Routing, Scheduling

Aspects of Production Planning

Planning

Routing

Scheduling

Loading

Routing, Scheduling

Planning

Production planning may be defined as the technique of foreseeing every step in a long series of separate operations, each step to be taken at the right time and in the right place and each operation to be performed in maximum efficiency. It helps to work out the quantity of material manpower, machine and money requires for producing predetermined level of output in given period of time.

Routing, Scheduling

Routing

Under this, the operations, their path and sequence are established. To perform these operations the proper class of machines and personnel required are also worked out. The main aim of routing is to determine the best and cheapest sequence of operations and to ensure that this sequence is strictly followed.

Routing procedure involves following different activities.

(1) An analysis of the article to determine what to make and what to buy.

(2) To determine the quality and type of material

(3) Determining the manufacturing operations and their sequence.

(4) Determination of lot sizes

(5) Determination of scrap factors

(6) Analysis of cost of the article

(7) Organization of production control forms.

Routing, Scheduling

Scheduling

It means working out of time that should be required to perform each operation and also the time necessary to perform the entire series as routed, making allowances for all factors concerned. It mainly concerns with time element and priorities of a job. The pattern of scheduling differs from one job to another

Production schedule:
The main aim is to schedule that amount of work which can easily be handled by plant and equipment without interference. It takes into account following factors.
(1) Plant facilities of the type required to process the material being scheduled.
(2) Personnel with desired skills and experience to operate the equipment
(3) Necessary materials and purchased parts.

Master Schedule:
Scheduling usually starts with preparation of master schedule which is weekly or monthly break-down of the production requirement for each product. A master schedule is followed by **operator schedule** which fixes total time required to do a piece of work with a given machine and then by **Manufacturing Schedule**

Production Planning and Control

Loading

Loading is the execution of the schedule plan as per the route chalked out it includes the assignment of the work to the operators at their machines or work places. So loading determines who will do the work as routing determines where and scheduling determines when it shall be done.

Gantt Charts are most commonly used in small industries in order to determine the existing load and also to foresee how fast a job can be done. The usefulness of their technique lies in the fact that they compare what has been done and what ought to have been done.

CPM/PERT

Scheduling and Control Techniques

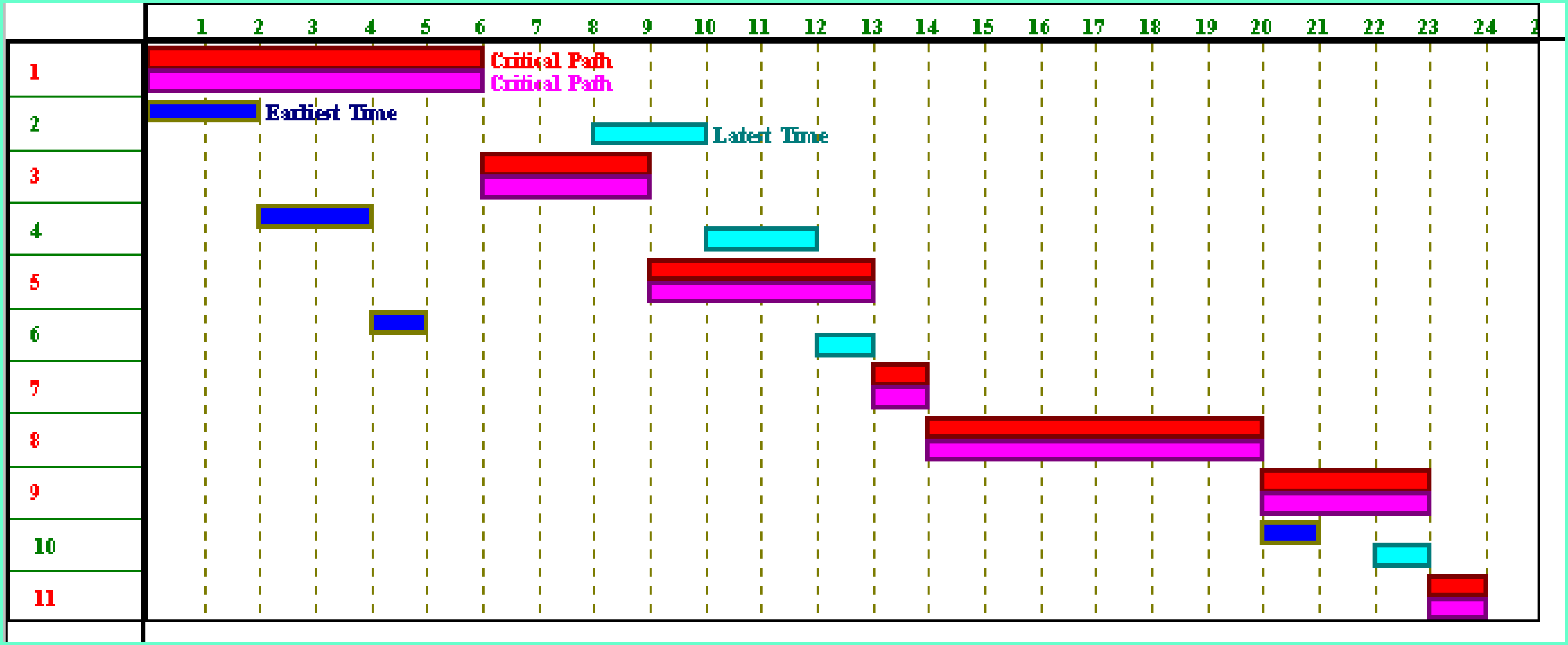
Gantt Chart

Critical Path Method (CPM)

Program Evaluation and Review Technique (PERT)

Gantt Chart

- Graph or bar chart with a bar for each project activity that shows passage of time
- Provides visual display of project schedule



History of CPM/PERT

- Critical Path Method (CPM)
  - E I Du Pont de Nemours & Co. (1957) for construction of new chemical plant and maintenance shut-down
  - Deterministic task times
  - Activity-on-node network construction
  - Repetitive nature of jobs
- Project Evaluation and Review Technique (PERT)
  - U S Navy (1958) for the POLARIS missile program
  - Multiple task time estimates (probabilistic nature)
  - Activity-on-arrow network construction
  - Non-repetitive jobs (R & D work)

Project Network

- Network analysis is the general name given to certain specific techniques which can be used for the planning, management and control of projects

- Use of nodes and arrows

  Arrows An arrow leads from tail to head directionally

  – Indicate ACTIVITY, a time consuming effort that is required to perform a part of the work.

  Nodes A node is represented by a circle

  - Indicate EVENT, a point in time where one or more activities start and/or finish.

- Activity
  – A task or a certain amount of work required in the project
  – Requires time to complete
  – Represented by an arrow

- Dummy Activity
  – Indicates only precedence relationships
  – Does not require any time of effort

Project Network

- Event
  - Signals the beginning or ending of an activity
  - Designates a point in time
  - Represented by a circle (node)
- Network
  - Shows the sequential relationships among activities using nodes and arrows

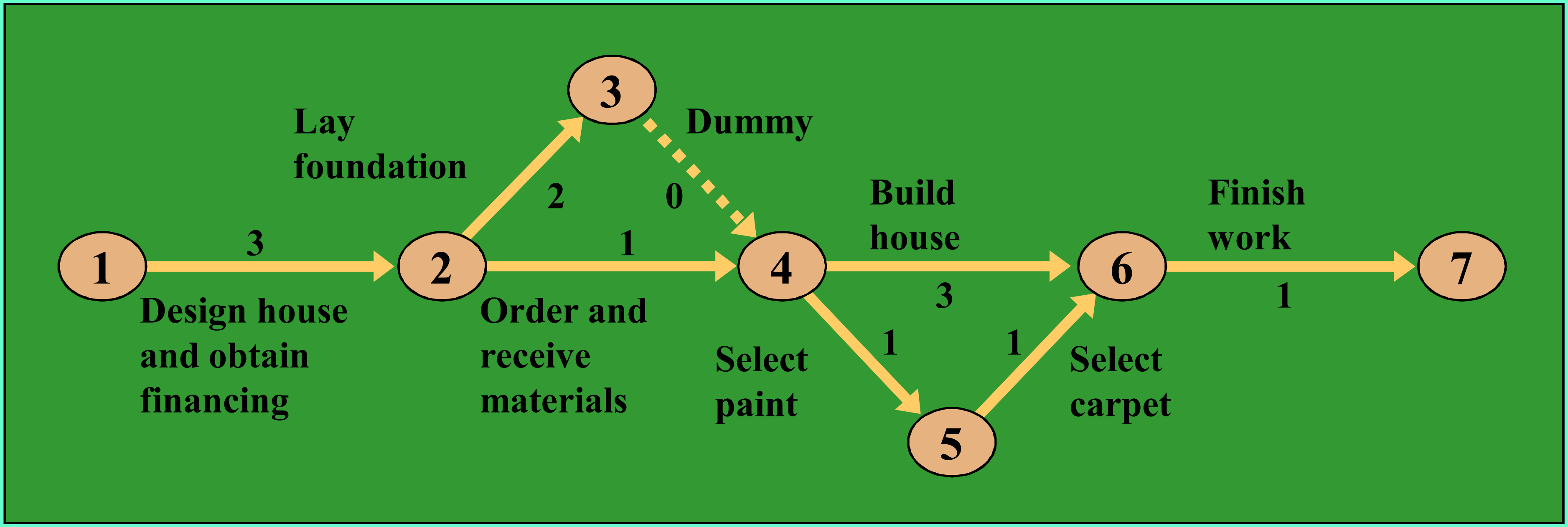
- Activity-on-node (AON)

