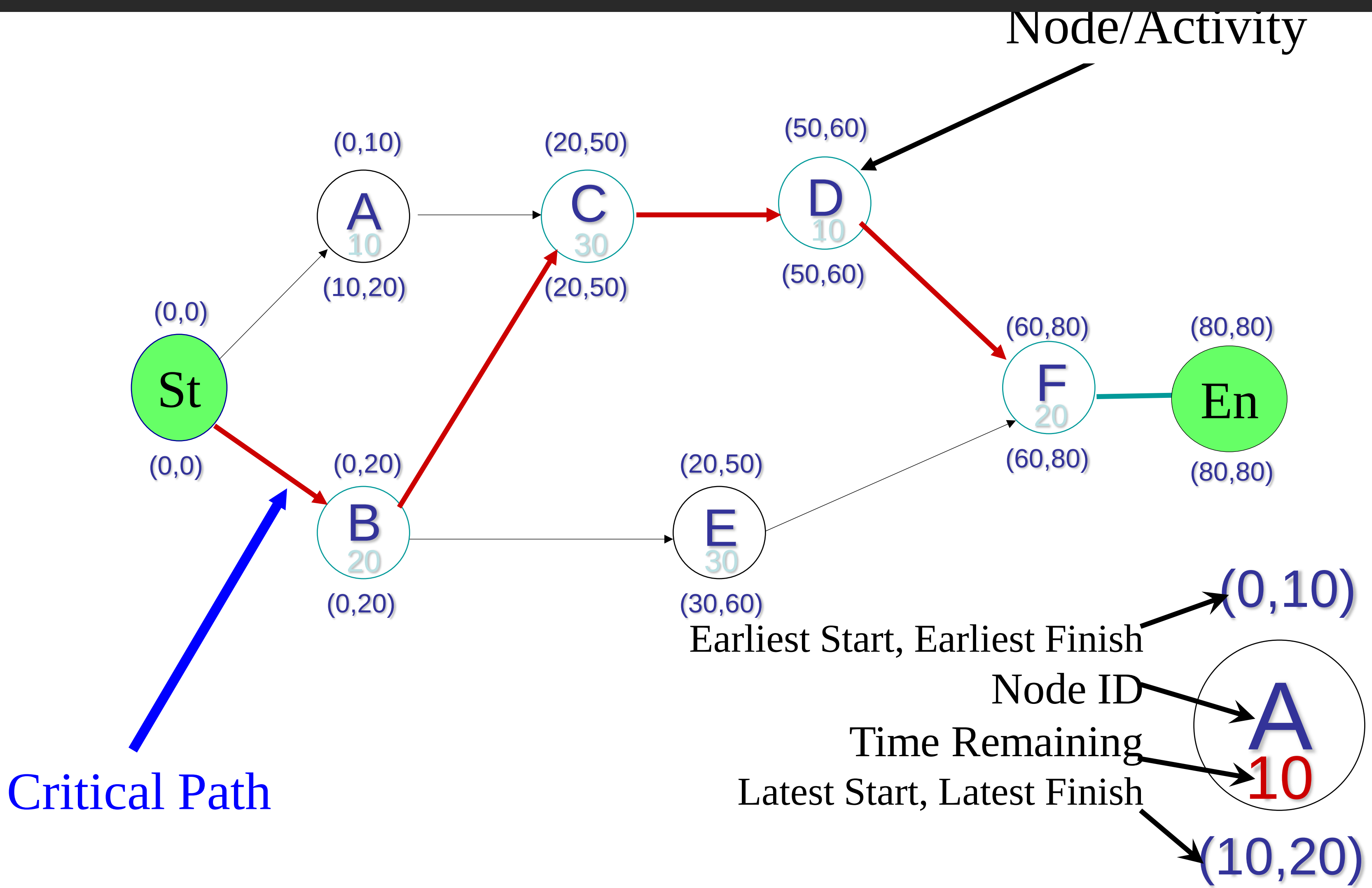
Software Project Management

Lecture 22

Critical Path Method (CPM)

- CPM is a project network analysis technique used to predict total project duration
- A critical path for a project is the series of activities that determines the earliest time by which the project can be completed
- The critical path is the longest path through the network diagram and has the least amount of slack or float

CPM



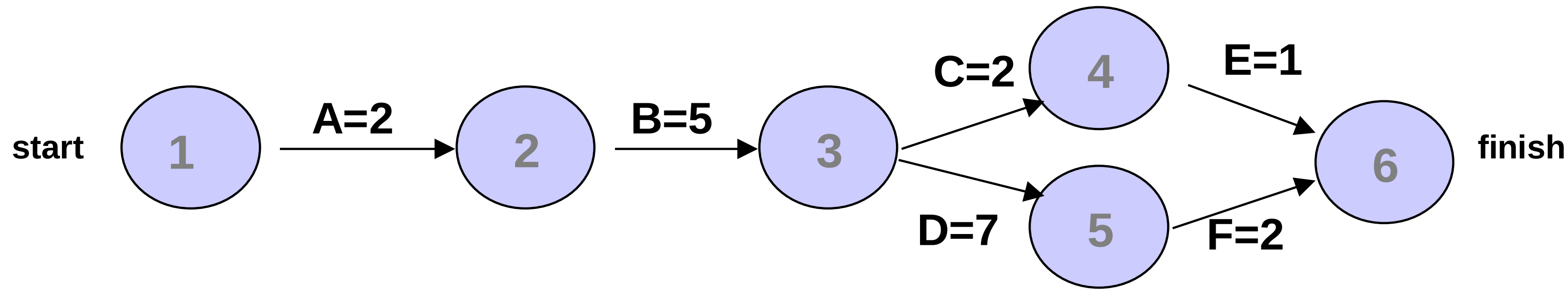
Node/Activity
(0,10)
A
10
(10,20)
(20,50)
C
30
(20,50)
(50,60)
D
10
(50,60)
(0,0)
St
(0,0)
(0,20)
B
20
(0,20)
(20,50)
E
30
(30,60)
(60,80)
F
20
(60,80)
(80,80)
En
(80,80)
Critical Path
Earliest Start, Earliest Finish
Node ID
Time Remaining
Latest Start, Latest Finish
(0,10)
A
10
(10,20)

Finding the Critical Path

- First develop a good project network diagram
- Add the durations for all activities on each path through the project network diagram
- The longest path is the critical path

Simple Example of Determining the Critical Path

- Consider the following project network diagram. Assume all times are in days.



