Project Scheduling

INTRODUCTION

- Schedule converts action plan into operating time table
- Basis for monitoring and controlling project
- Scheduling more important in projects than in production, because unique nature
- Sometimes customer specified/approved requirement-e.g: JKR projects
- Based on Work Breakdown Structure (WBS)

NETWORK TECHNIQUES

PERT

-Program Evaluation and Review Technique
- developed by the US Navy with Booz Hamilton Lockheed
- on the Polaris Missile/Submarine program 1958

CPM

Critical Path Method

Developed by El Dupont for Chemical Plant Shutdown Project- about same time as PERT

- ✓Both use same calculations, almost similar
- ✓Main difference is probabilistic and deterministic in time estimation
- ✓Gantt Chart also used in scheduling

NETWORK

- Graphical portrayal of activities and event
- Shows dependency relationships between tasks/activities in a project
- Clearly shows tasks that must precede (precedence) or follow (succeeding) other tasks in a logical manner
- Clear representation of plan – a powerful tool for planning and controlling project

Example of Simple Network – Survey

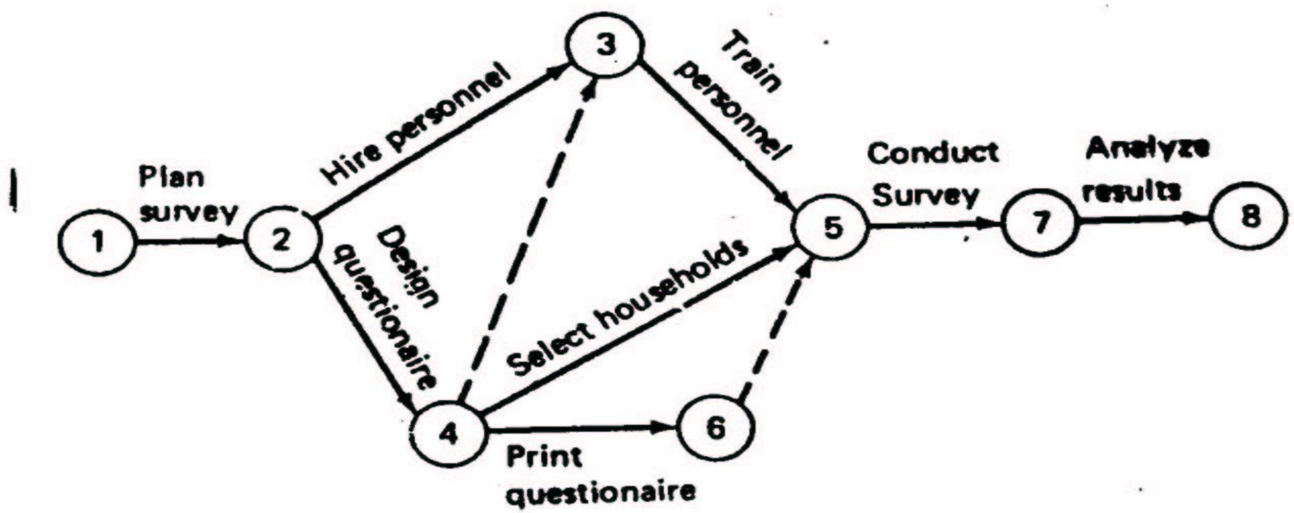


Figure 2-18

Example of Network – More Complex

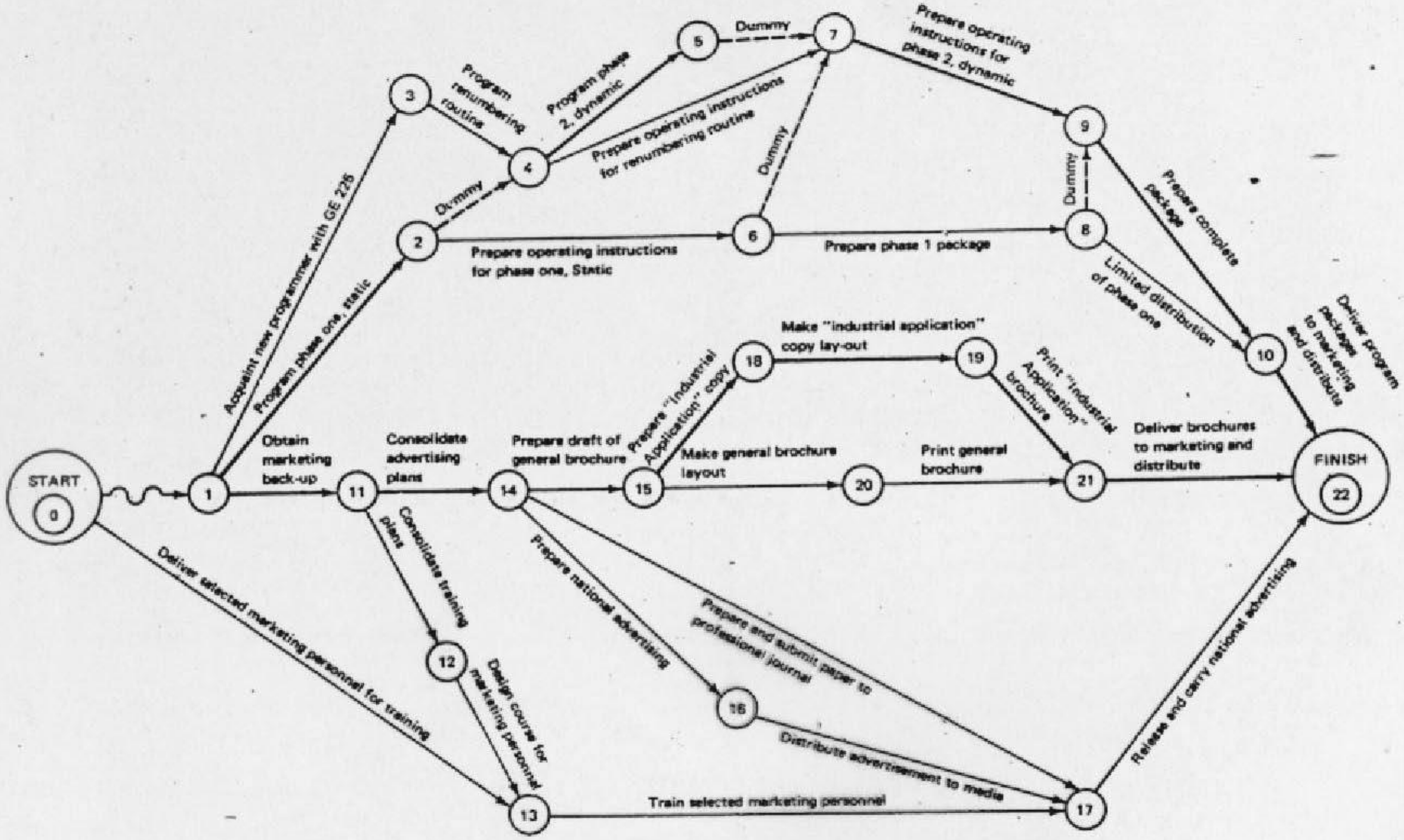
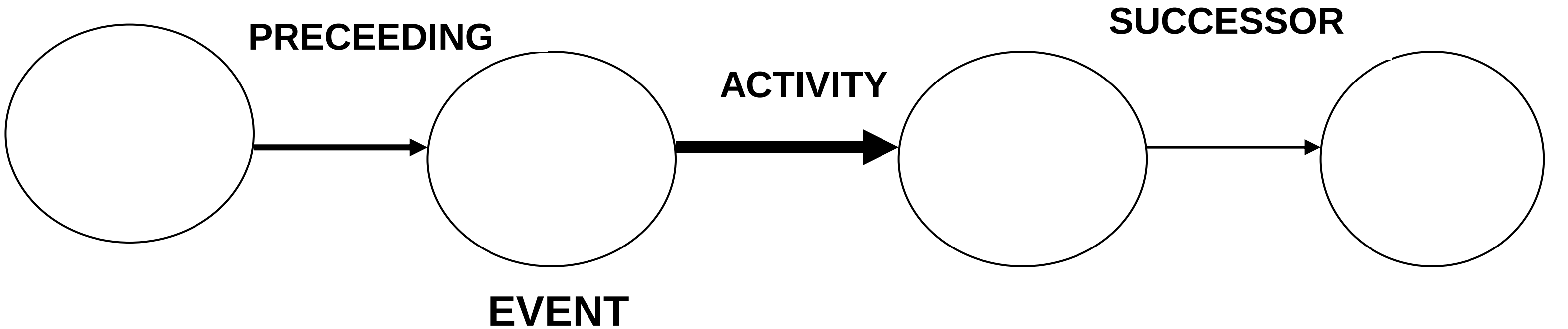