  nodes represent activities, and arrows show precedence relationships

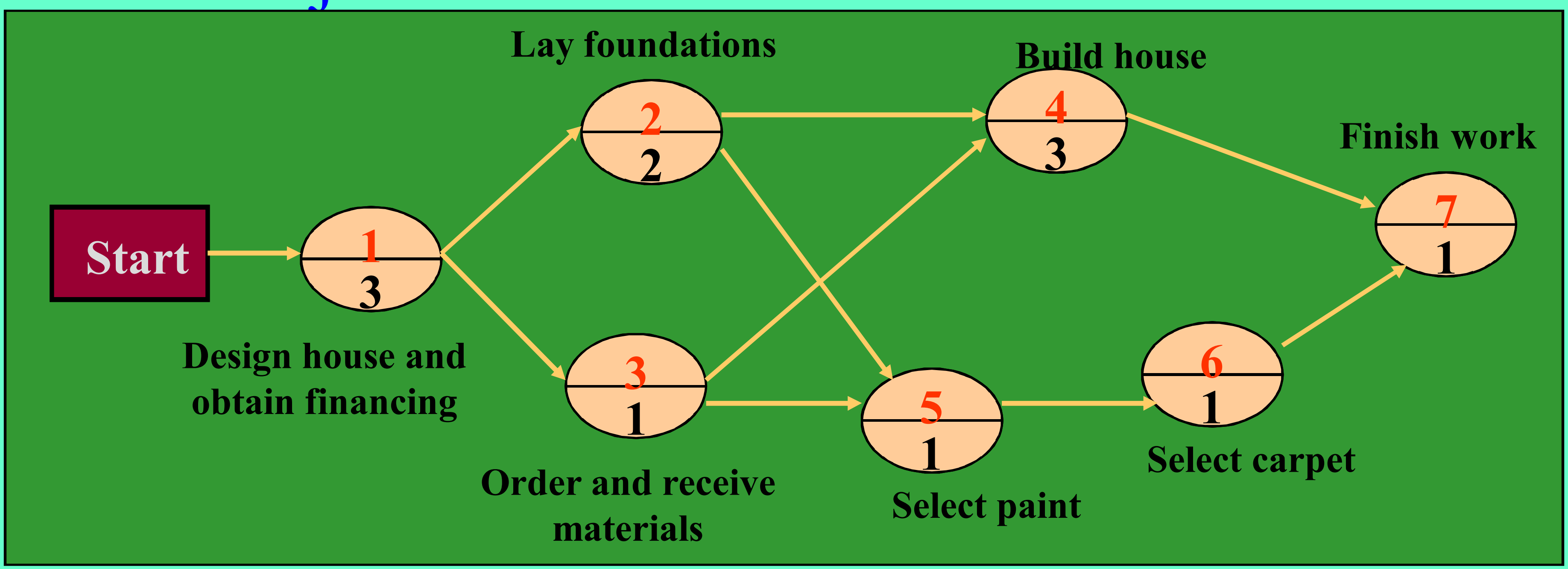
- Activity-on-arrow (AOA)

  arrows represent activities and nodes are events for points in time

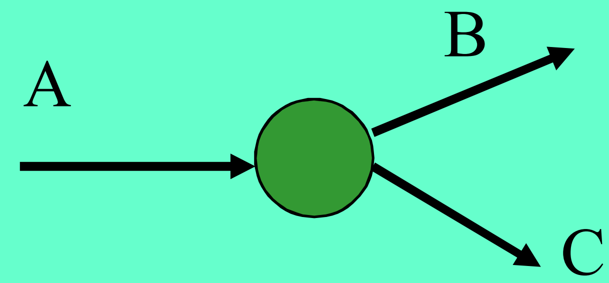
AOA Project Network for House



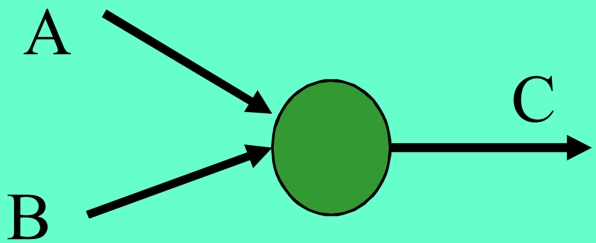
AON Project Network for House



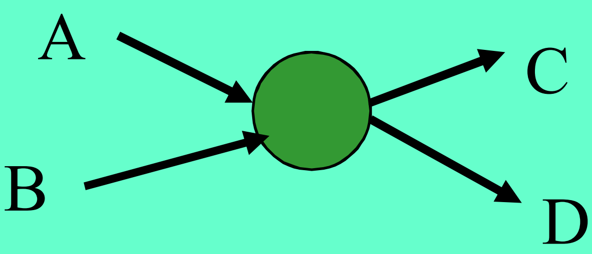
Situations in network diagram



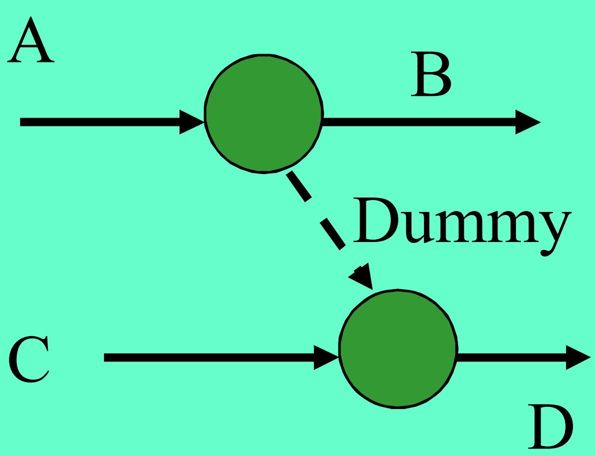
A must finish before either B or C can start



both A and B must finish before C can start



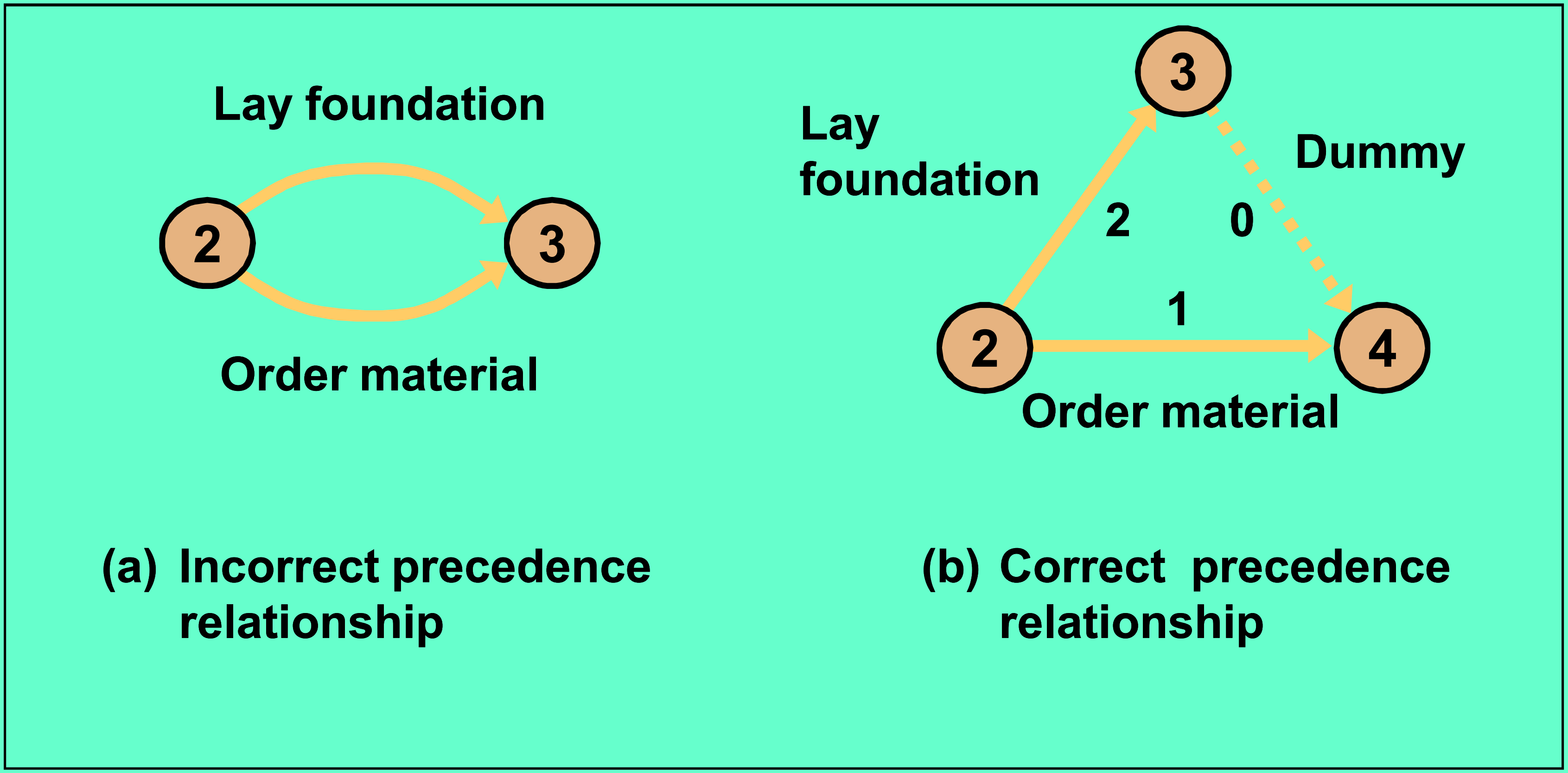
both A and C must finish before either of B or D can start



A must finish before B can start

both A and C must finish before D can start

Concurrent Activities



Network example

Illustration of network analysis of a minor redesign of a product and its associated packaging.

The key question is: How long will it take to complete this project ?

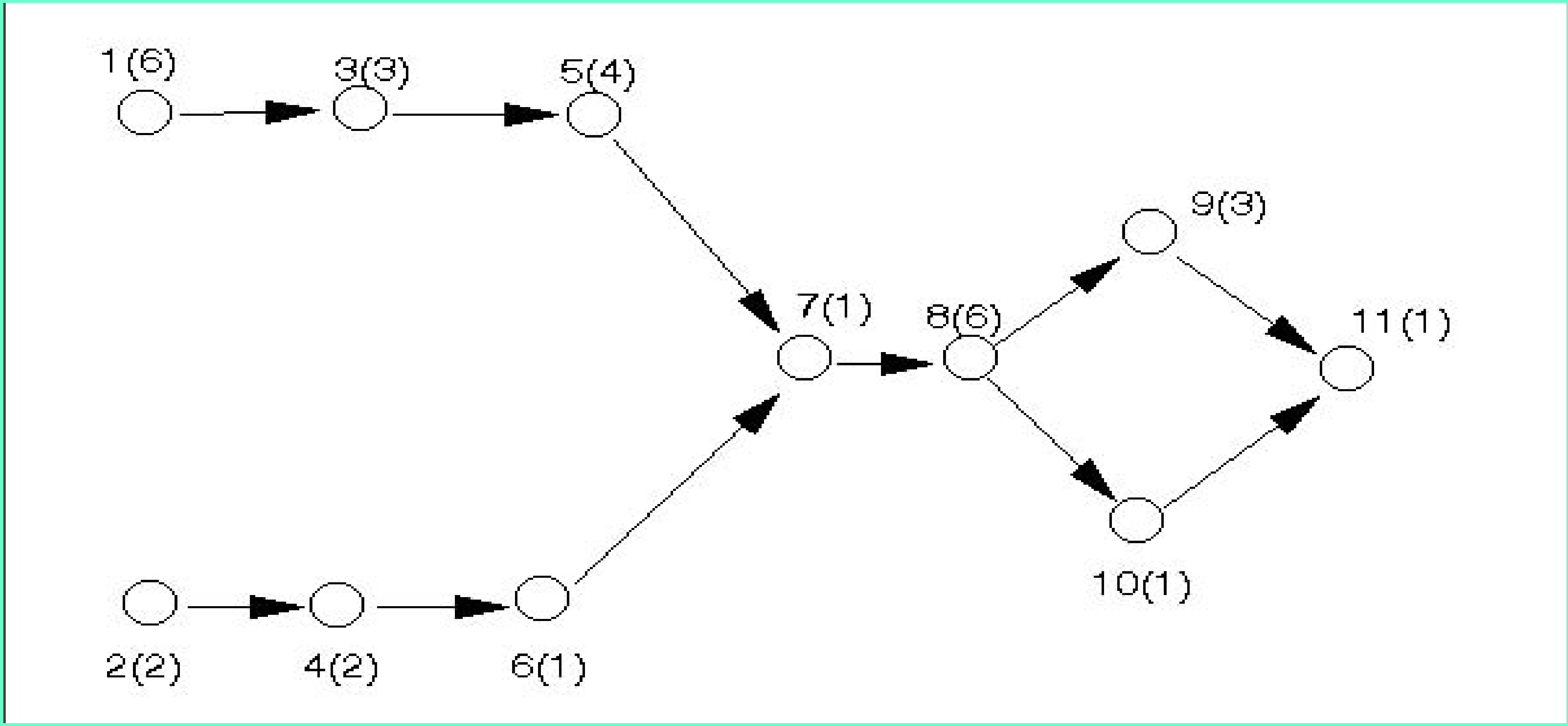
Activity number		Completion time (weeks)
1	Redesign product	6
2	Redesign packaging	2
3	Order and receive components for redesigned product	3
4	Order and receive material for redesigned packaging	2
5	Assemble products	4
6	Make up packaging	1
7	Package redesigned product	1
8	Test market redesigned product	6
9	Revise redesigned product	3
10	Revise redesigned packaging	1
11	Present results to the Board	1

