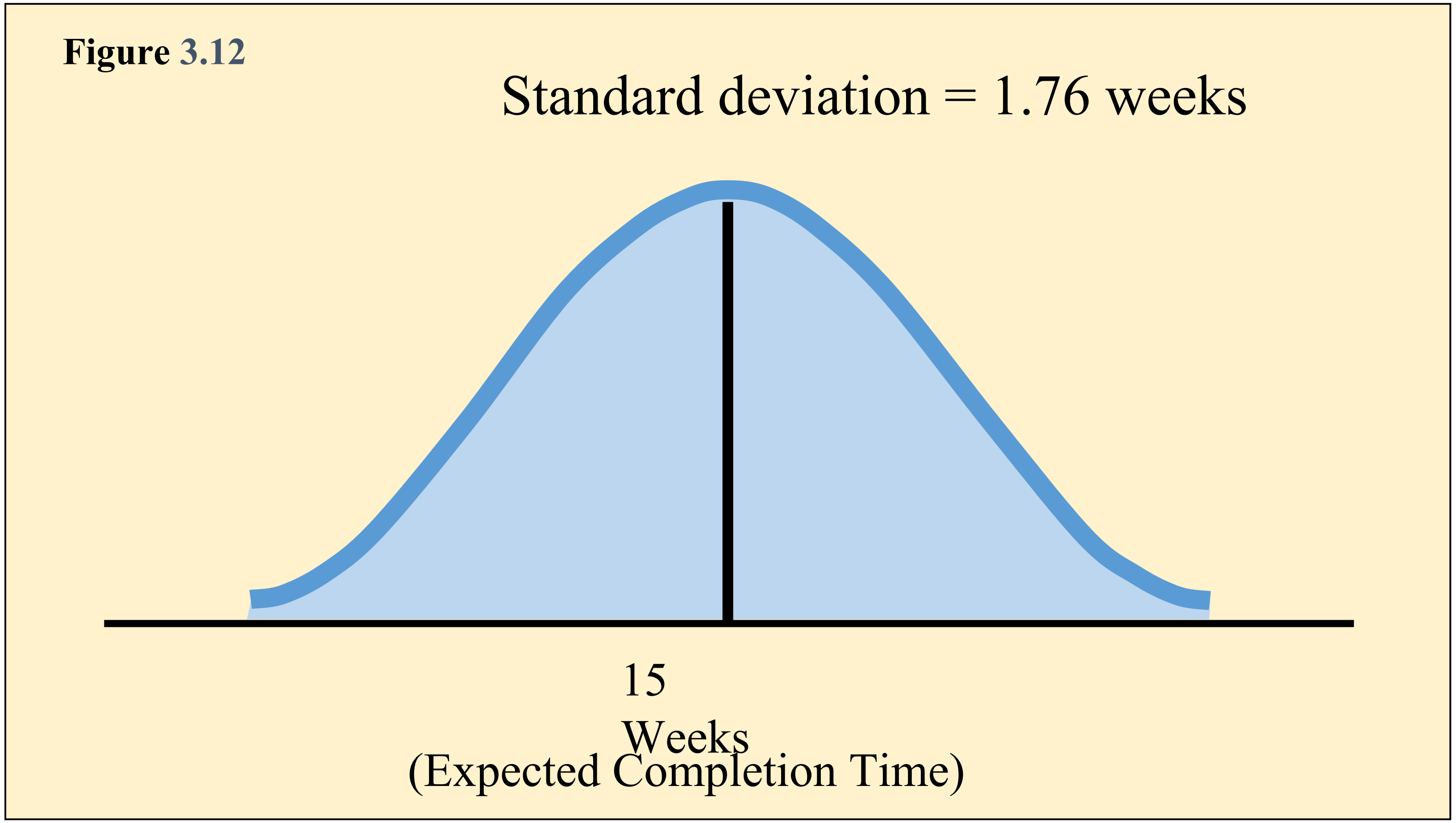
$$= \sqrt{3.11} = 1.76 \text{ weeks}$$

Probability of Project Completion

PERT makes two more assumptions:

- Total project completion times follow a normal probability distribution
- Activity times are statistically independent

Probability of Project Completion



Cost–Time 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

1. The amount by which an activity is crashed is, in fact, permissible
2. Taken together, the shortened activity durations will enable us to finish the project by the due date
3. 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:

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

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

Steps in Project Crashing

3. 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.