Figure 2-19 Network for the development and marketing of a new computer program.

DEFINITION OF TERMS IN A NETWORK

- **Activity:** any portions of project (tasks) which required by project, uses up resource and consumes time – may involve labor, paper work, contractual negotiations, machinery operations
  - Activity on Arrow (AOA) showed as arrow,
  - AON – Activity on Node
- **Event:** beginning or ending points of one or more activities, instantaneous point in time, also called ‘nodes’
- **Network** : Combination of all project activities and the events



Emphasis on Logic in Network Construction

- Construction of network should be based on logical or technical dependencies among activities
- Example - before activity 'Approve Drawing' can be started the activity 'Prepare Drawing' must be completed
- Common error – build network on the basis of time logic (a feeling for proper sequence) see example below

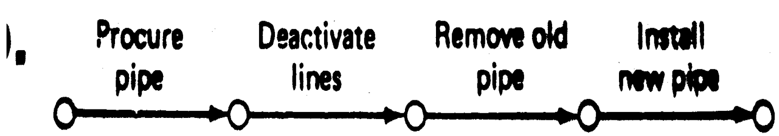


Figure 2-5a

WRONG !!!

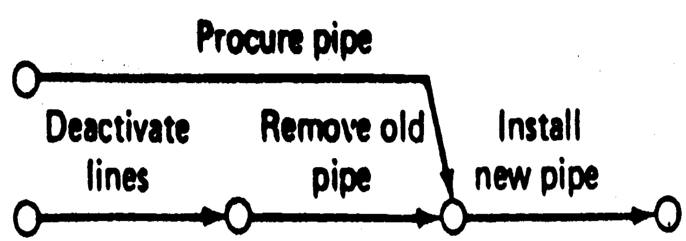


Figure 2-5b

CORRECT ✓

Example 1- A simple network

Consider the list of four activities for making a simple product:

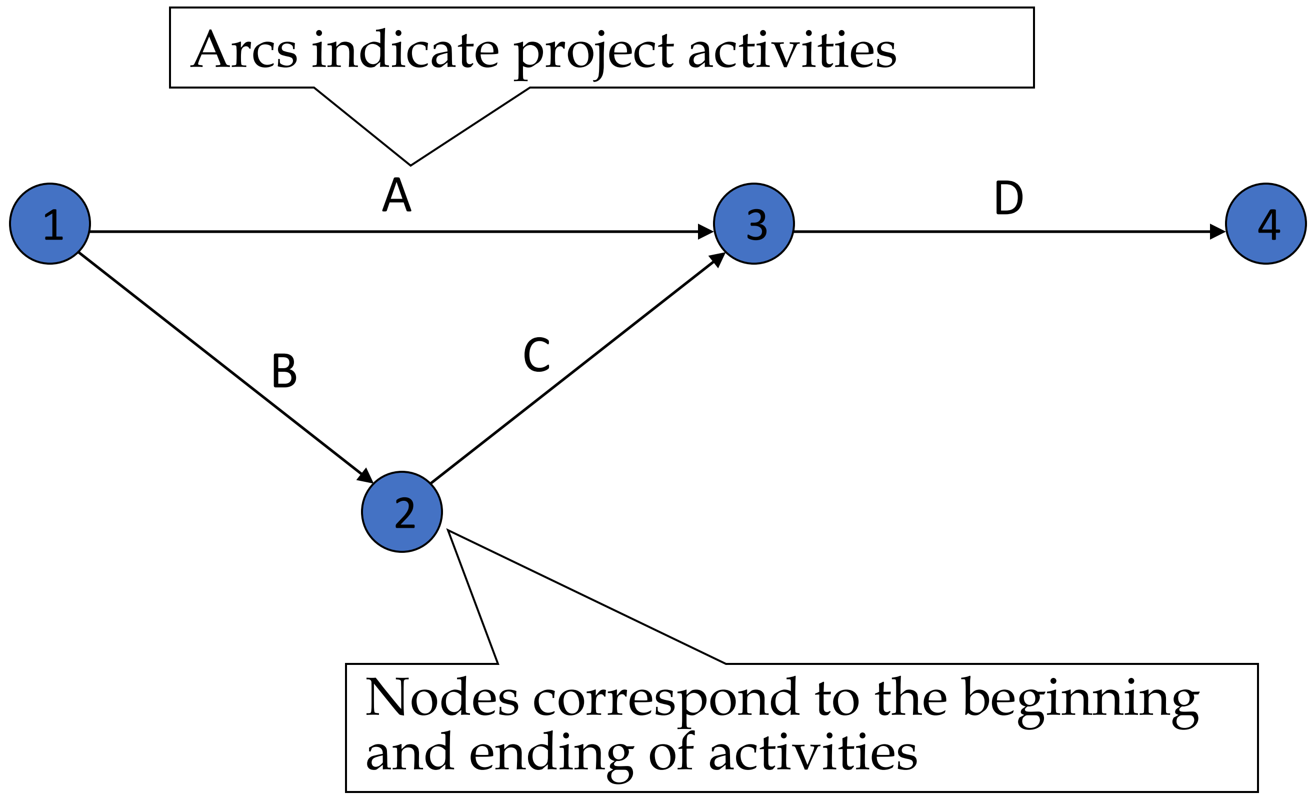
Activity	Description	Immediate predecessors
A	Buy Plastic Body	-
B	Design Component	-
C	Make Component	B
D	Assemble product	A,C

Immediate predecessors for a particular activity are the activities that, when completed, enable the start of the activity in question.