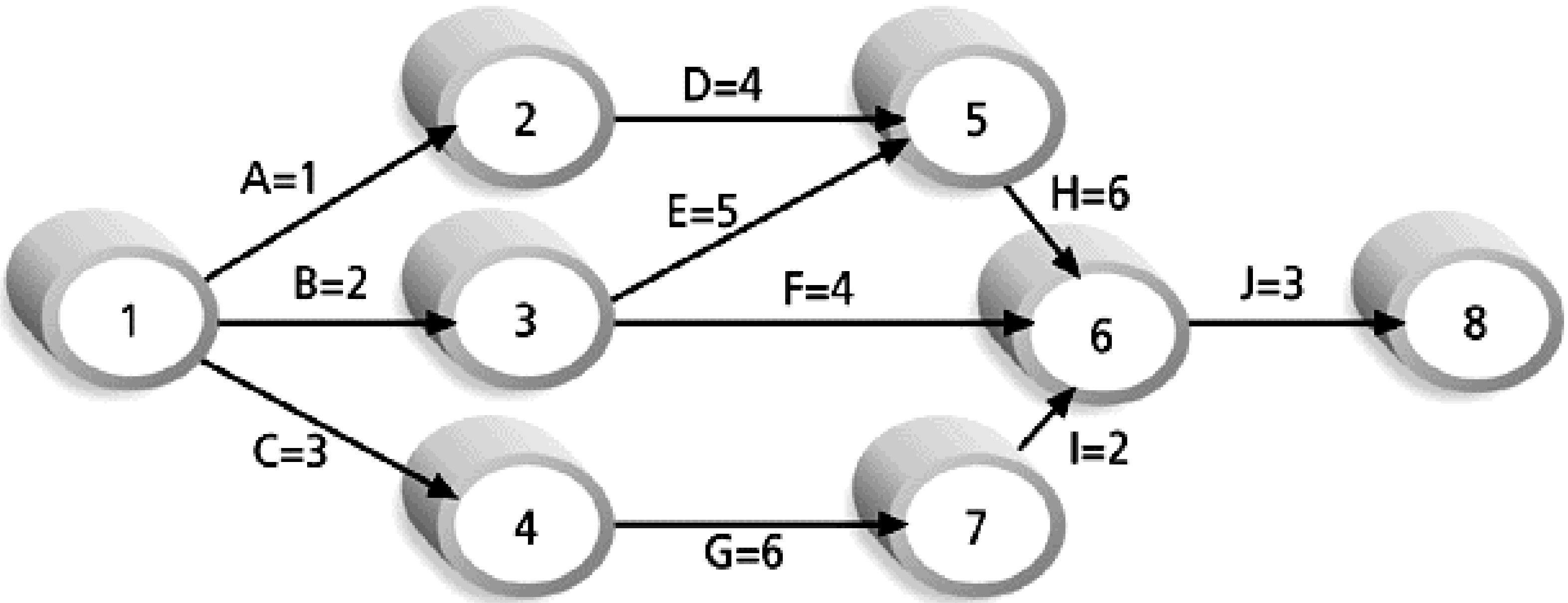
a) How many paths are on this network diagram?

b) How long is each path?

c) Which is the critical path?

d) What is the shortest amount of time needed to complete this project?

Determining the Critical Path



Note: Assume all durations are in days.

Path 1:	A-D-H-J	Length = 1+4+6+3 = 14 days
Path 2:	**B-E-H-J**	**Length = 2+5+6+3 = 16 days**
Path 3:	B-F-J	Length = 2+4+3 = 9 days
Path 4:	C-G-I-J	Length = 3+6+2+3 = 14 days

Since the critical path is the longest path through the network diagram, Path 2, B-E-H-J, is the critical path for Project X.

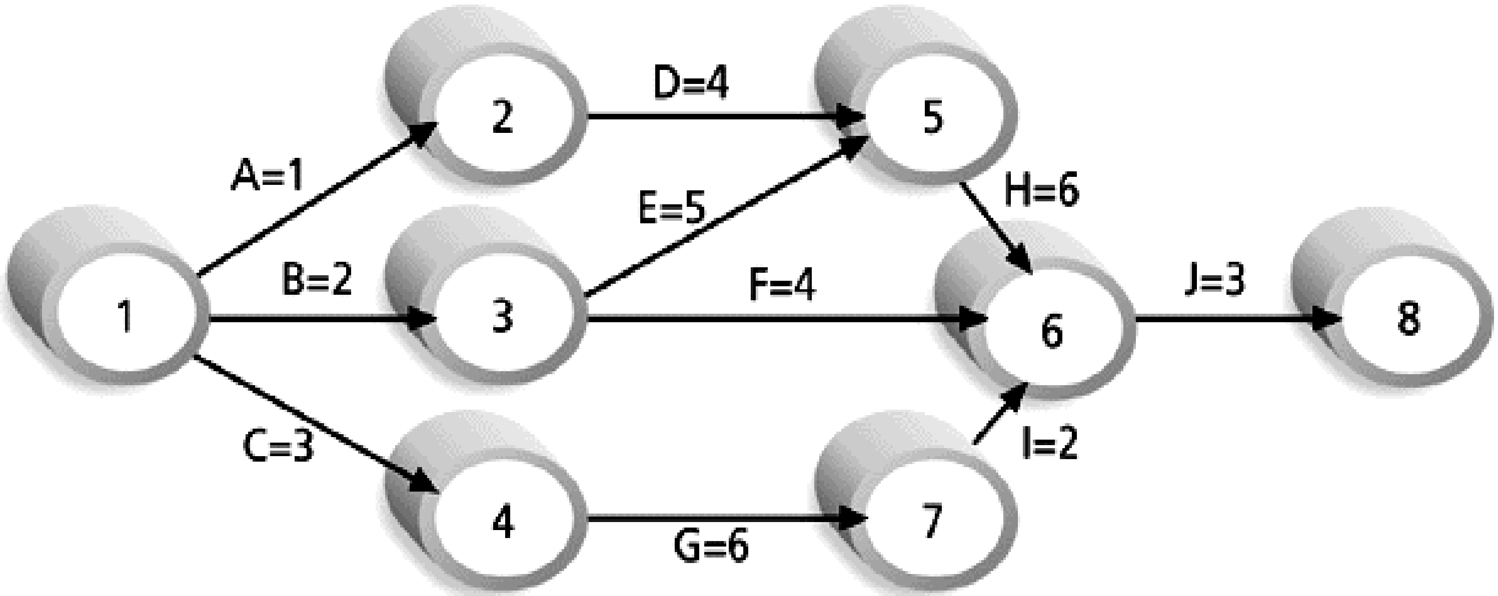
More on the Critical Path

- If one of more activities on the critical path takes longer than planned, the whole project schedule will slip unless corrective action is taken
- Remember:
  - The critical path is not the one with all the critical activities; it only accounts for time
  - There can be more than one critical path if the lengths of two or more paths are the same
  - The critical path can change as the project progresses