For clarity, this list is kept to a minimum by specifying only immediate relationships, that is relationships involving activities that "occur near to each other in time".

Activity number		Activity number	
1	must be finished before	3	can start
2		4	
3		5	
4		6	
5,6		7	
7		8	
8		9	
8		10	
9,10		11	

Questions to prepare activity network

- Is this a Start Activity?
- Is this a Finish Activity?
- What Activity Precedes this?
- What Activity Follows this?
- What Activity is Concurrent with this?



CPM calculation

- Path
  - A connected sequence of activities leading from the starting event to the ending event
- Critical Path
  - The longest path (time); determines the project duration
- Critical Activities
  - All of the activities that make up the critical path

Forward Pass

- Earliest Start Time (ES)
  - earliest time an activity can start
  - ES = maximum EF of immediate predecessors
- Earliest finish time (EF)
  - earliest time an activity can finish
  - earliest start time plus activity time

$$EF = ES + t$$

Backward Pass

- Latest Start Time (LS)

  Latest time an activity can start without delaying critical path time

  $$LS = LF - t$$

- Latest finish time (LF)

  latest time an activity can be completed without delaying critical path time

  LS = minimum LS of immediate predecessors

CPM analysis

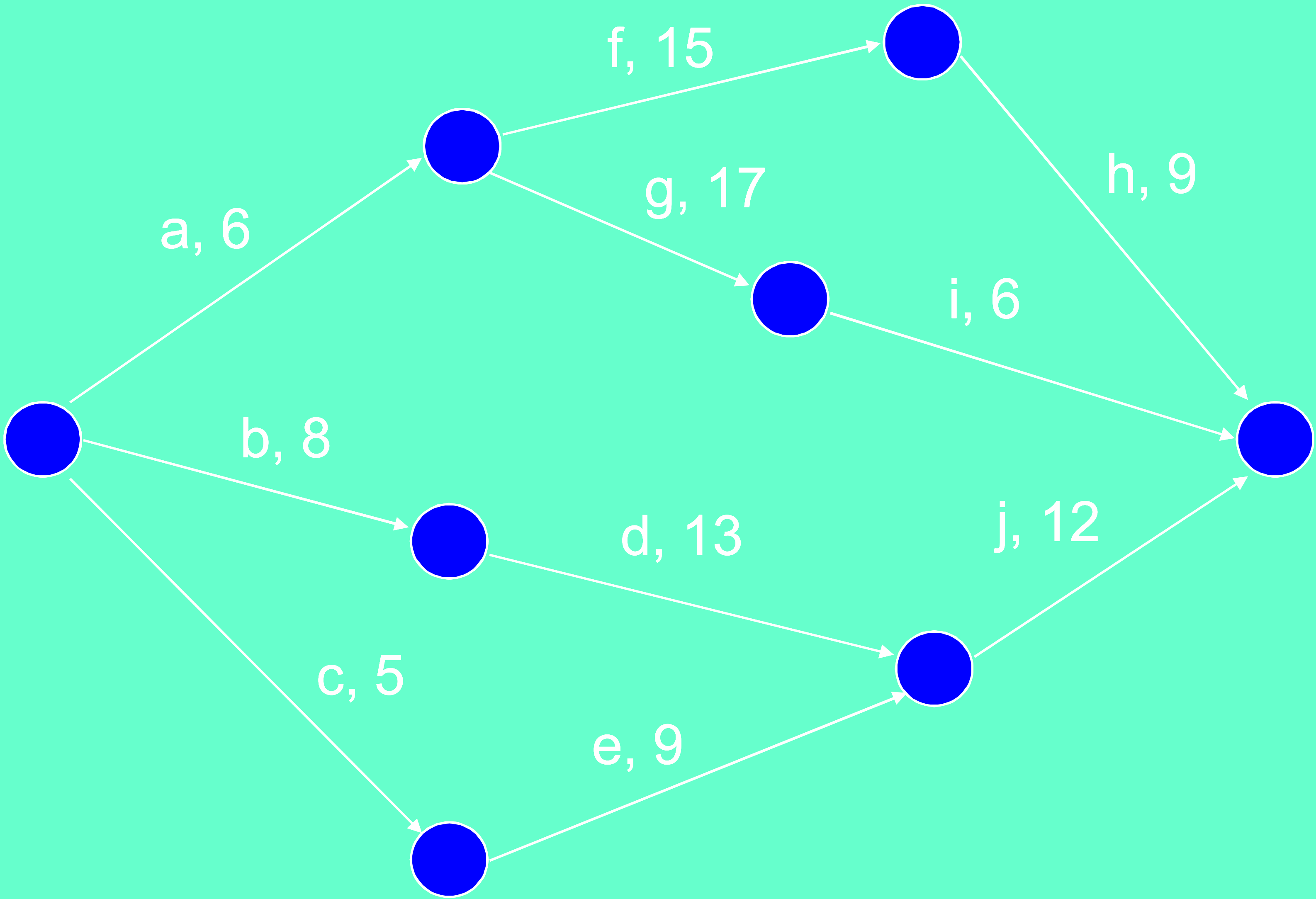
- Draw the CPM network
- Analyze the paths through the network
- Determine the float for each activity
  – Compute the activity's float

$$\text{float} = LS - ES = LF - EF$$

  – Float is the maximum amount of time that this activity can be delay in its completion before it becomes a critical activity, i.e., delays completion of the project
- Find the critical path is that the sequence of activities and events where there is no "slack" i.e.. Zero slack
  – Longest path through a network
- Find the project duration is minimum project completion time

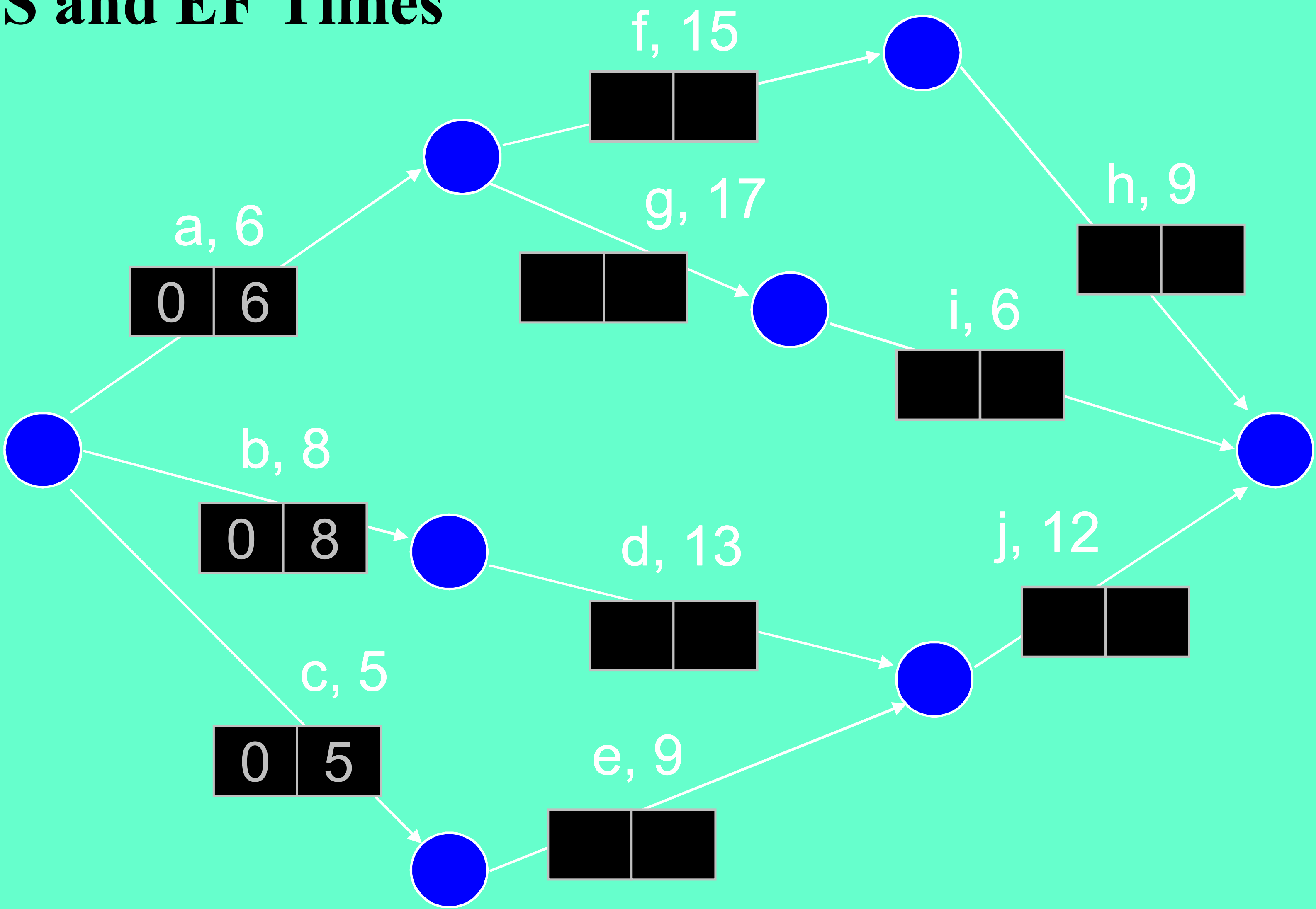
CPM Example:

- **CPM Network**



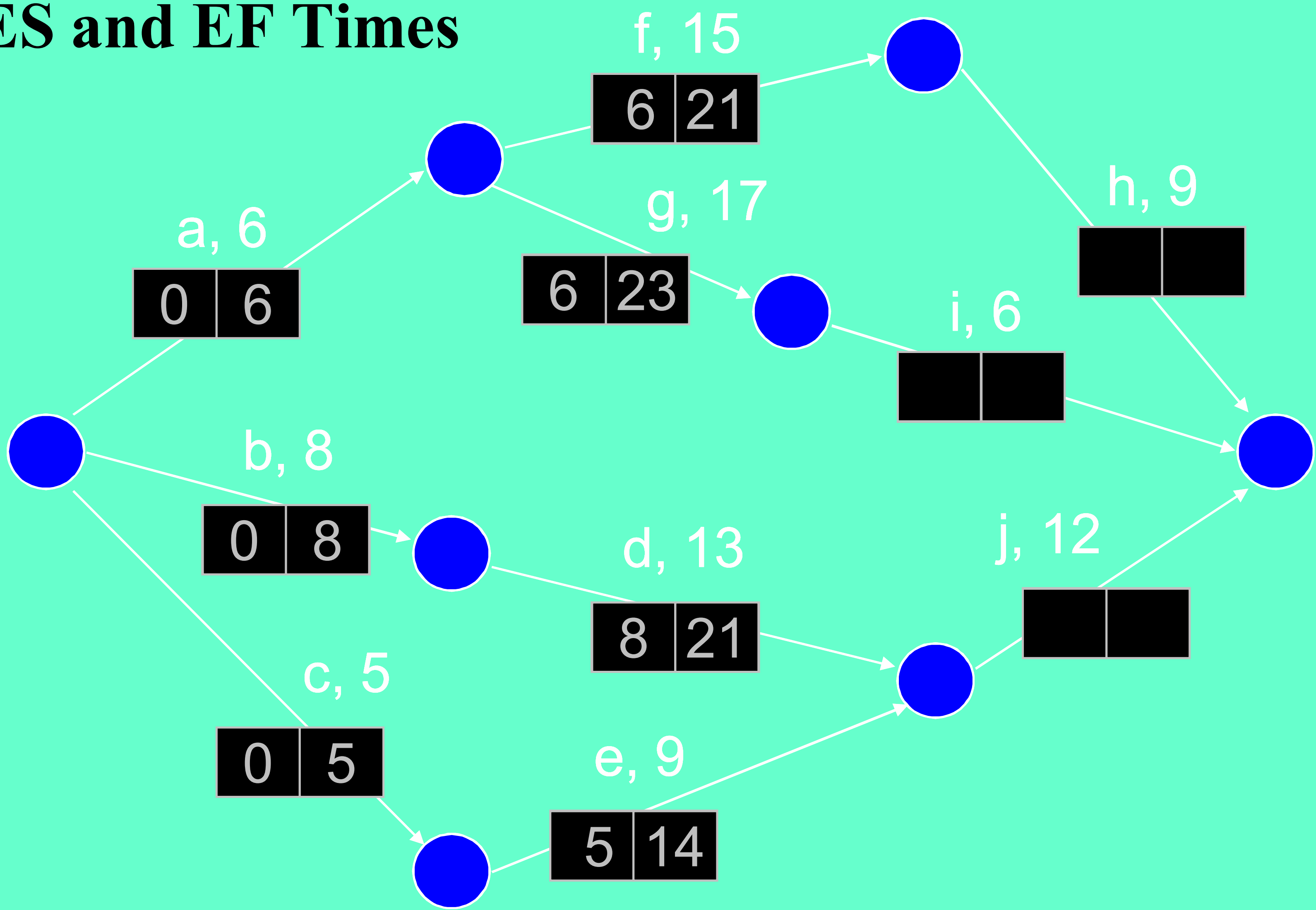
CPM Example

- **ES and EF Times**



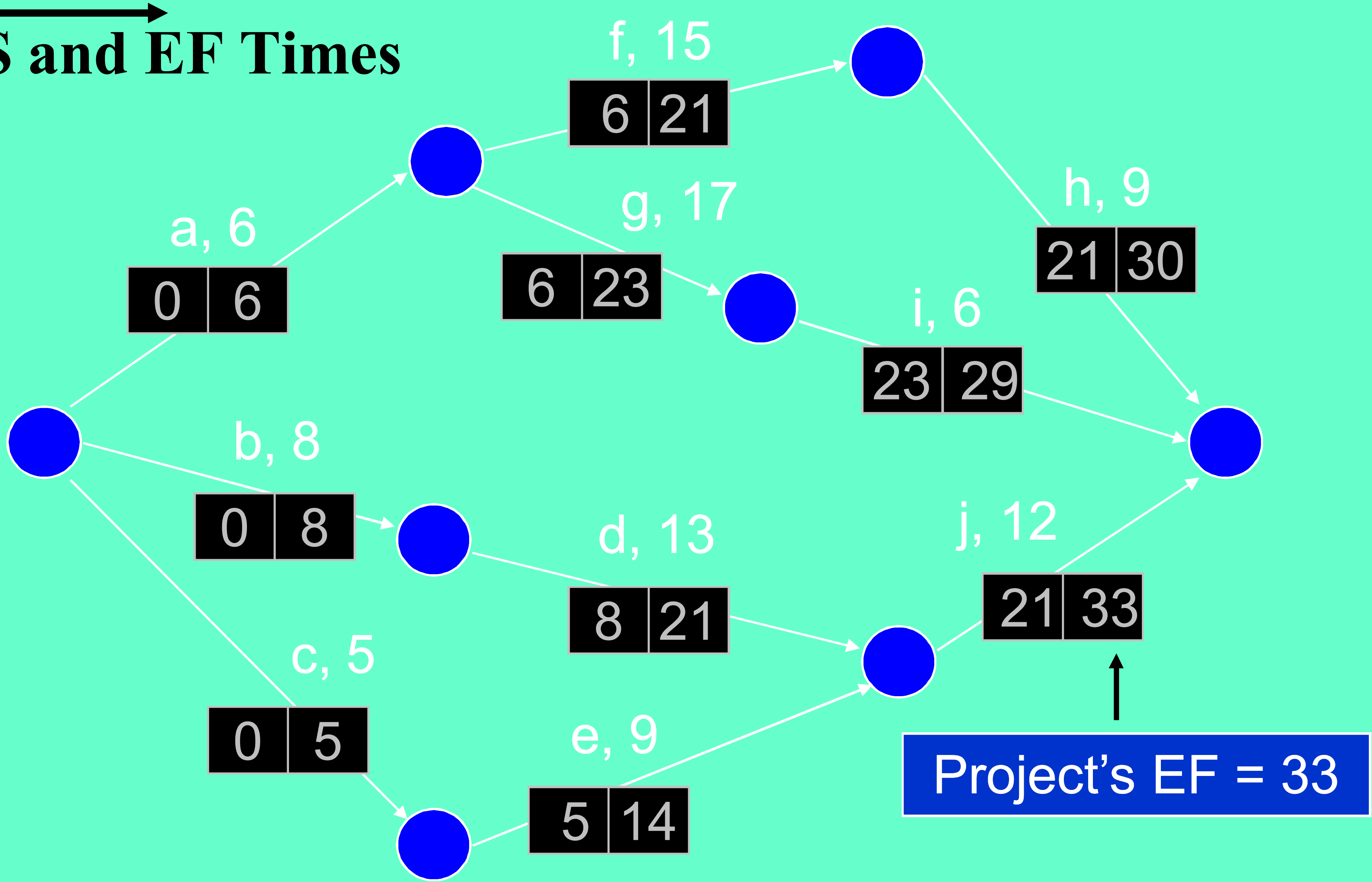
CPM Example

- **ES and EF Times**



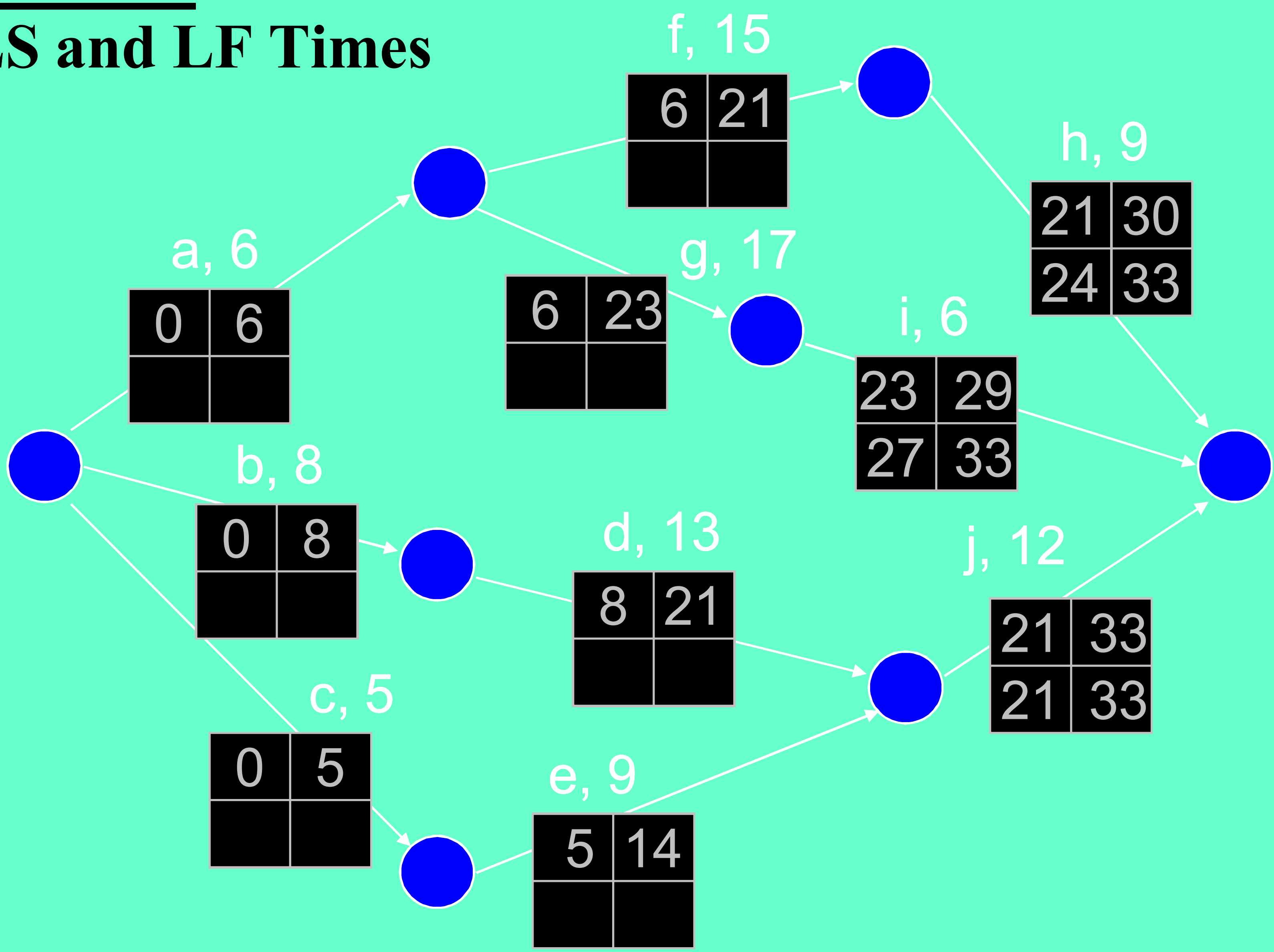
CPM Example

- **ES and EF Times**



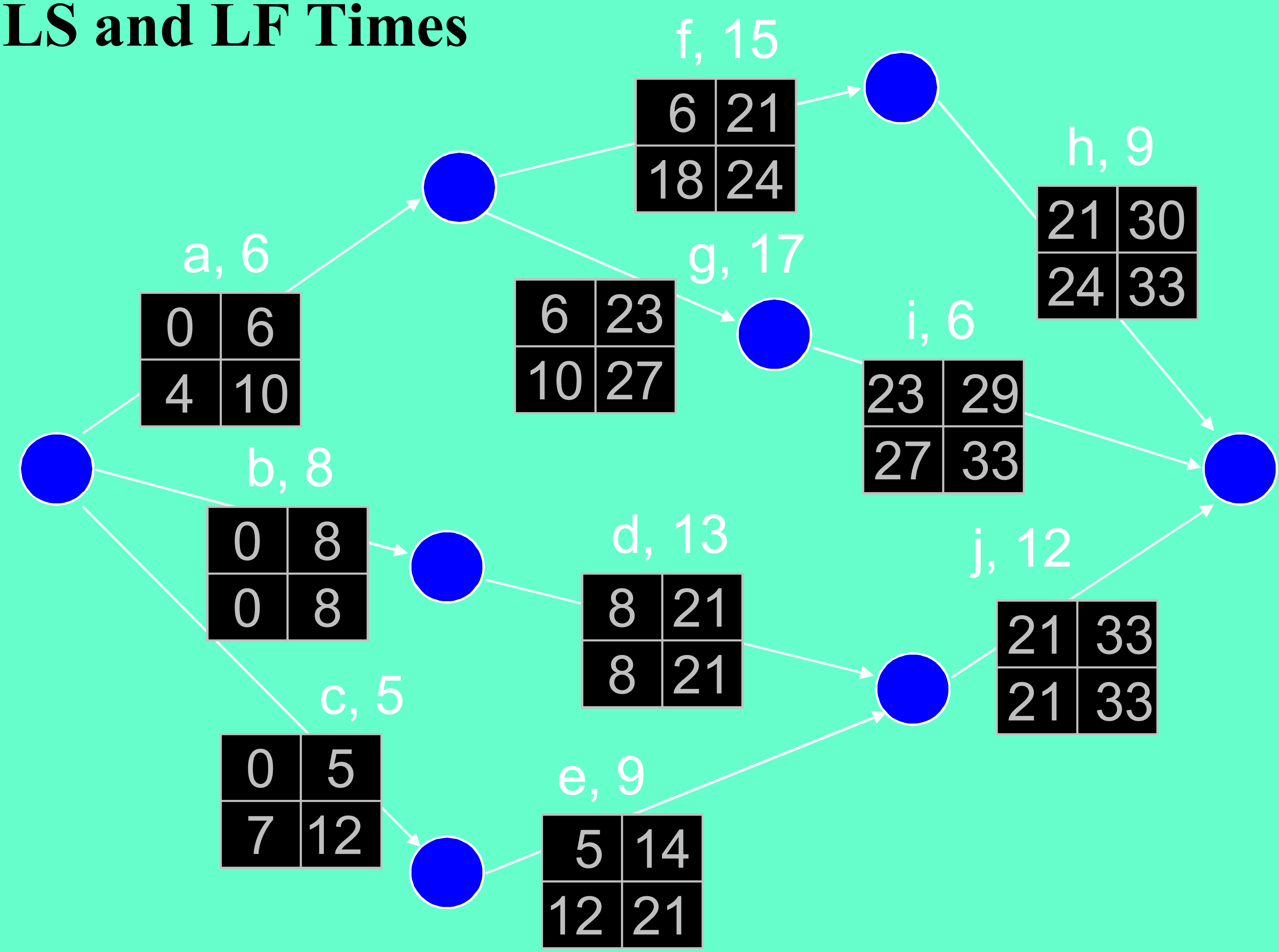
CPM Example

- **LS and LF Times**



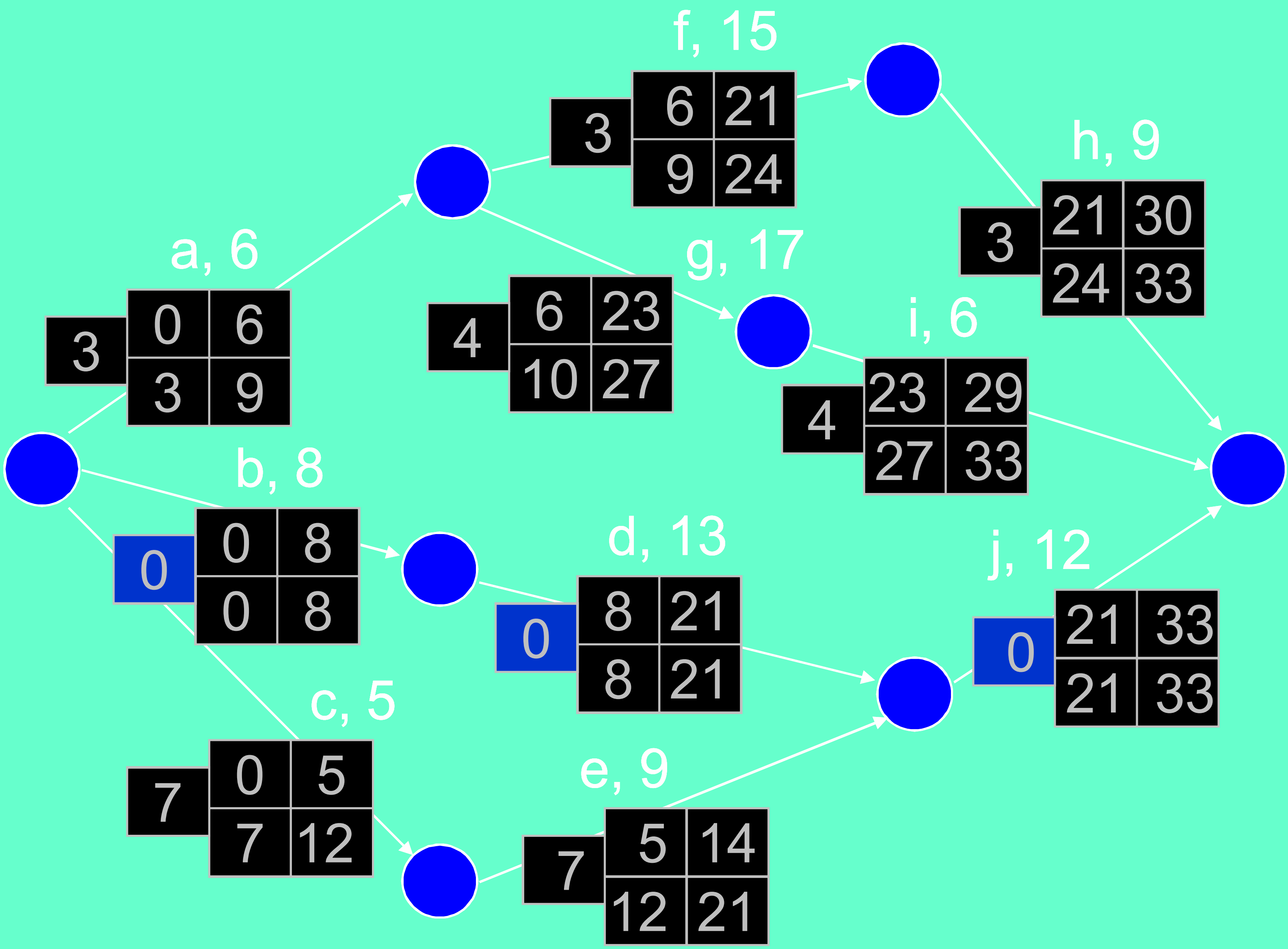
CPM Example

- **LS and LF Times**



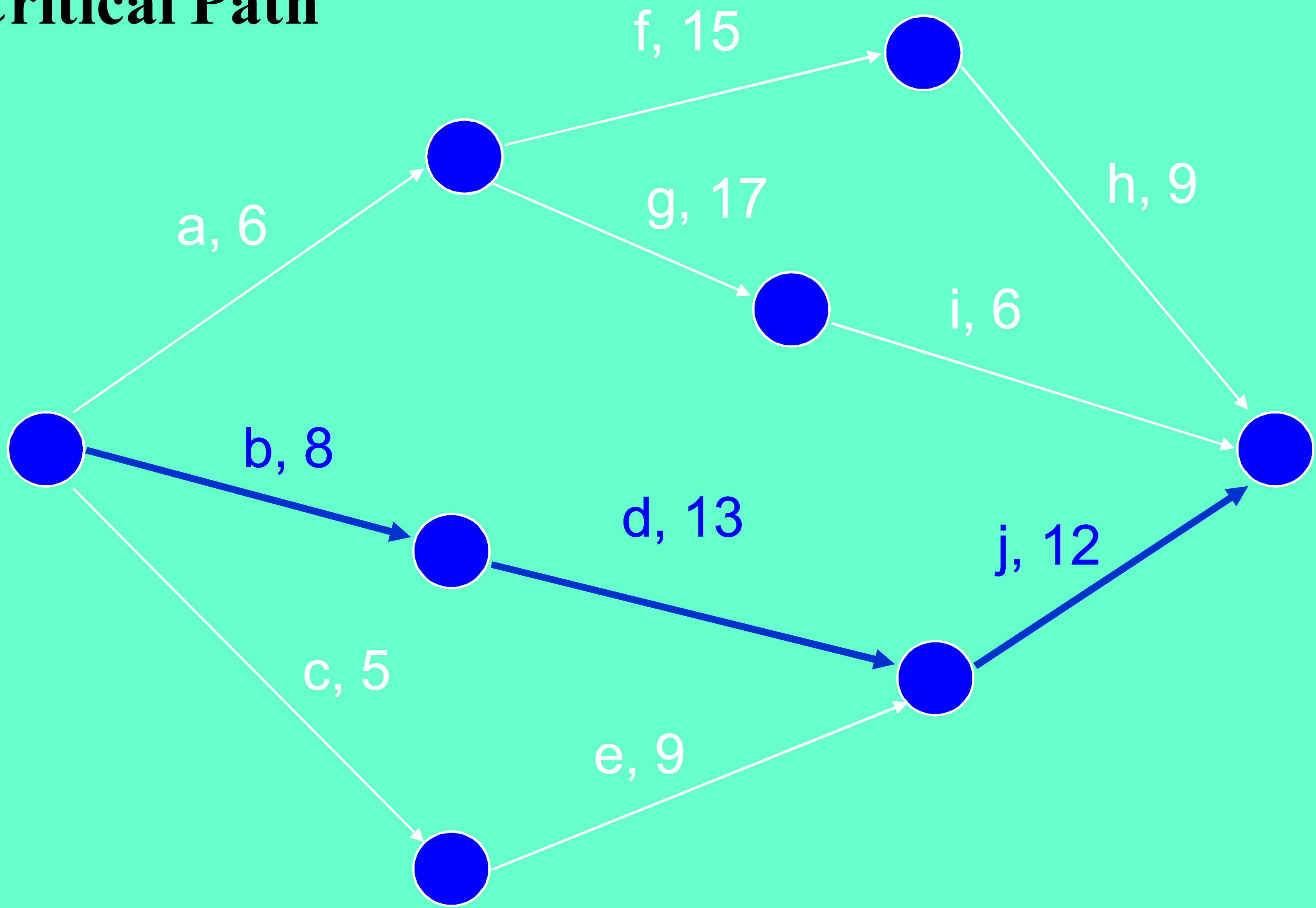
CPM Example

- **Float**



CPM Example

- **Critical Path**



PERT

- PERT is based on the assumption that an activity's duration follows a probability distribution instead of being a single value
- Three time estimates are required to compute the parameters of an activity's duration distribution:
  - pessimistic time (t_p) - the time the activity would take if things did not go well
  - most likely time (t_m) - the consensus best estimate of the activity's duration
  - optimistic time (t_o) - the time the activity would take if things did go well

Mean (expected time): $$t_e = \frac{t_p + 4\,t_m + t_o}{6}$$

Variance: $$V_t = \sigma^2 = \left(\frac{t_p - t_o}{6}\right)^2$$

PERT analysis

- Draw the network.
- Analyze the paths through the network and find the critical path.
- The length of the critical path is the mean of the project duration probability distribution which is assumed to be normal
- The standard deviation of the project duration probability distribution is computed by adding the variances of the critical activities (all of the activities that make up the critical path) and taking the square root of that sum
- Probability computations can now be made using the normal distribution table.

Probability computation

Determine probability that project is completed within specified time

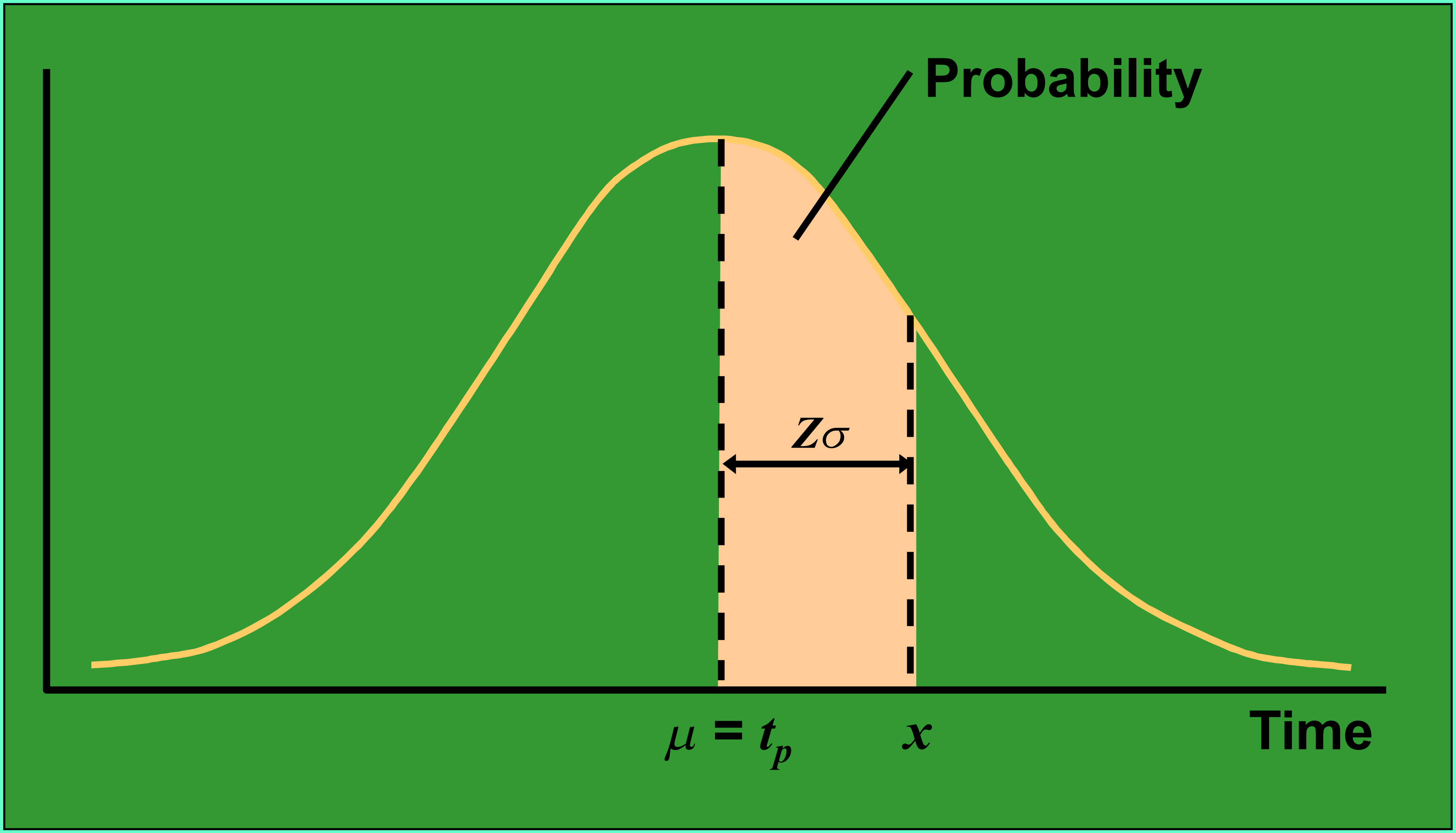
$$Z = \frac{x - \mu}{\sigma}$$

where $\mu = t_p$ = project mean time

σ = project standard mean time

x = (proposed) specified time

Normal Distribution of Project Time

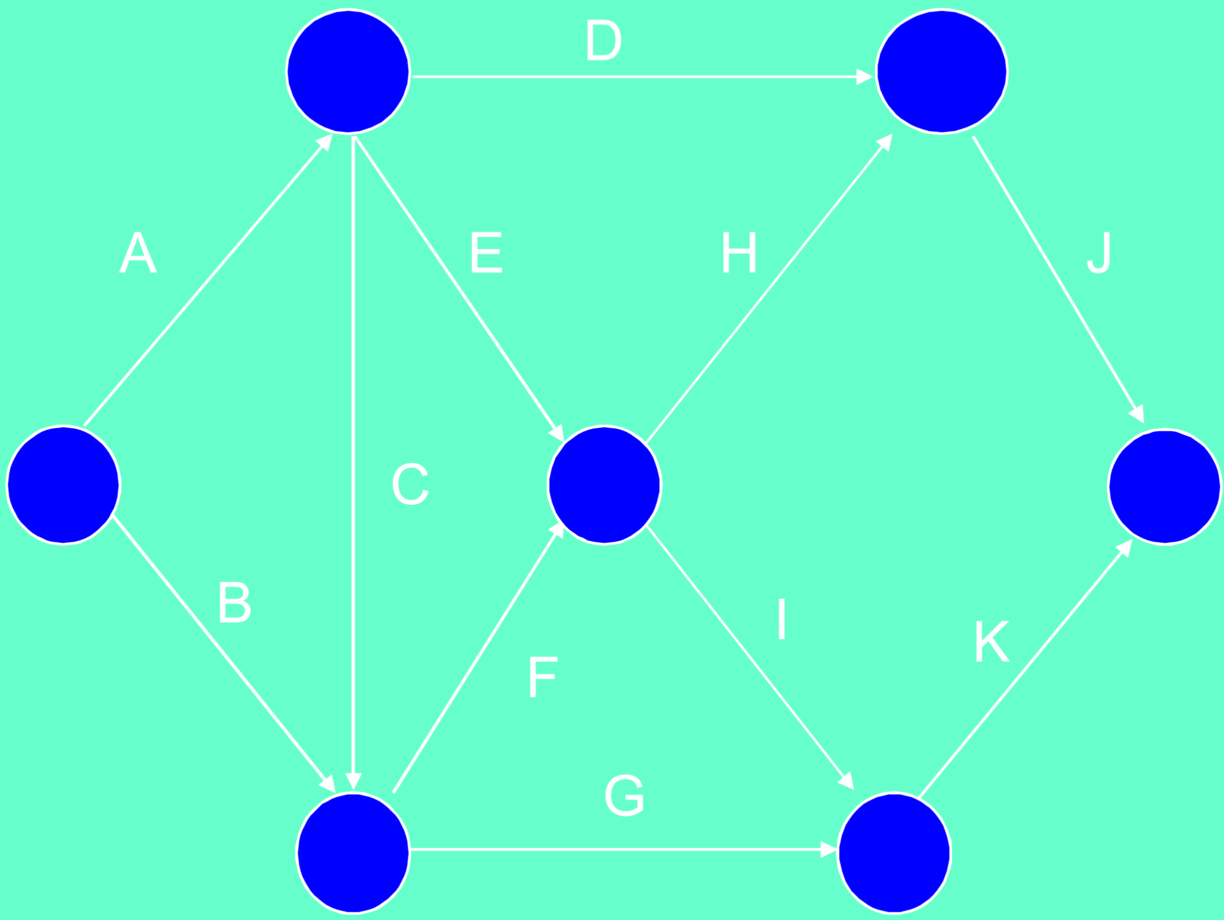


PERT Example

Activity	Immed. Predec.	Optimistic Time (Hr.)	Most Likely Time (Hr.)	Pessimistic Time (Hr.)
A	--	4	6	8
B	--	1	4.5	5
C	A	3	3	3
D	A	4	5	6
E	A	0.5	1	1.5
F	B,C	3	4	5
G	B,C	1	1.5	5
H	E,F	5	6	7
I	E,F	2	5	8
J	D,H	2.5	2.75	4.5
K	G,I	3	5	7