Sequence of activities

- Can start work on activities A and B anytime, since neither of these activities depends upon the completion of prior activities.
- Activity C cannot be started until activity B has been completed
- Activity D cannot be started until both activities A and C have been completed.
- The graphical representation (next slide) is referred to as the PERT/CPM network

Network of Four Activities



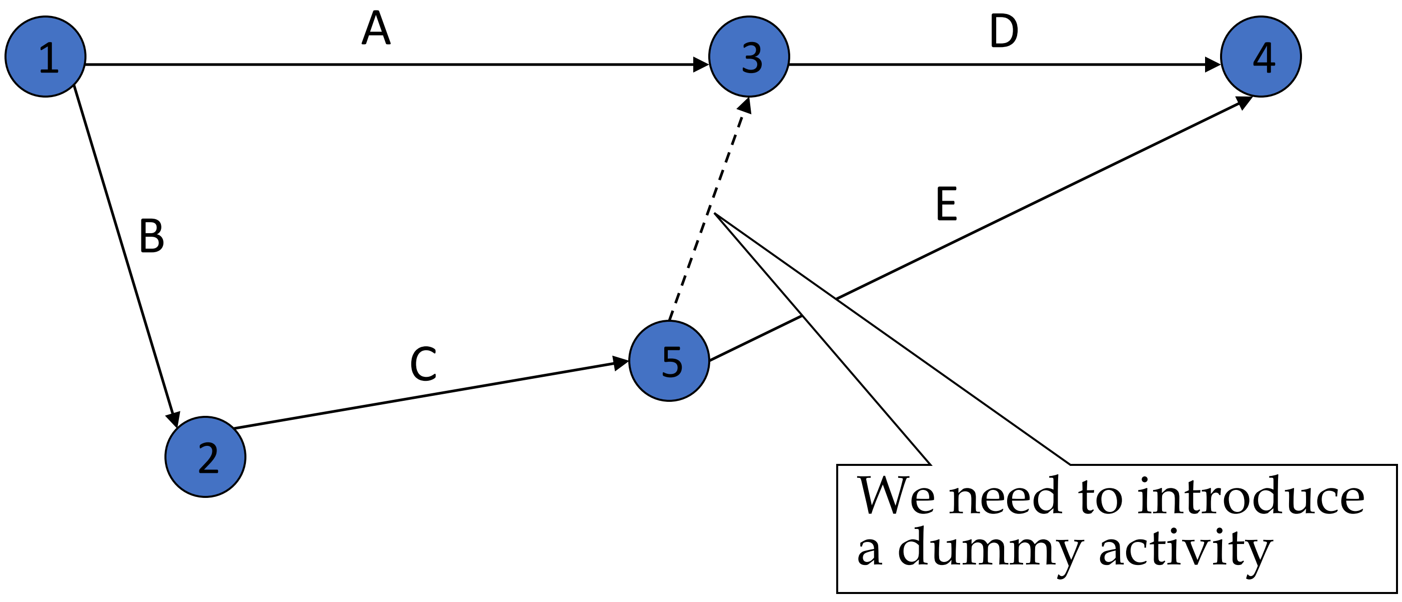
Example 2

Develop the network for a project with following activities and immediate predecessors:

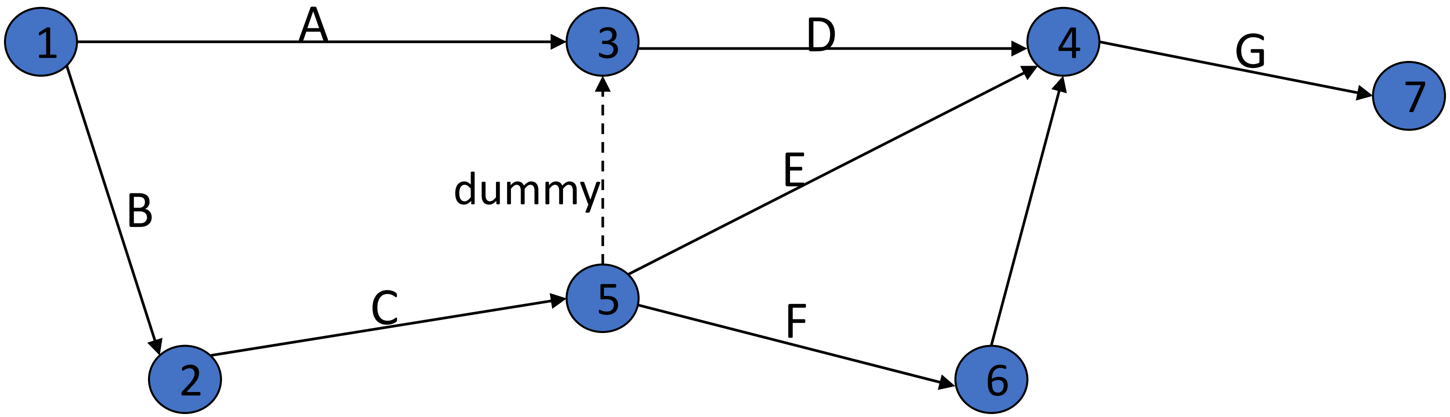
Activity	**Immediate predecessors**
A	-
B	-
C	B
D	A, C
E	C
F	C
G	D,E,F

Try to do for the first five (A,B,C,D,E) activities

Network of first five activities



Network of Seven Activities



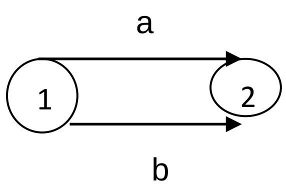
- Note how the network correctly identifies D, E, and F as the immediate predecessors for activity G.

- Dummy activities is used to identify precedence relationships correctly and to eliminate possible confusion of two or more activities having the same starting and ending nodes

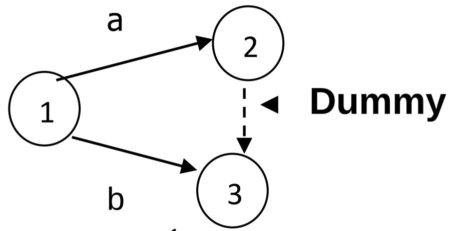
- Dummy activities have no resources (time, labor, machinery, etc) – purpose is to PRESERVE LOGIC of the network

EXAMPLES OF THE USE OF DUMMYACTIVITY

Network concurrent activities

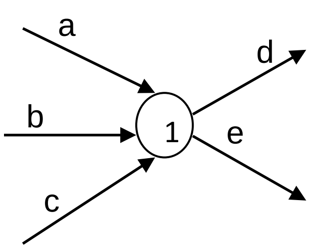


WRONG!!!

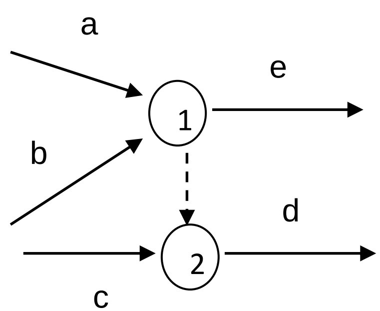


RIGHT ✓

Activity c not required for e



WRONG !!!