4. 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
   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.

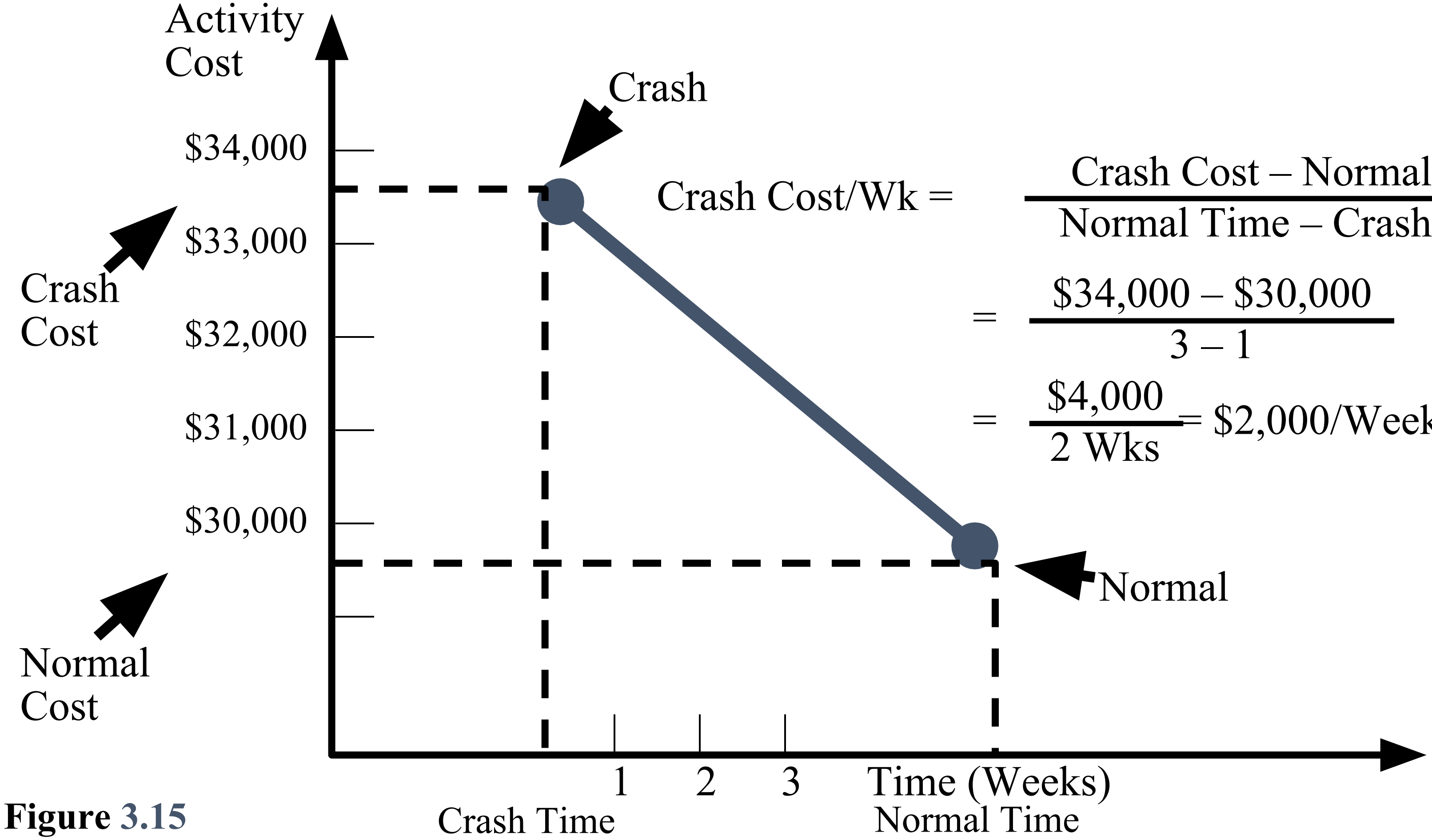
Steps in Project Crashing

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

Crashing The Project

TABLE 3.5	Normal and Crash Data for Milwaukee Paper Manufacturing					
	TIME (WEEKS)		***COST ($)***			
ACTIVITY	**NORMAL**	**CRASH**	**NORMAL**	**CRASH**	**CRASH COST PER WEEK ($)**	**CRITICAL PATH ?**
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



$$\text{Crash Cost/Wk} = \frac{\text{Crash Cost} - \text{Normal Cost}}{\text{Normal Time} - \text{Crash Time}}$$