Using Critical Path Analysis to Make Schedule Trade-offs

- Knowing the critical path helps you make schedule trade-offs
- Free slack or free float is the amount of time an activity can be delayed without delaying the early start of any immediately following activities
- Total slack or total float is the amount of time an activity may be delayed from its early start without delaying the planned project finish date

Determining the Critical Path



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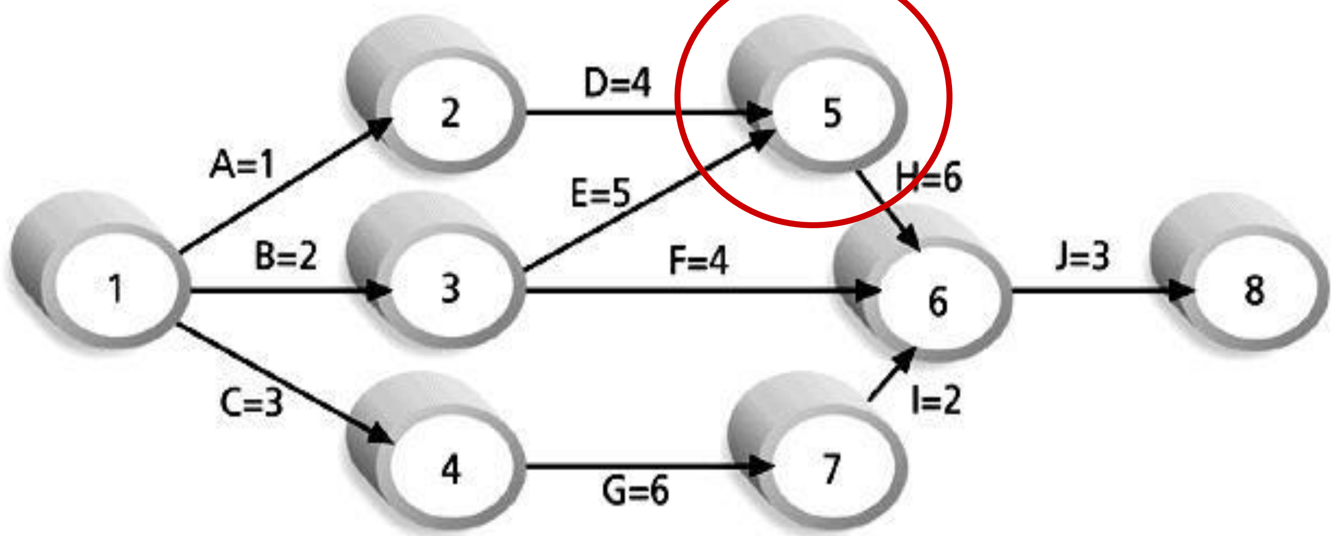
Free and Total Float or Slack

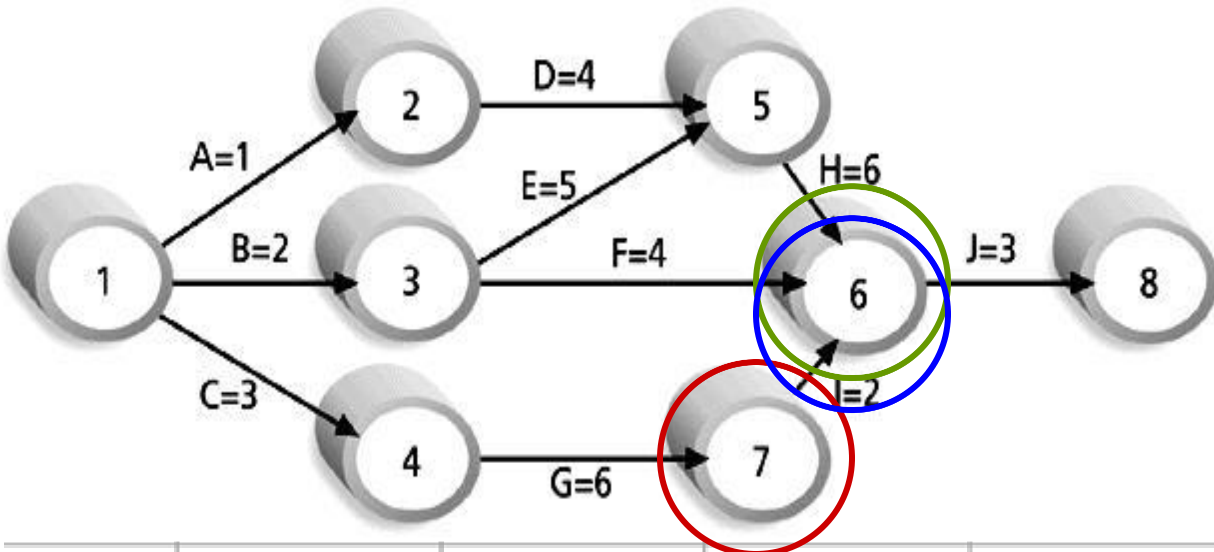
Task	Start	Finish	Late Start	Late Finish	Free Slack	Total Slack
A	6/2/02	6/2/02	6/4/02	6/4/02	0d	2d
B	6/2/02	6/3/02	6/2/02	6/3/02	0d	0d
C	6/2/02	6/4/02	6/4/02	6/6/02	0d	2d
D	6/3/02	6/6/02	6/5/02	6/10/02	2d	2d
E	6/4/02	6/10/02	6/4/02	6/10/02	0d	0d
F	6/4/02	6/9/02	6/13/02	6/18/02	7d	7d
G	6/5/02	6/12/02	6/9/02	6/16/02	0d	2d
H	6/11/02	6/18/02	6/11/02	6/18/02	0d	0d
I	6/13/02	6/16/02	6/17/02	6/18/02	2d	2d
J	6/19/02	6/23/02	6/19/02	6/23/02	0d	0d

Free and Total Float or Slack

Task	Start	Finish	Late Start	Late Finish	Free Slack
A	6/2/02	6/2/02	6/4/02	6/4/02	0d
B	6/2/02	6/3/02	6/2/02	6/3/02	0d
C	6/2/02	6/4/02	6/4/02	6/6/02	0d
D	6/3/02	6/6/02	6/5/02	6/10/02	2d
E	6/4/02	6/10/02	6/4/02	6/10/02	0d
F					
G					
H					
I					
J					