RIGHT ✓

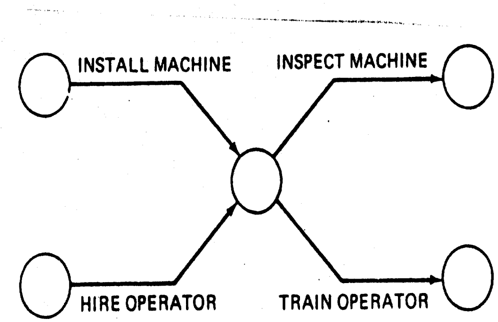


Figure 2-16

WRONG !

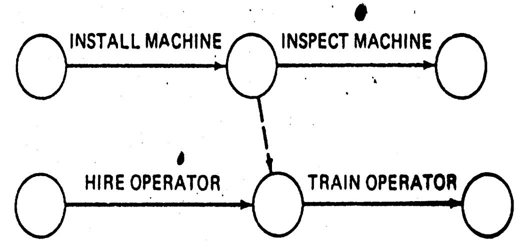
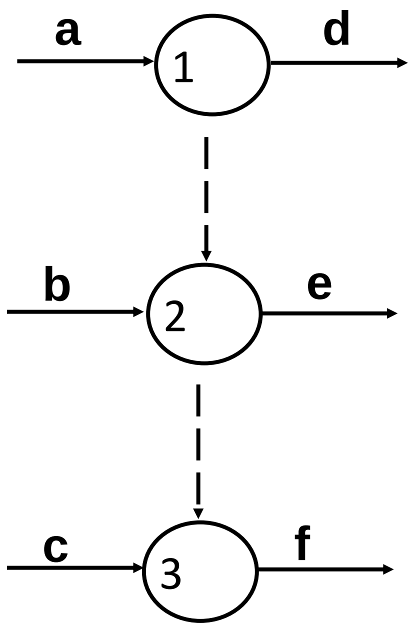


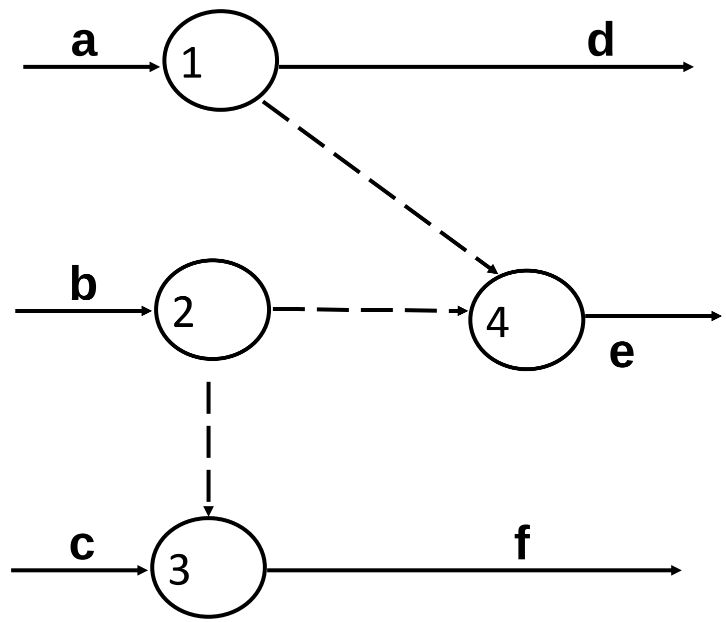
Figure 2-17

RIGHT ✓

WRONG!!!



RIGHT!!!



a precedes **d.**
a and **b** precede **e,**
b and **c** precede **f** (**a** does not precede **f**)

Scheduling with activity time

Activity	Immediate predecessors	Completion Time (week)
A	-	5
B	-	6
C	A	4
D	A	3
E	A	1
F	E	4
G	D,F	14
H	B,C	12
I	G,H	2
	Total ……	51

This information indicates that the total time required to complete activities is 51 weeks. However, we can see from the network that several of the activities can be conducted simultaneously (A and B, for example).

Earliest Start (ES) & Earliest Finish(EF) time

- We are interested in the longest path through the network, i.e., the critical path.

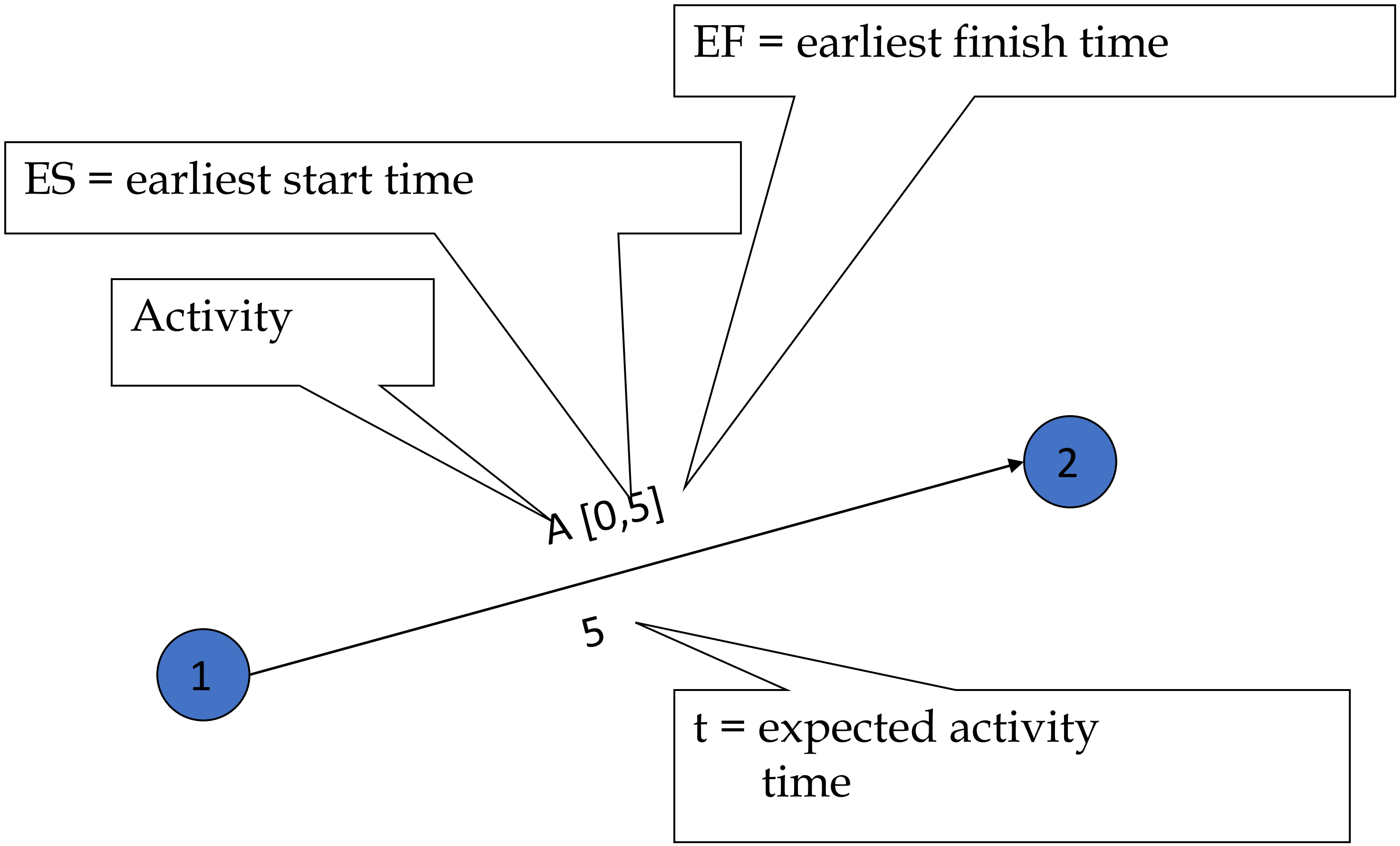
- Starting at the network's origin (node 1) and using a starting time of 0, we compute an ***earliest start*** (ES) and ***earliest finish*** (EF) time for each activity in the network.