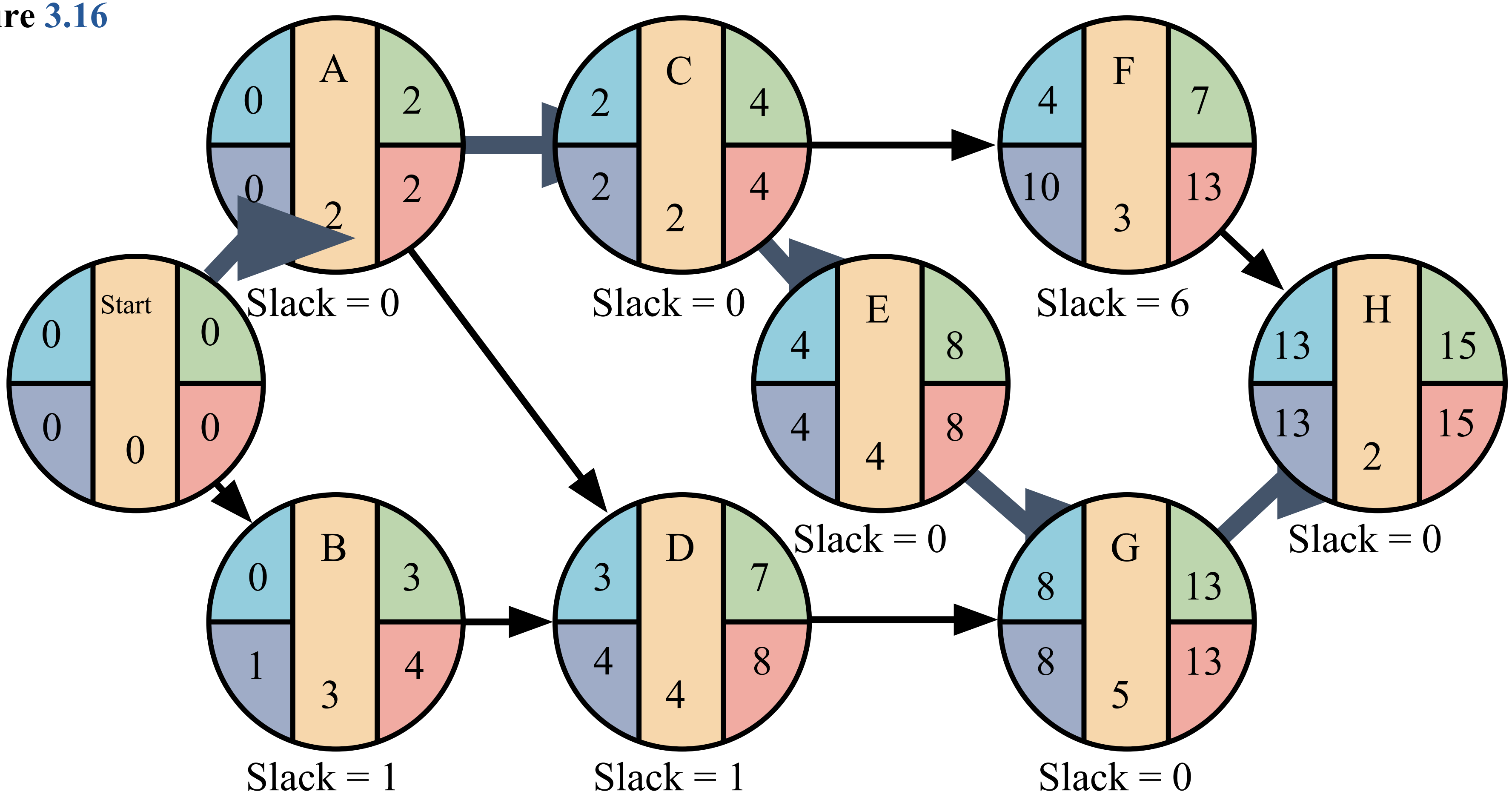
$$= \frac{\$34{,}000 - \$30{,}000}{3 - 1}$$