Free and Total Float or Slack



					Free Slack
					0d
					0d
					0d
					2d
					0d
F	6/4/02	6/9/02	6/13/02	6/18/02	7d
G	6/5/02	6/12/02	6/9/02	6/16/02	0d
H	6/11/02	6/18/02	6/11/02	6/18/02	0d
I	6/13/02	6/16/02	6/17/02	6/18/02	2d
J	6/19/02	6/23/02	6/19/02	6/23/02	0d

Free and Total Float or Slack

Task	Start	Finish	Late Start	Late Finish	Free Slack	Total Slack
A	6/2/02	6/2/02	6/4/02	6/4/02	0d	2d
B	6/2/02	6/3/02	6/2/02	6/3/02	0d	0d
C	6/2/02	6/4/02	6/4/02	6/6/02	0d	2d
D	6/3/02	6/6/02	6/5/02	6/10/02	2d	2d
E	6/4/02	6/10/02	6/4/02	6/10/02	0d	0d
F	6/4/02	6/9/02	6/13/02	6/18/02	7d	7d
G	6/5/02	6/12/02	6/9/02	6/16/02	0d	2d
H	6/11/02	6/18/02	6/11/02	6/18/02	0d	0d
I	6/13/02	6/16/02	6/17/02	6/18/02	2d	2d
J	6/19/02	6/23/02	6/19/02	6/23/02	0d	0d

Techniques for Shortening a Project Schedule

- Shortening durations of critical tasks for adding more resources or changing their scope
- *Crashing* tasks by obtaining the greatest amount of schedule compression for the least incremental cost
- *Fast tracking* tasks by doing them in parallel or overlapping them

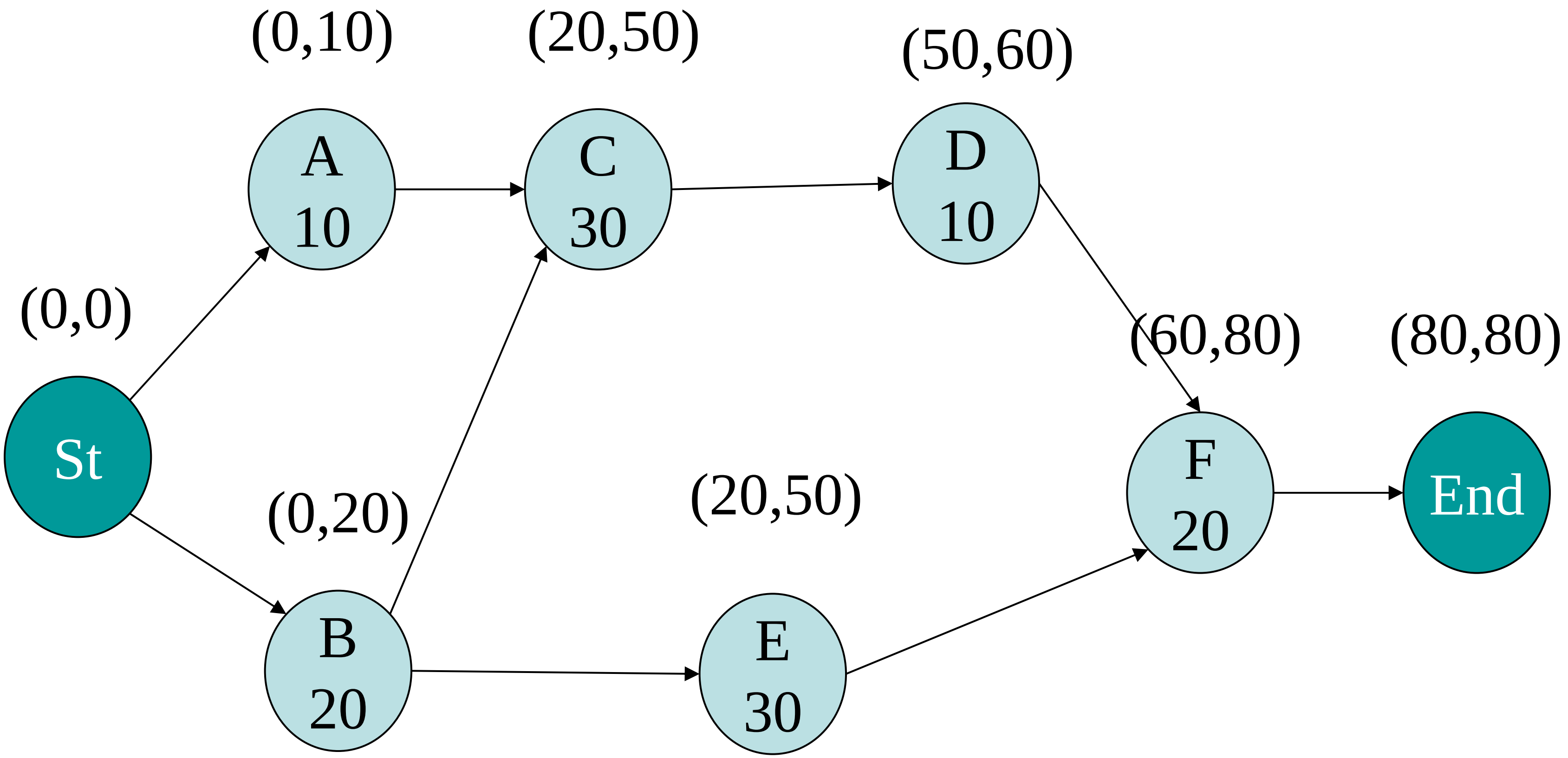
Importance of Updating Critical Path Data

- It is important to update project schedule information
- The critical path may change as you enter actual start and finish dates
- If you know the project completion date will slip, negotiate with the project sponsor

CPM and Float

- Float - the difference between the time available for a task and the time required to complete it
- two-path analysis
  - Forward pass
  - Backward pass
- For forward pass
  - To calculate the earliest date on which each activity may be started and completed.
  - Start at the start node
  - Compute the top pair of numbers (started, completed)
  - Always add the duration to the connecting node's earliest finish time
- Forward pass
  - Start with the node which being with zeros – both earliest start and earliest finish.
  - At node A the earliest start time will be zero and the earliest finish time will be zero plus task duration of A