- The expression EF = ES + t can be used to find the earliest finish time for a given activity.

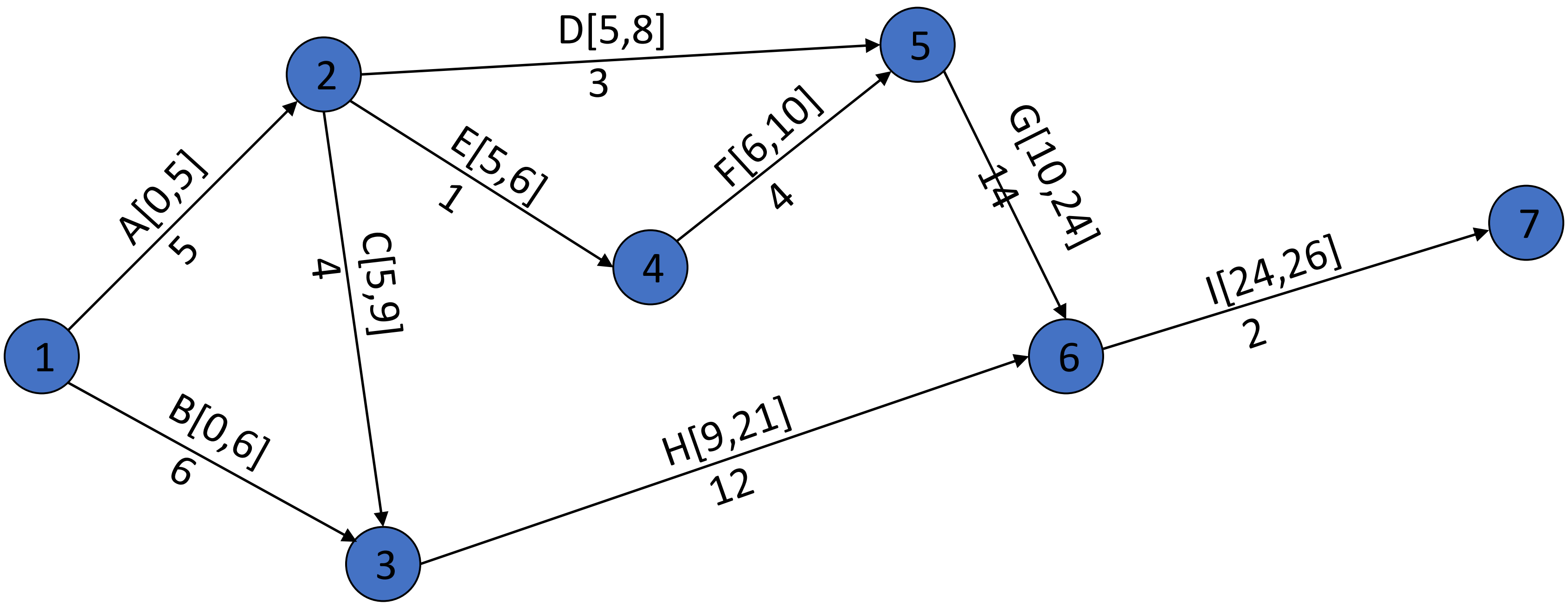
  For example, for activity A, ES = 0 and t = 5; thus the earliest finish time for activity A is

$$EF = 0 + 5 = 5$$

Arc with ES & EF time



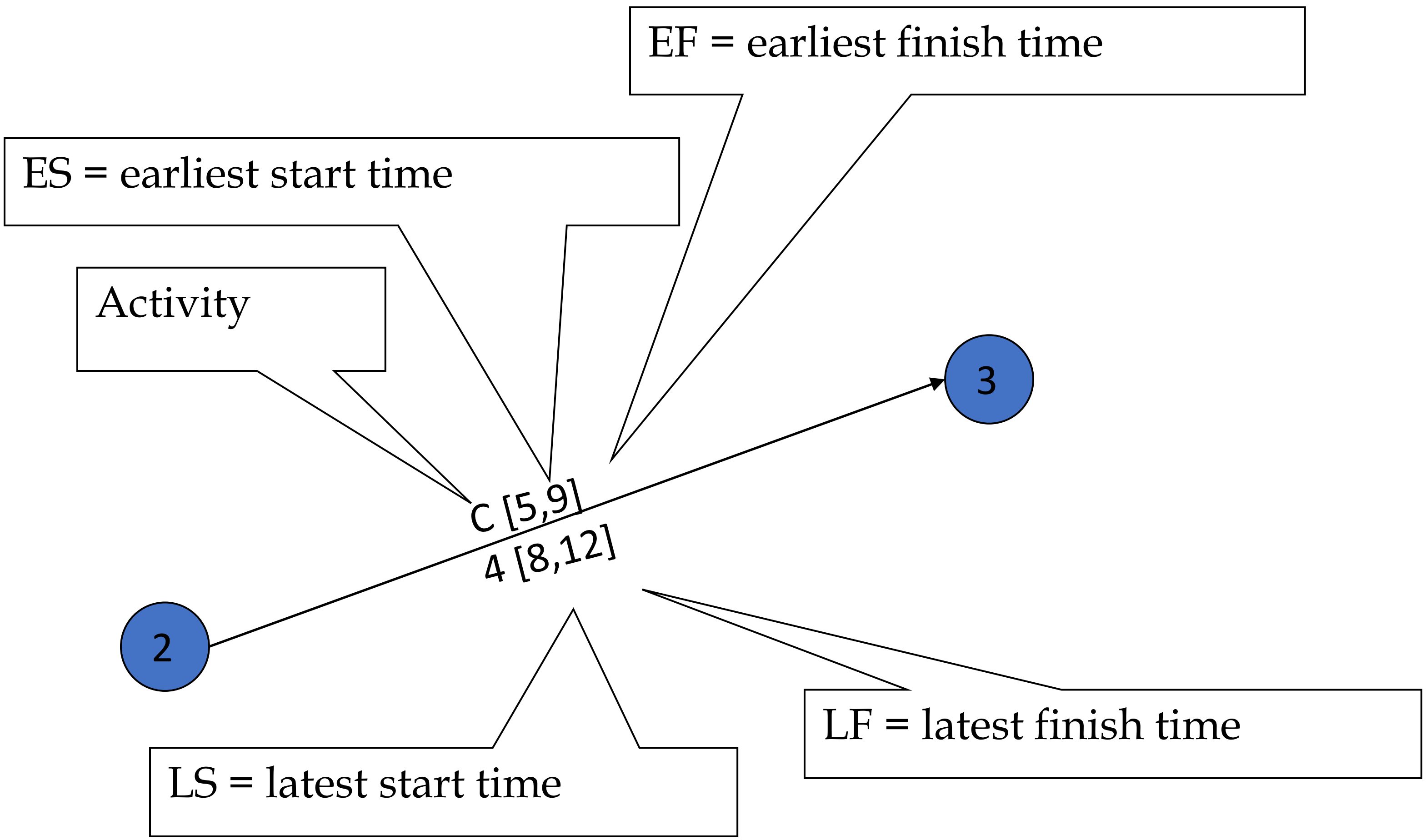
Network with ES & EF time



<u>Earliest start time rule</u>:

The earliest start time for an activity leaving a particular node is equal to the **largest** of the earliest finish times for all activities entering the node.