$$= \frac{\$4{,}000}{2\text{ Wks}} = \$2{,}000\text{/Week}$$

Figure 3.15

Critical Path and Slack Times for Milwaukee Paper

Figure 3.16



Advantages of PERT/CPM

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

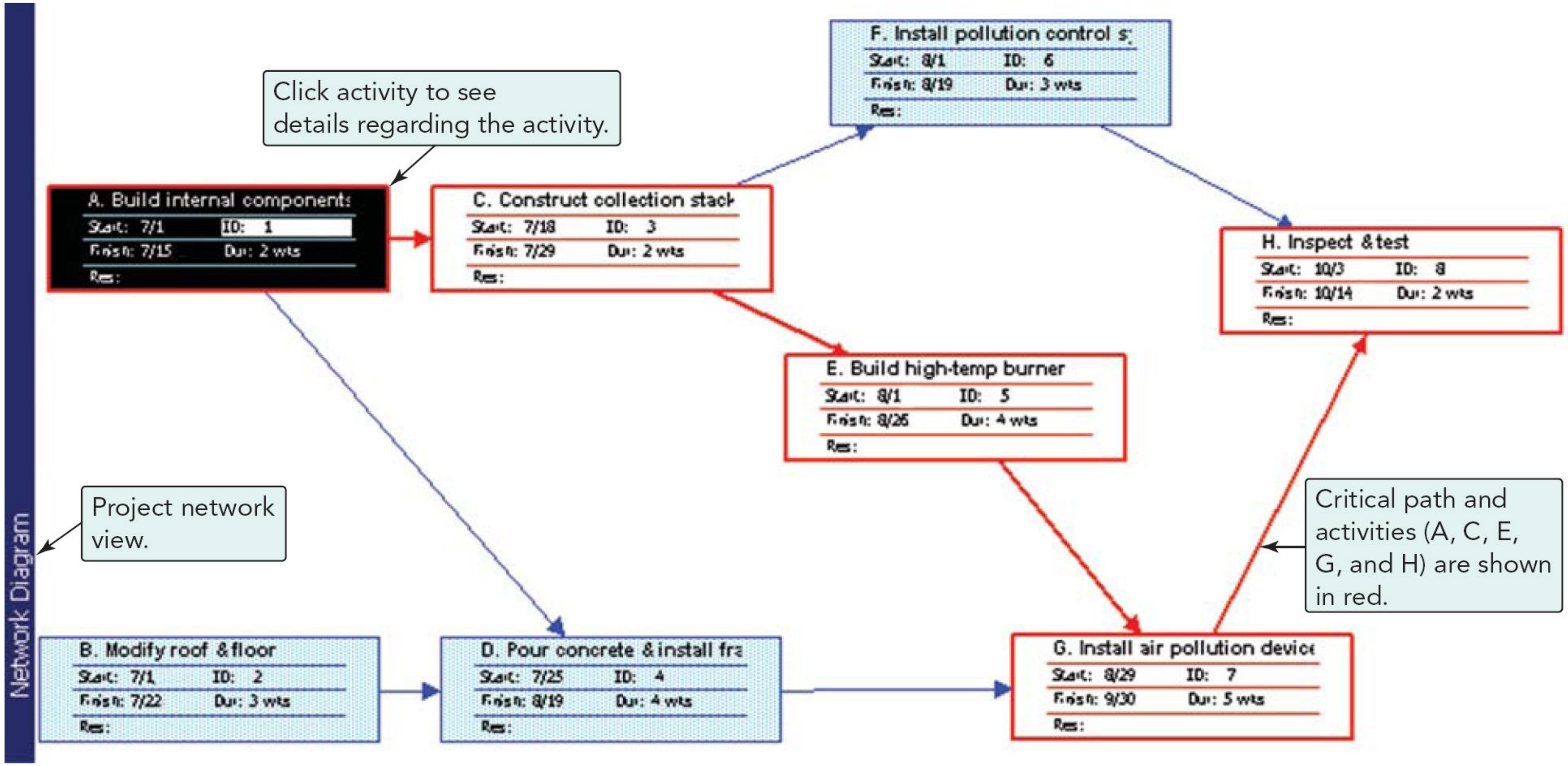
Advantages of PERT/CPM

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

Limitations of PERT/CPM

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

Using Microsoft Project



Program 3.2

Thank you!