PERT Example

PERT Network



PERT Example

Activity	Expected Time	Variance
A	6	4/9
B	4	4/9
C	3	0
D	5	1/9
E	1	1/36
F	4	1/9
G	2	4/9
H	6	1/9
I	5	1
J	3	1/9
K	5	4/9

PERT Example

Activity	ES	EF	LS	LF	Slack
A	0	6	0	6	0 *critical
B	0	4	5	9	5
C	6	9	6	9	0 *
D	6	11	15	20	9
E	6	7	12	13	6
F	9	13	9	13	0 *
G	9	11	16	18	7
H	13	19	14	20	1
I	13	18	13	18	0 *
J	19	22	20	23	1
K	18	$\boxed{23}$	18	23	0 *

PERT Example

$$V_{path} = V_A + V_C + V_F + V_I + V_K$$
$$= 4/9 + 0 + 1/9 + 1 + 4/9$$
$$= 2$$
$$\sigma_{path} = 1.414$$
$$z = (24 - 23)/\sigma = (24\text{-}23)/1.414 = .71$$

From the Standard Normal Distribution table:

$$P(z \leq .71) = .5 + .2612 = \boxed{.7612}$$

PROJECT COST

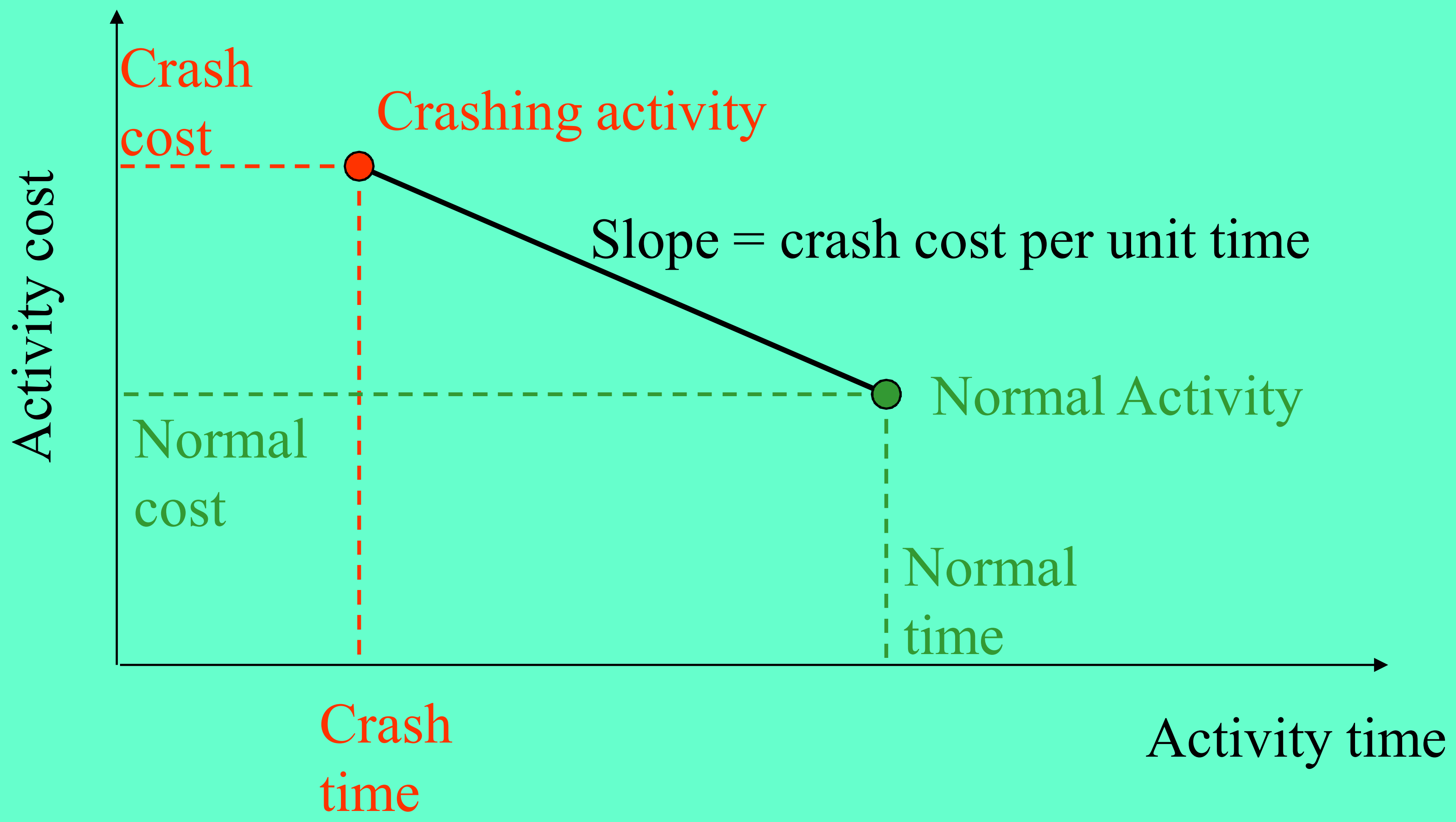
Cost consideration in project

- Project managers may have the option or requirement to crash the project, or accelerate the completion of the project.
- This is accomplished by reducing the length of the critical path(s).
- The length of the critical path is reduced by reducing the duration of the activities on the critical path.
- If each activity requires the expenditure of an amount of money to reduce its duration by one unit of time, then the project manager selects the least cost critical activity, reduces it by one time unit, and traces that change through the remainder of the network.
- As a result of a reduction in an activity’s time, a new critical path may be created.
- When there is more than one critical path, each of the critical paths must be reduced.
- If the length of the project needs to be reduced further, the process is repeated.

Project Crashing

- Crashing
  - reducing project time by expending additional resources
- Crash time
  - an amount of time an activity is reduced
- Crash cost
  - cost of reducing activity time
- Goal
  - reduce project duration at minimum cost