Activity, duration, ES, EF, LS, LF



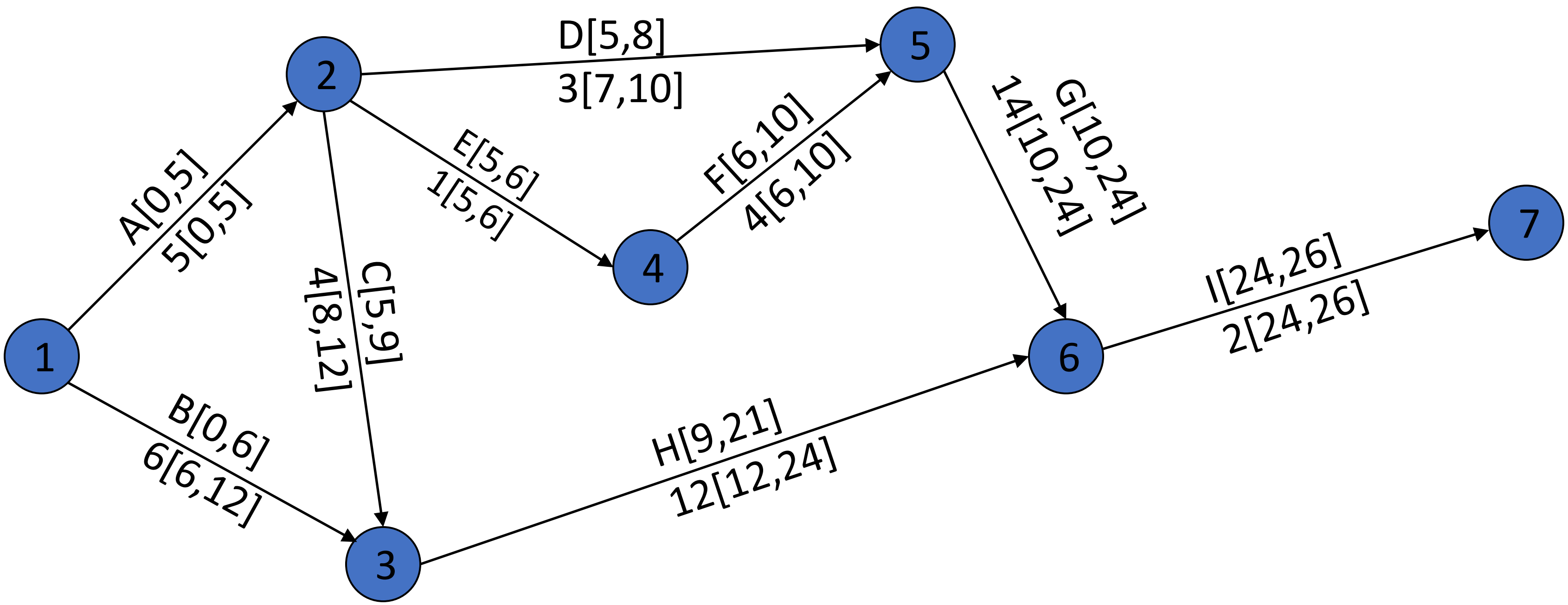
Latest start & latest finish time

- To find the critical path we need a <u>backward pass calculation</u>.

- Starting at the completion point (node 7) and using a <u>***latest finish***</u> time (LF) of 26 for activity I, we trace back through the network computing a <u>***latest start***</u> (LS) and latest finish time for each activity

- The expression **LS = LF – t** can be used to calculate latest start time for each activity. For example, for activity I, LF = 26 and t = 2, thus the latest start time for activity I is LS = 26 – 2 = 24

Network with LS & LF time



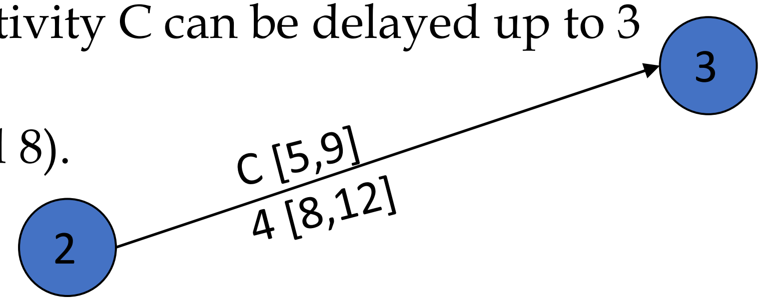
<u>Latest finish time rule</u>:
The latest finish time for an activity entering a particular node is equal to the **smallest** of the latest start times for all activities leaving the node.

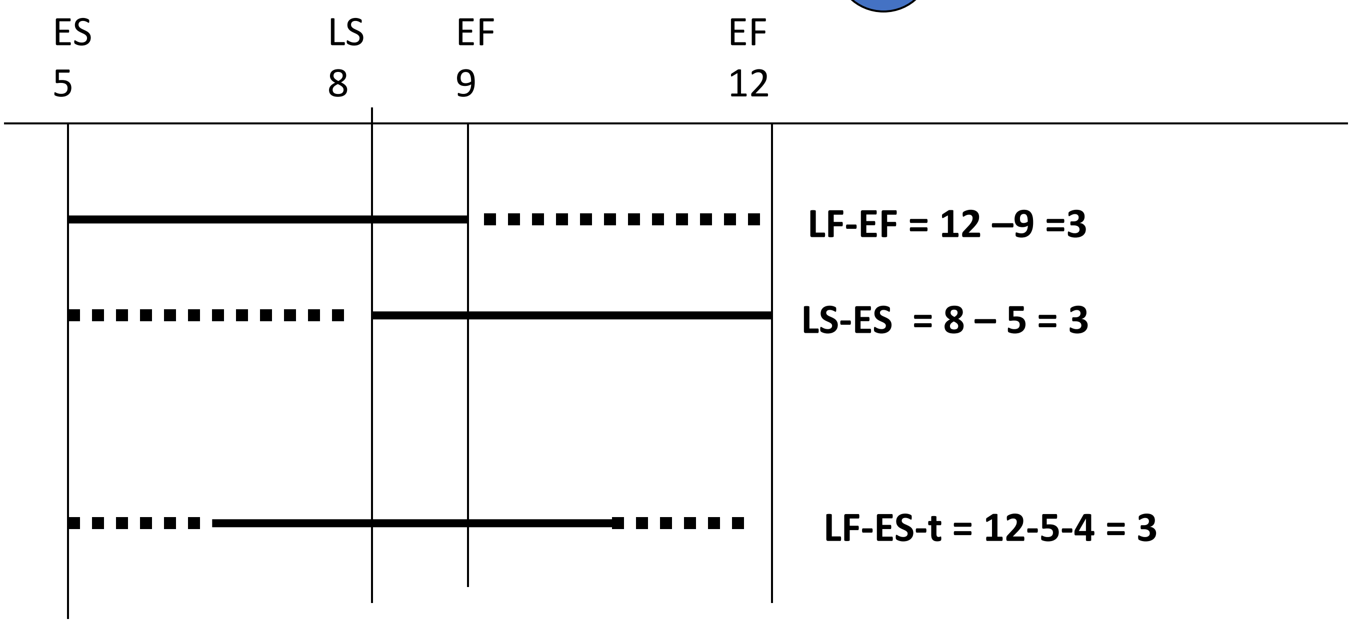
Slack or Free Time or Float

Slack is the length of time an activity can be delayed without affecting the completion date for the entire project.