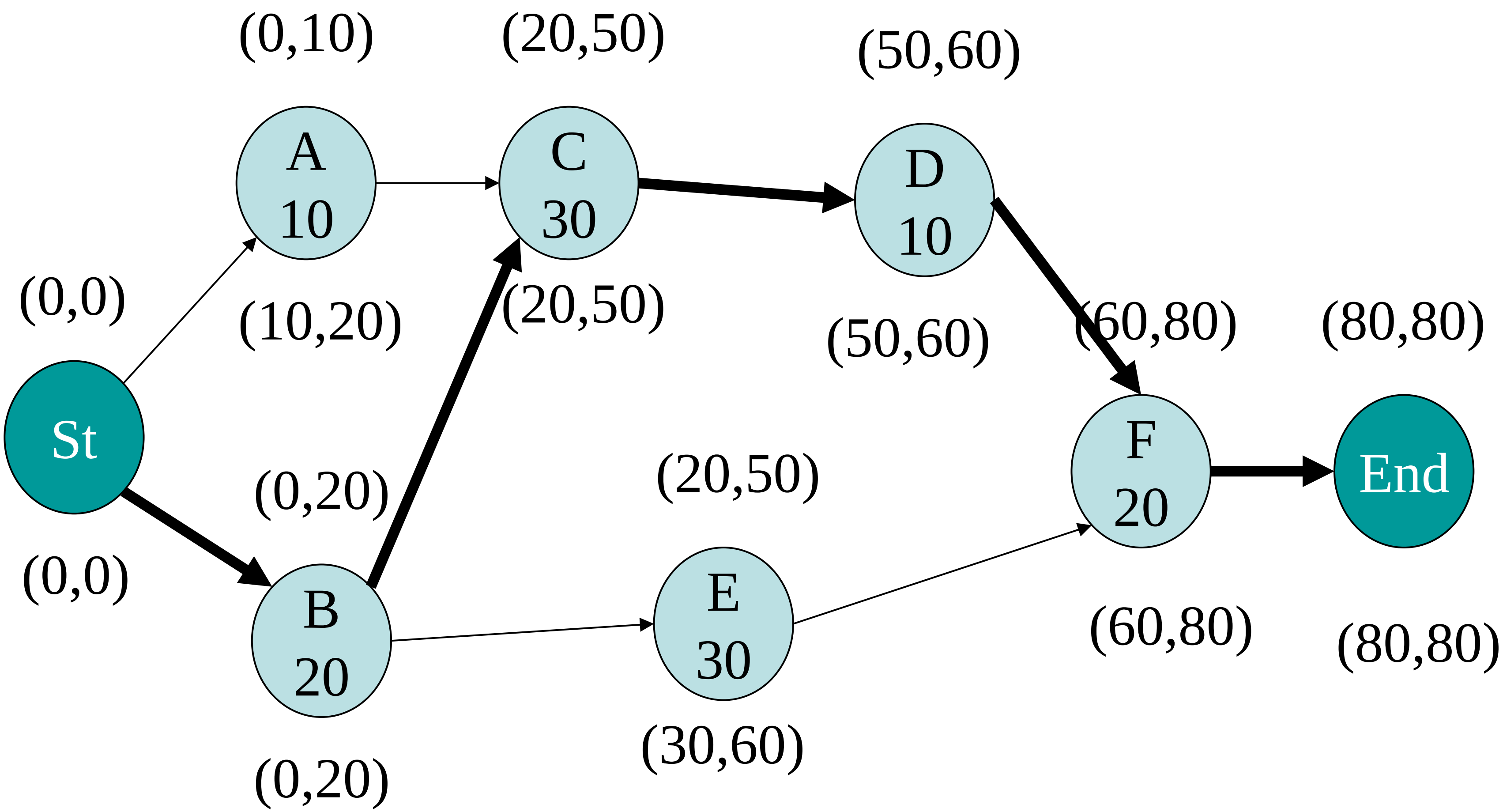
Float – Forward Pass



Float – Backward Pass

- For backward pass
  - To calculate the latest date on which each activity may be started and completed.
  - Start at the end node
  - Compute the bottom pair of numbers
  - Always subtract the duration from the connecting node’s earliest start time
- Backward pass
  - Starting at the end node, calculate the latest start and finish
  - For end node (80,80)
  - For node F the latest start time will be the finish time of 80 – the duration of F (20) so it will be 60

Float – Backward Pass



PERT

- Program Evaluation and Review Technique
- PERT was developed for US navy special projects office polaris missile submarine project by consultants Booz, Allen, and Hamilton
- PERT is a network analysis technique used to estimate project duration when there is a high degree of uncertainty about the individual activity duration estimates
- Estimates involve beta probability distribution to capture three estimates of activity durations
  - optimistic, most likely, and pessimistic

- Beta distribution a.k.a Murphy's law distribution
  - "When things go badly, they go very badly"
- There is no chance at all of an actual duration being zero or infinity. If the actual duration is shorter than the most likely, it will not be much shorter, but if it is longer then it could be a lot longer
- Expected duration:

$$\frac{\text{OD x OWF + MD X MWF + PD x PWF}}{\text{OWF+MWF+PWF}}$$

PERT Formula and Example

- PERT weighted average formula:

$$\frac{\text{optimistic time} + 4\text{X most likely time} + \text{pessimistic time}}{6}$$

- Example:

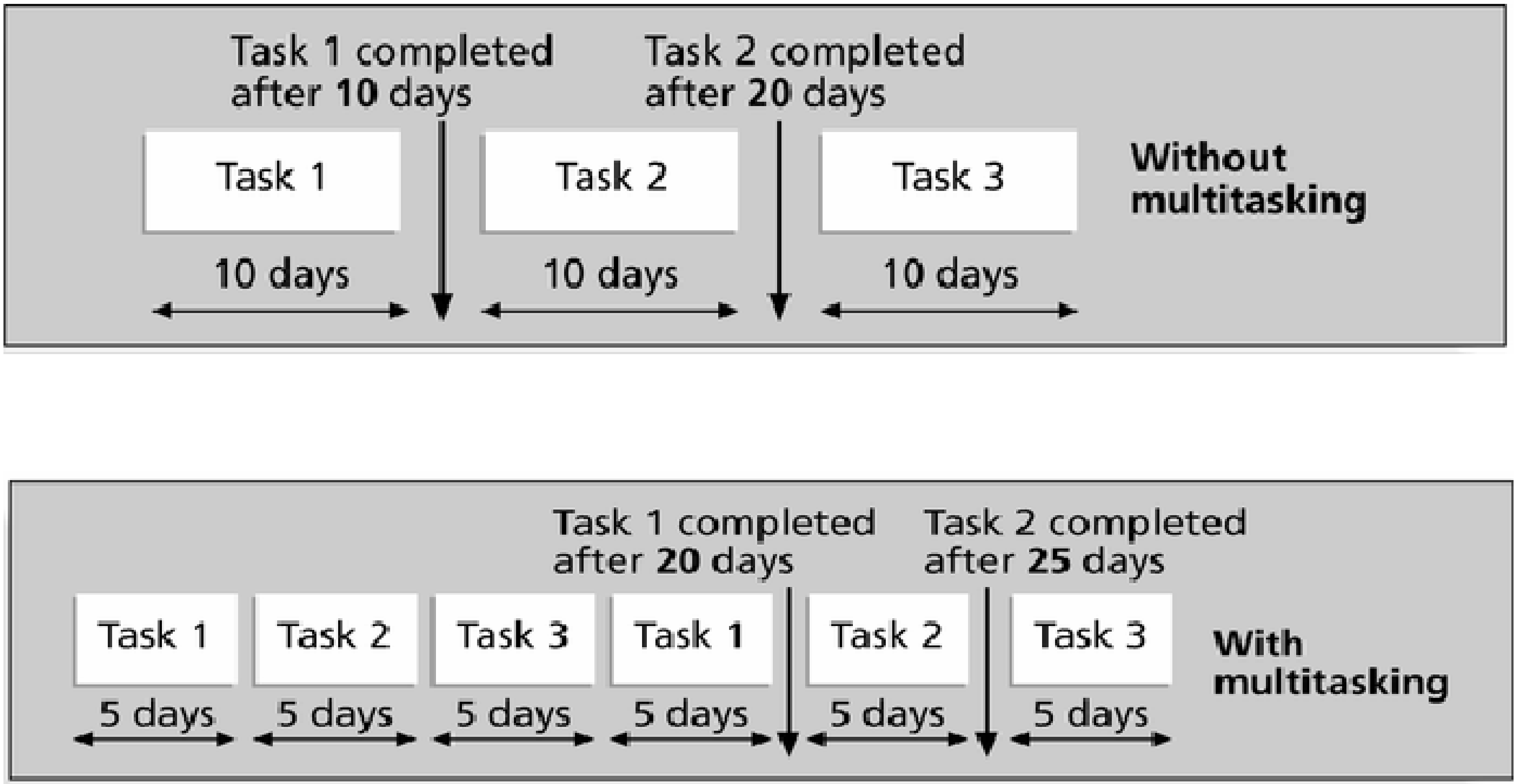
$$\frac{\text{8 workdays} + 4 \text{ X } \text{10 workdays} + \text{24 workdays}}{6} = \text{12 days}$$

where 8 = optimistic time, 10 = most likely time, and 24 = pessimistic time

Critical Chain Scheduling

- Critical chain scheduling is a method of scheduling that takes limited resources into account when creating a project schedule and includes buffers to protect the project completion date
- Critical chain scheduling assumes resources do not multitask because it often delays task completions and increases total durations
- The Critical Chain of a project is defined as the longest sequence of dependent events that prevents the project plan from being any shorter.
  - precedence dependencies
  - resource dependencies

Multitasking Example



Buffers and Critical Chain

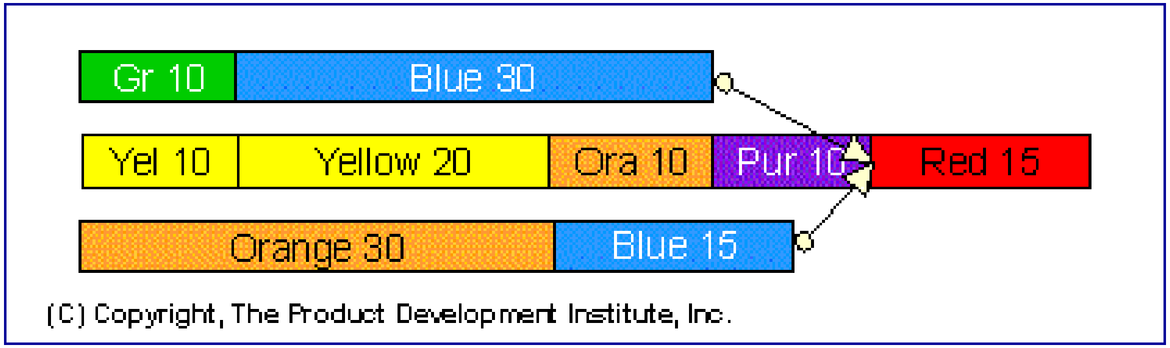
- A buffer is additional time to complete a task
- Murphy’s Law states that if something can go wrong, it will
- Parkinson’s Law states that work expands to fill the time allowed.
- In traditional estimates, people often add a buffer and use it if it’s needed or not
- Critical chain schedule removes buffers from individual tasks and instead creates
  - A project buffer, which is additional time added before the project’s due date
  - Feeding buffers, which are additional time added before tasks on the critical path

Steps in Critical Chain

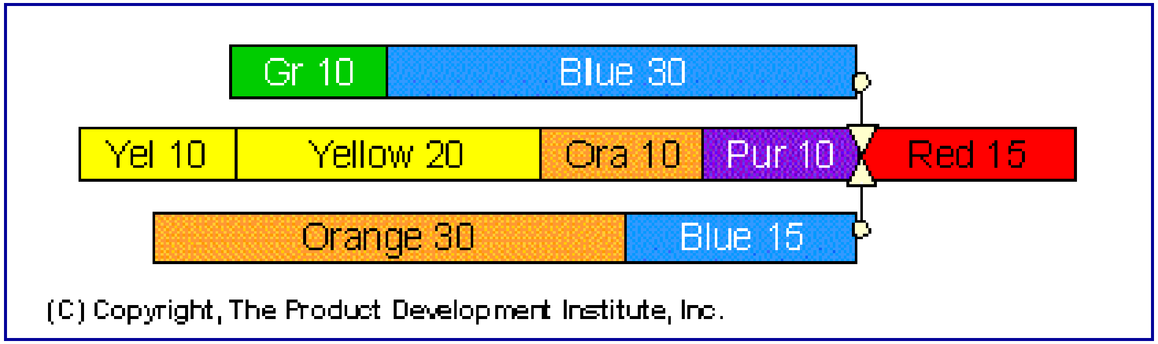
- Develop <u>late start</u> schedule using <u>average</u> task durations
- Eliminate resource contentions
- Identify critical chain(s)
- Insert feeding buffers
- Insert project buffer