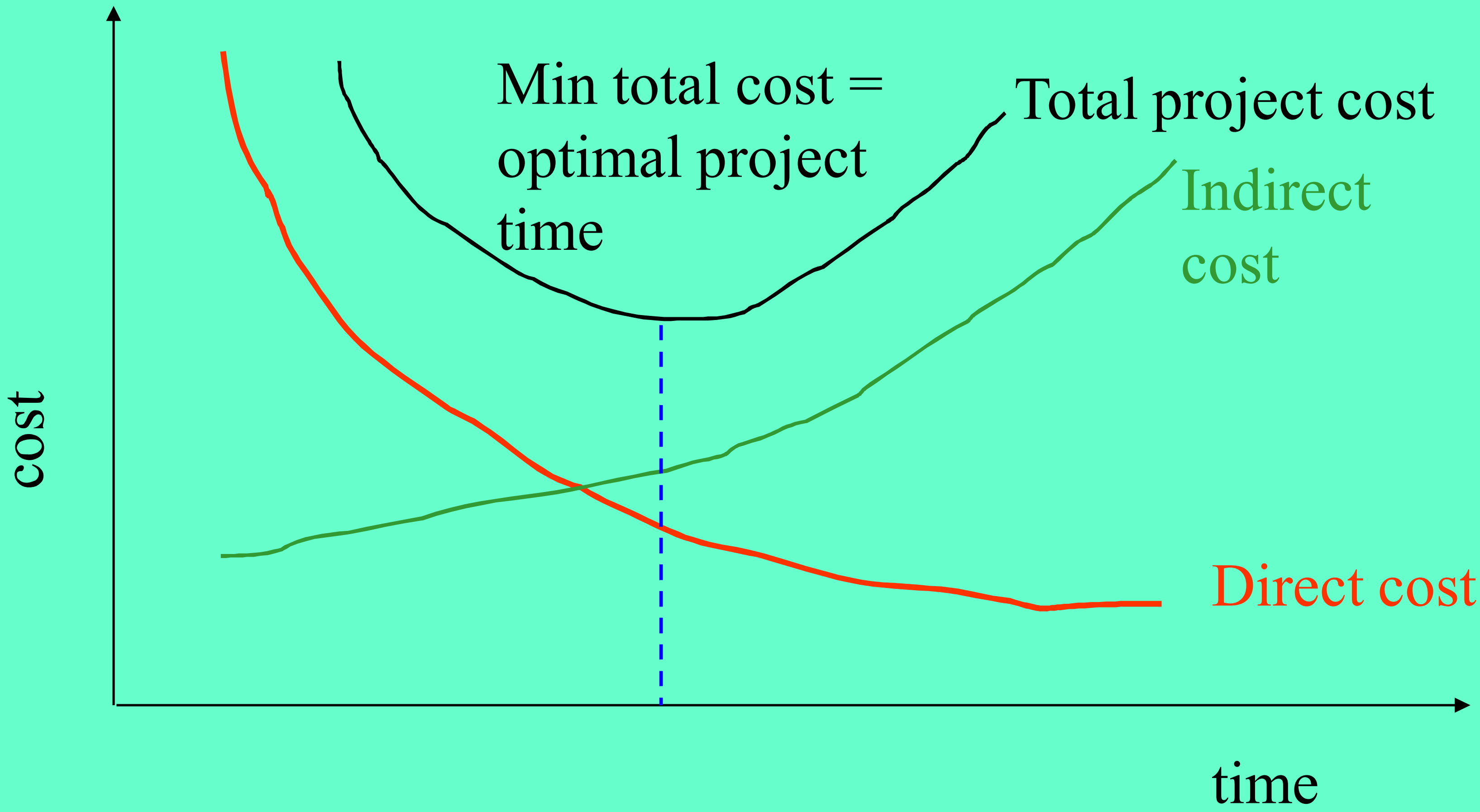
Activity crashing



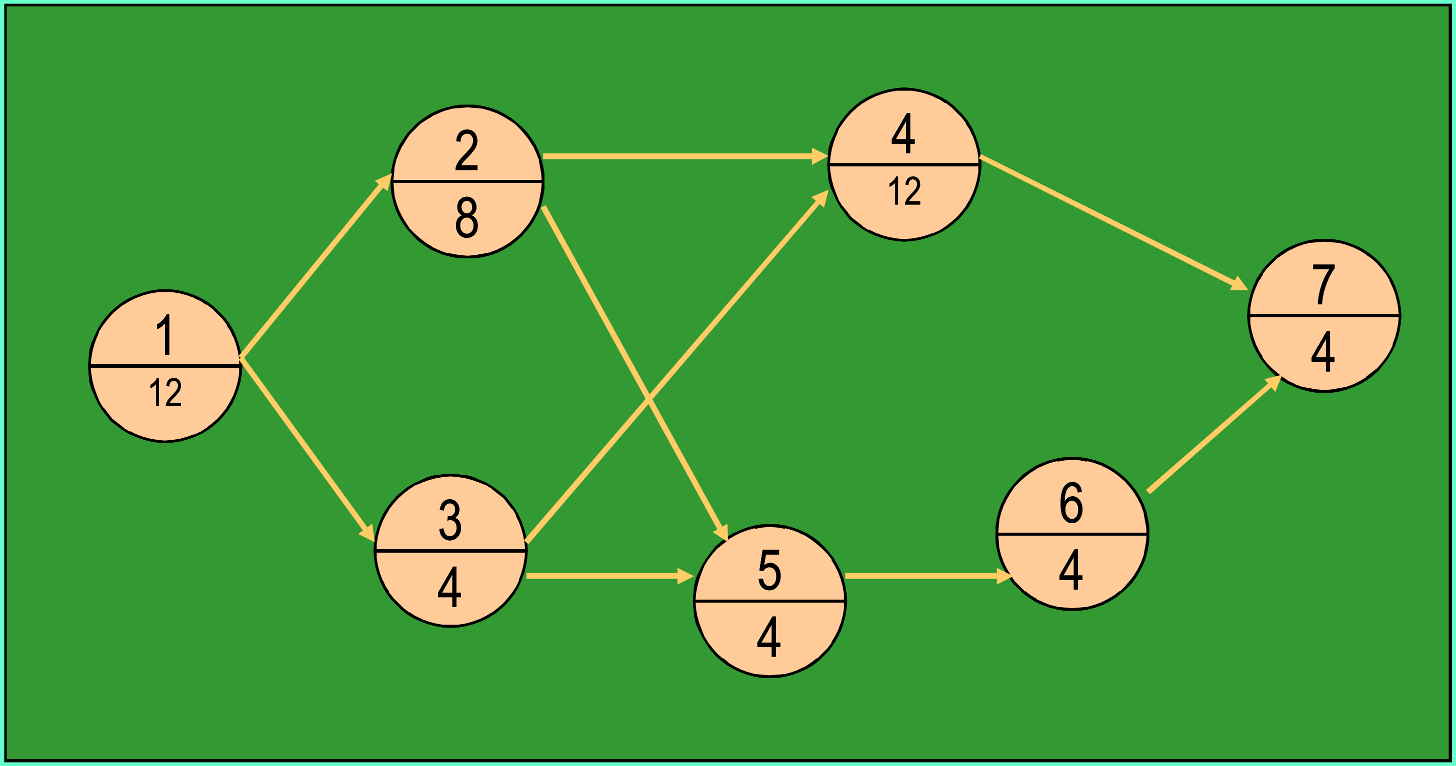
Time-Cost Relationship

- Crashing costs increase as project duration decreases
- Indirect costs increase as project duration increases
- Reduce project length as long as crashing costs are less than indirect costs

Time-Cost Tradeoff

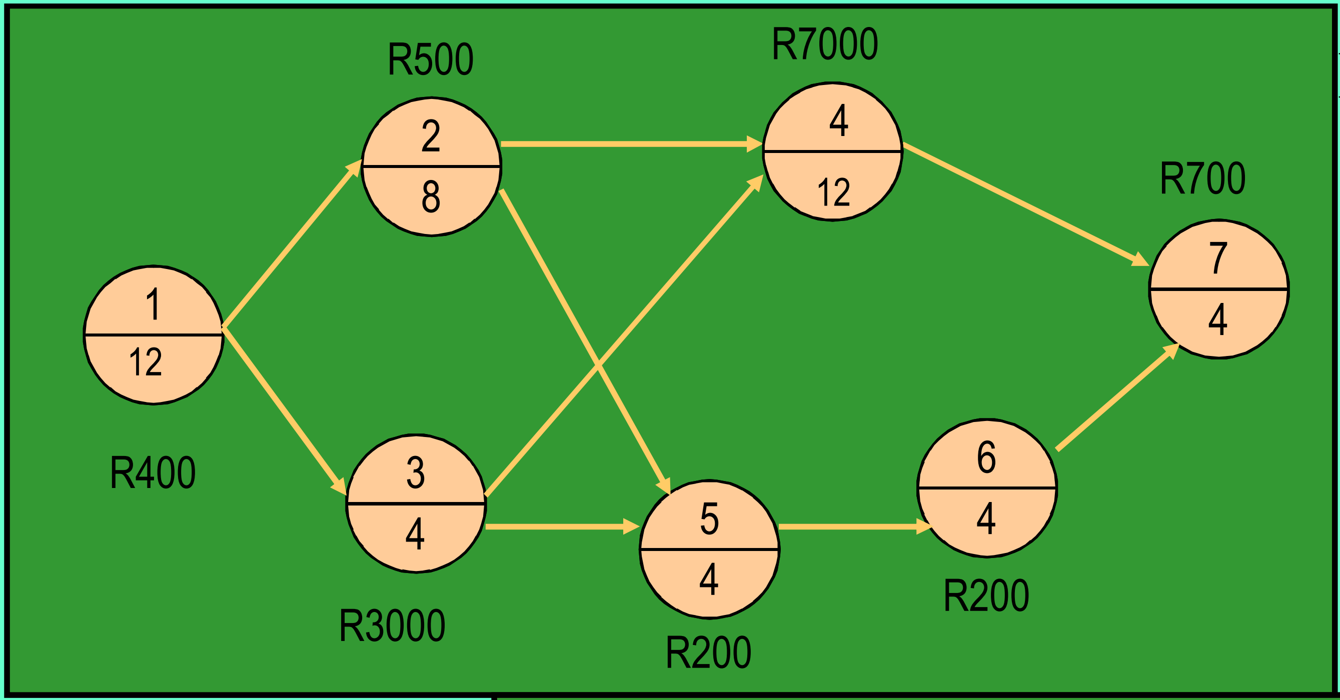


Project Crashing example



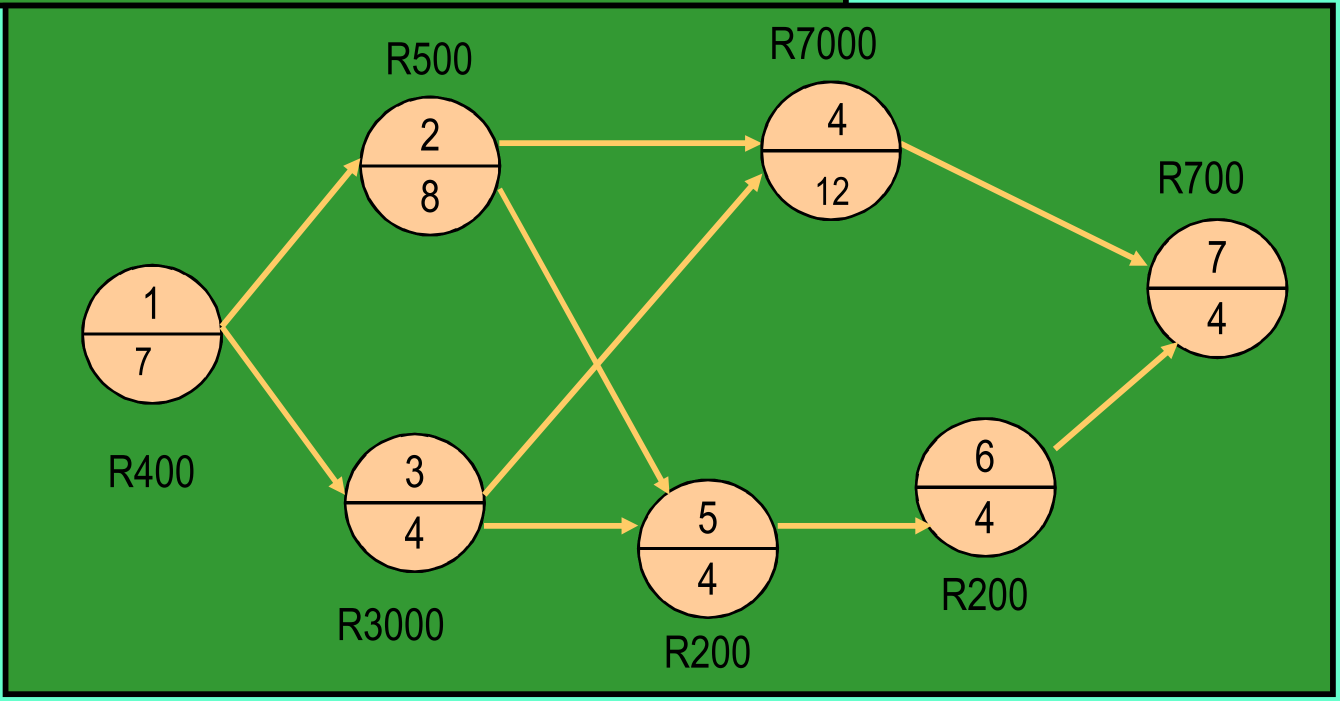
Time Cost data

Activity	Normal time	Normal cost Rs	Crash time	Crash cost Rs	Allowable crash time	slope
1	12	3000	7	5000	5	400
2	8	2000	5	3500	3	500
3	4	4000	3	7000	1	3000
4	12	50000	9	71000	3	7000
5	4	500	1	1100	3	200
6	4	500	1	1100	3	200
7	4	1500	3	22000	1	7000
		75000		110700		



Project duration = 36

From…..



To…..

Project

duration = 31

Additional cost = R2000

Benefits of CPM/PERT

- Useful at many stages of project management
- Mathematically simple
- Give critical path and slack time
- Provide project documentation
- Useful in monitoring costs

CPM/PERT can answer the following important questions:

- How long will the entire project take to be completed? What are the risks involved?
- Which are the critical activities or tasks in the project which could delay the entire project if they were not completed on time?
- Is the project on schedule, behind schedule or ahead of schedule?
- If the project has to be finished earlier than planned, what is the best way to do this at the least cost?

Limitations to CPM/PERT

- Clearly defined, independent and stable activities
- Specified precedence relationships
- Over emphasis on critical paths
- Deterministic CPM model
- Activity time estimates are subjective and depend on judgment
- PERT assumes a beta distribution for these time estimates, but the actual distribution may be different
- PERT consistently underestimates the expected project completion time due to alternate paths becoming critical

To overcome the limitation, Monte Carlo simulations can be performed on the network to eliminate the optimistic bias