For example, slack for C = 3 weeks, i.e Activity C can be delayed up to 3 weeks

(start anywhere between weeks 5 and 8).





Activity schedule for our example

Activity	Earliest start (ES)	Latest start (LS)	Earliest finish (EF)	Latest finish (LF)	Slack (LS-ES)	Critical path
A	0	0	5	5	0	Yes
B	0	6	6	12	6	
C	5	8	9	12	3	
D	5	7	8	10	2	
E	5	5	6	6	0	Yes
F	6	6	10	10	0	Yes
G	10	10	24	24	0	Yes
H	9	12	21	24	3	
I	24	24	26	26	0	Yes

IMPORTANT QUESTIONS

- **What is the total time to complete the project?**
  - 26 weeks if the individual activities are completed on schedule.

- **What are the scheduled start and completion times for each activity?**
  - ES, EF, LS, LF are given for each activity.

- **What activities are *critical* and must be completed as scheduled in order to keep the project on time?**
  - Critical path activities: A, E, F, G, and I.

- **How long can *non-critical* activities be delayed before they cause a delay in the project's completion time**
  - Slack time available for all activities are given.

Importance of Float (Slack) and Critical Path

1. Slack or Float shows how much allowance each activity has, i.e how long it can be delayed without affecting completion date of project

2. Critical path is a sequence of activities from start to finish with zero slack. Critical activities are activities on the critical path.

3. Critical path identifies the minimum time to complete project

4. If any activity on the critical path is shortened or extended, project time will be shortened or extended accordingly

Importance of Float (Slack) and Critical Path (cont)

5. So, a lot of effort should be put in trying to control activities along this path, so that project can meet due date. If any activity is lengthened, be aware that project will not meet deadline and some action needs to be taken.

6. If can spend resources to speed up some activity, do so only for critical activities.

7. Don’t waste resources on non-critical activity, it will not shorten the project time.

8. If resources can be saved by lengthening some activities, do so for non-critical activities, up to limit of float.

9. Total Float belongs to the path

PERT For Dealing With Uncertainty

- So far, times can be estimated with relative certainty, confidence

- For many situations this is not possible, e.g Research, development, new products and projects etc.

- Use 3 time estimates

  m= most likely time estimate, mode.

  a = optimistic time estimate,

  b = pessimistic time estimate, and

Expected Value (TE) = (a + 4m + b) /6

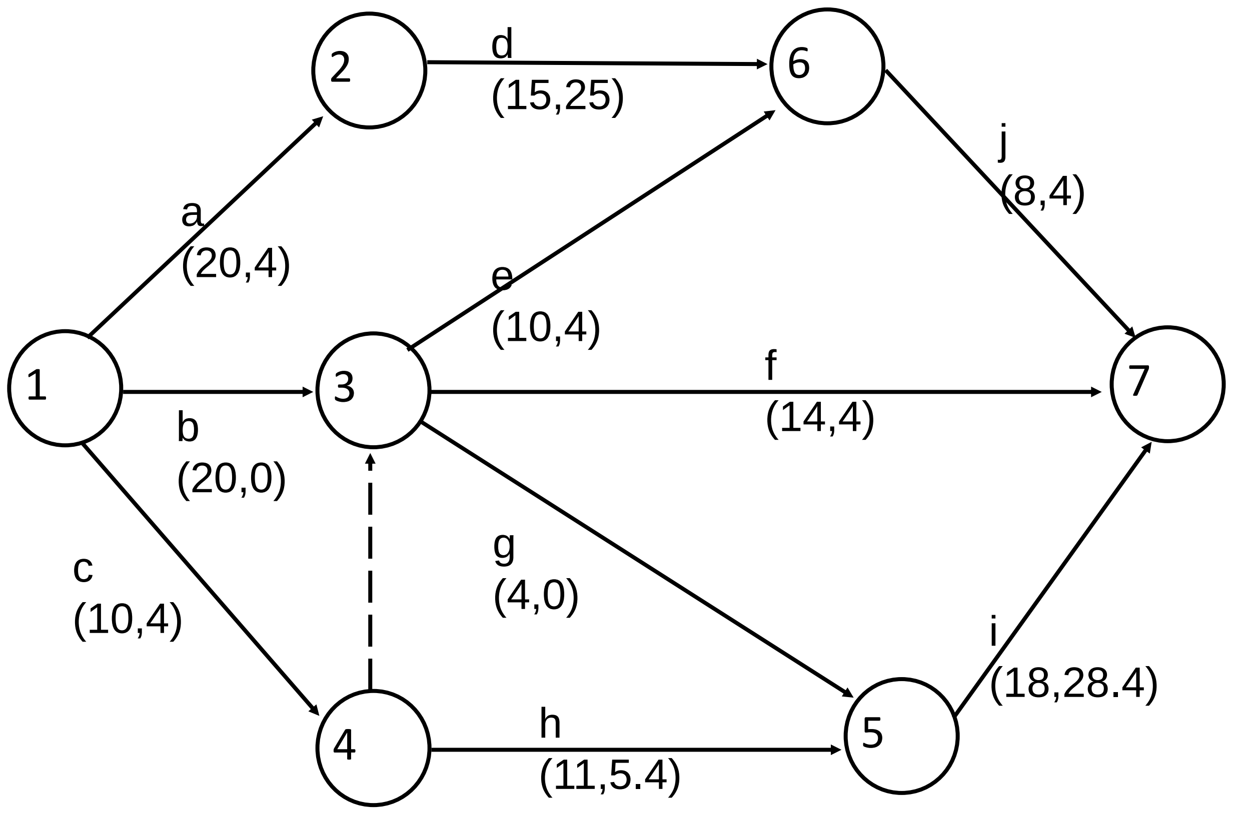
Variance (V) = ((b – a) / 6)^2

Std Deviation (δ) = SQRT (V)