An Example

Three paths, nine tasks and six resources

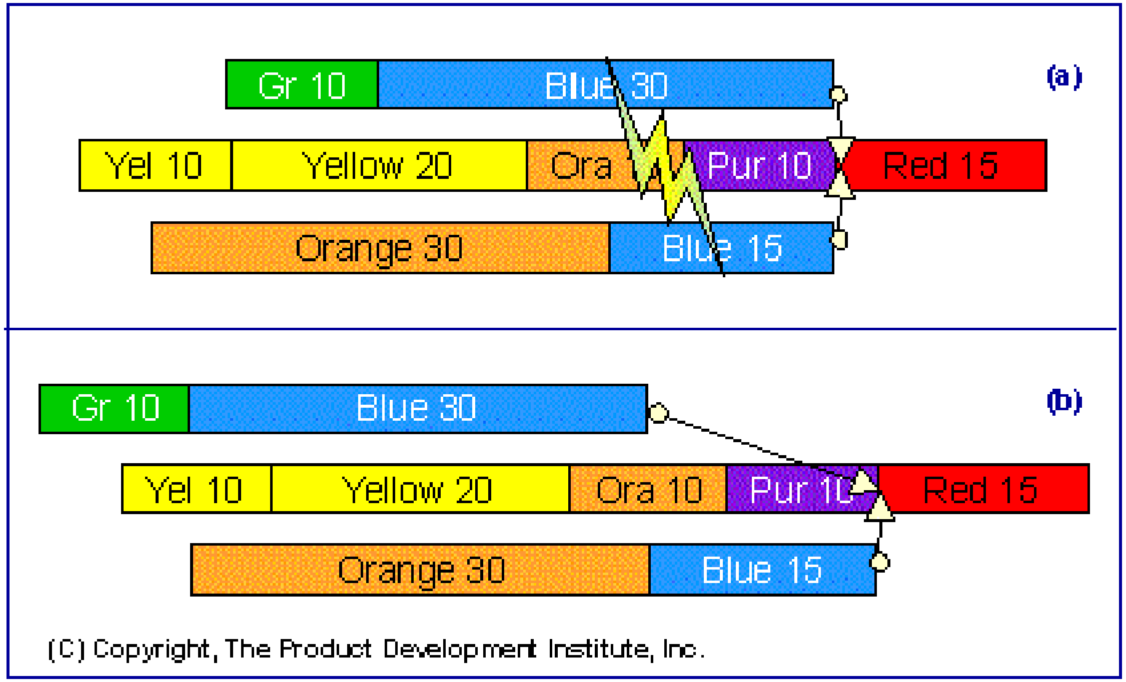


Late start schedule



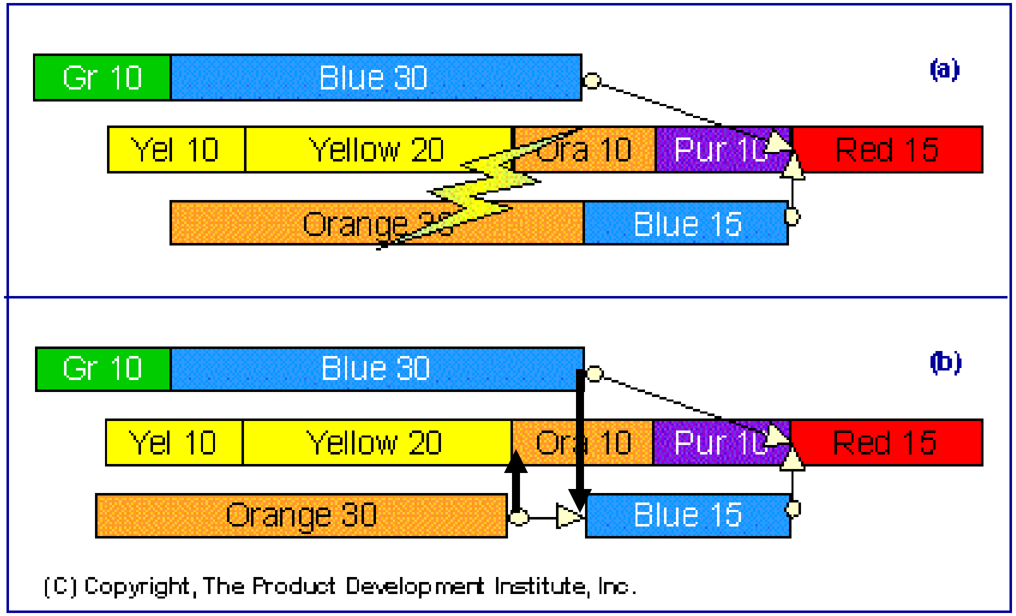
Resource Conflicts

Eliminate resource contentions, blue and orange

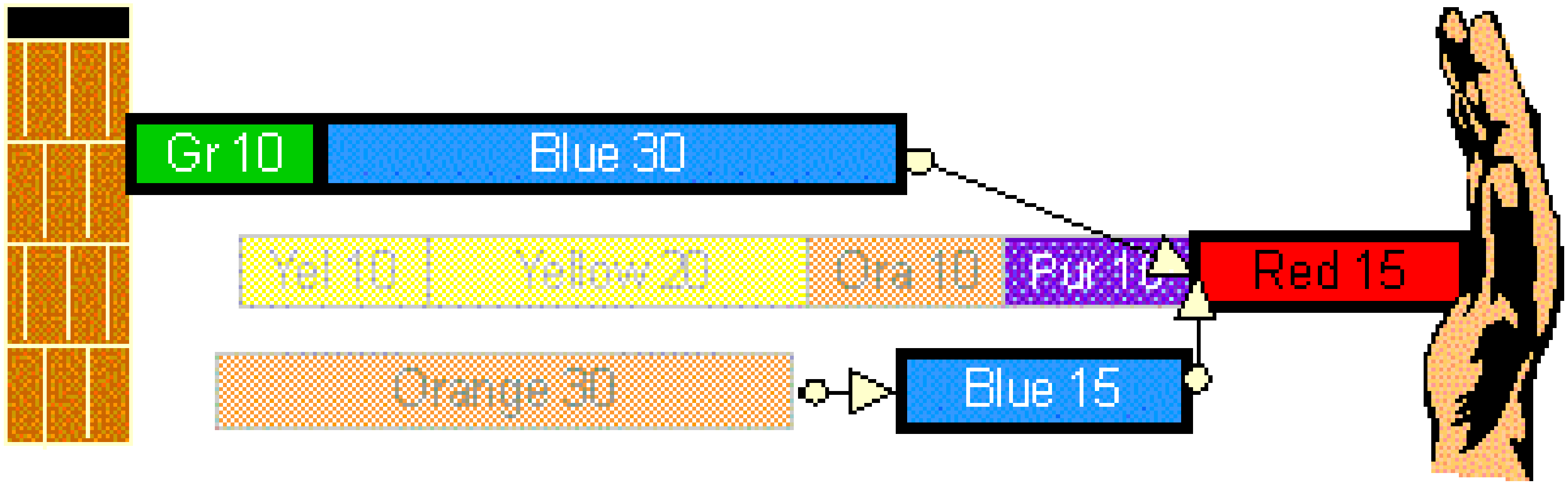


Resolve Contentions

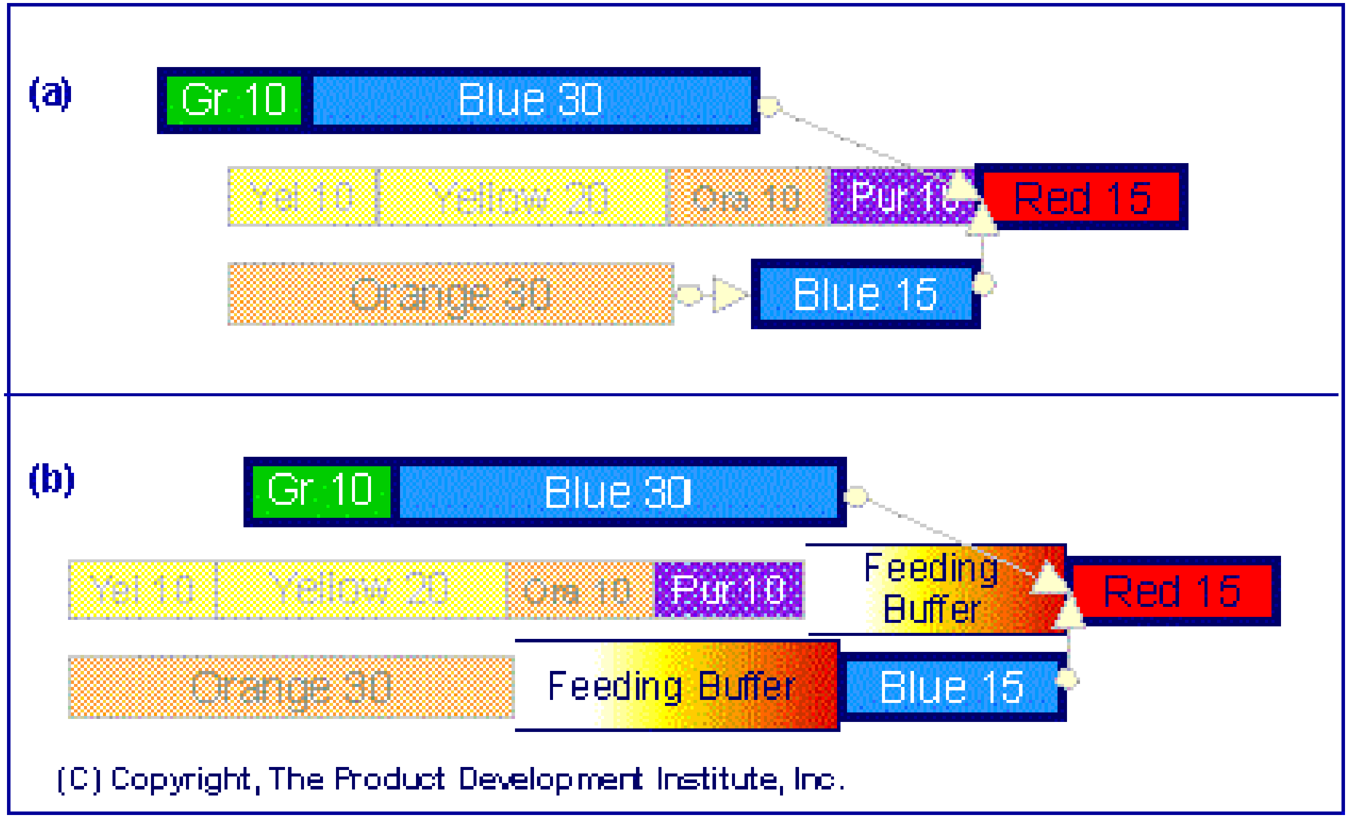
Add two artificial precedence relations



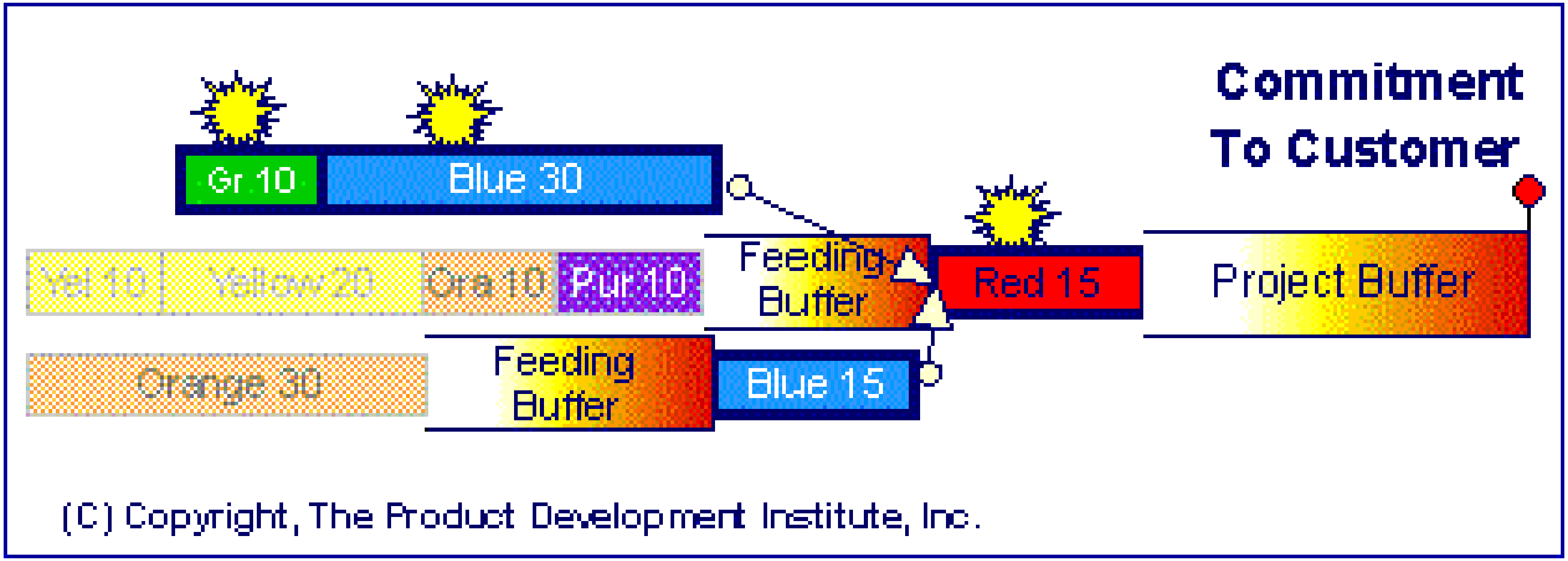
Determine Critical Chain



Insert Feeding Buffers



Insert Project Buffer



Q&A