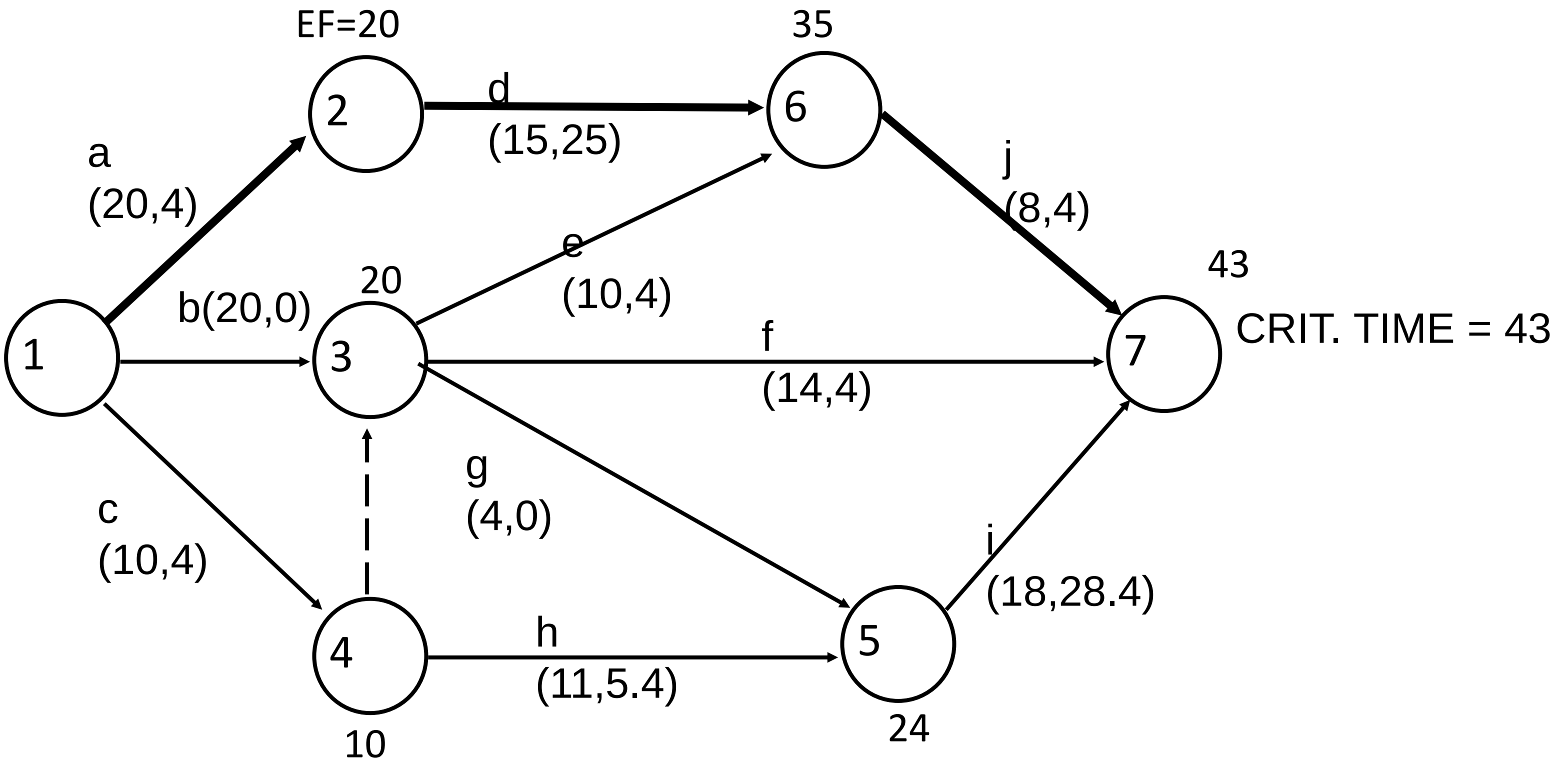
Precedence And Project Activity Times

Activity	Immediate Predecessor	Optimistic Time	Most Likely Time	Pessimistic Time	EXP TE	Var V	S.Dev σ
a	-	10	22	22	20	4	2
b	-	20	20	20	20	0	0
c	-	4	10	16	10	4	2
d	a	2	14	32	15	25	5
e	b,c	8	8	20	10	4	2
f	b,c	8	14	20	14	4	2
g	b,c	4	4	4	4	0	0
h	c	2	12	16	11	5.4	2.32
I	g,h	6	16	38	18	28.4	5.33
j	d,e	2	8	14	8	4	2

The complete network



The complete Network



Critical Path Analysis (PERT)

Activity	LS	ES	Slacks	Critical ?
a	**0**	**0**	**0**	**Yes**
b	1	0	1	
c	4	0	4	
d	**20**	**20**	**0**	**Yes**
e	25	20	5	
f	29	20	9	
g	21	20	1	
h	14	10	4	
i	25	24	1	
j	**35**	**35**	**0**	**Yes**

Assume, PM promised to complete the project in the fifty days.
What are the chances of meeting that deadline?
Calculate Z, where

$$Z = (D-S) / \sqrt{V}$$

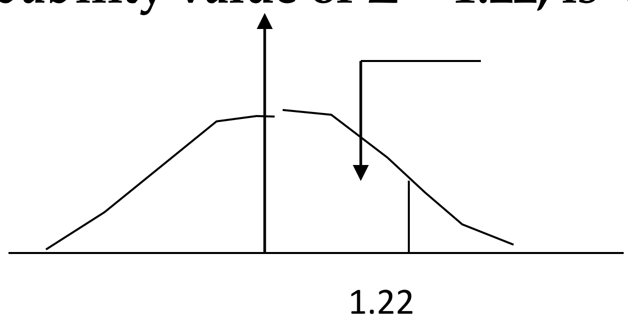
Example,

D = 50; S(Scheduled date) = 20+15+8 =43; V = (4+25+4) =33

Z = (50 – 43) / 5.745

= 1.22 standard deviations.

The probability value of Z = 1.22, is 0.888



What deadline are you 95% sure of meeting

Z value associated with 0.95 is 1.645

$$
\begin{aligned}
D &= S + 5.745\ (1.645) \\
&= 43 + 9.45 \\
&= 52.45 \text{ days}
\end{aligned}
$$

Thus, there is a 95 percent chance of finishing the project by 52.45 days.

Comparison Between CPM and PERT

	CPM	PERT
1	Uses network, calculate float or slack, identify critical path and activities, guides to monitor and controlling project	Same as CPM
2	Uses one value of activity time	Requires 3 estimates of activity time Calculates mean and variance of time
3	Used where times can be estimated with confidence, familiar activities	Used where times cannot be estimated with confidence. Unfamiliar or new activities
4	Minimizing cost is more important	Meeting time target or estimating percent completion is more important
5	Example: construction projects, building one off machines, ships, etc	Example: Involving new activities or products, research and development etc

BENEFITS OFCPM / PERT NETWORK

Consistent framework for planning, scheduling, monitoring, and controlling project.

- Shows interdependence of all tasks, work packages, and work units.
- Helps proper communications between departments and functions.
- Determines expected project completion date.
- Identifies so-called critical activities, which can delay the project completion time.

BENEFITS OFCPM / PERT NETWORK (cont.)

- Identified activities with slacks that can be delayed for specified periods without penalty, or from which resources may be temporarily borrowed

- Determines the dates on which tasks may be started or must be started if the project is to stay in schedule.

- Shows which tasks must be coordinated to avoid resource or timing conflicts.

- Shows which tasks may run in parallel to meet project completion date