Project Management
Network Analysis : PERT & CPM

Introduction

- Network analysis is one of the important tools for project management.
- Whether major or minor a project has to be completed in a definite time & at a definite cost.
- The necessary information of any particular data can be represented as a project network.
- These techniques are very useful for planning, scheduling and executing large-time bound projects involving careful co-ordination of variety of complex and interrelated activities

Objectives of network analysis

- Helpful in planning
- Inter-relationship of various activities
- Cost control
- Minimisation of maintenance time
- Reduction of time
- Control on idle resources
- Avoiding delays, interruptions

Applications of network analysis

- Planning, scheduling, monitoring and control of large and complex projects.
- Construction of factories, highways, building, bridges, cinemas etc.
- Helpful to army for its missile development.
- Assembly line scheduling
- Installation of computers and high tech machineries
- To make marketing strategies

Stages for project management

- **Project planning stages :** it is an important step during which are set the plans and strategies for projects execution. It has two important aspects – **identification of activities and estimation of resources.**

  Project planning involves following steps :

1. **Setting the objectives of the project and the assumptions to be made.**
2. **Developing the WBS.**
3. **Determination of time estimates of these activities**
4. **Estimation of resources**
5. **establishment of interdependence relationship between activities i.e. The sequence of performing activities.**

Scheduling stage : once all work packages have been identified and given unique names or identifiers, scheduling of the project started. It consist of determining:

1. **Start and finish times of each activity and the earliest and latest times at which events can occur.**
2. **Critical activity that requires special attention.**
3. **Allocation resources-men, machines, materials, time, space, money etc.**
4. **Various constraints due to limitation of resources.**

- **Project control stage :** project control refers to evaluating actual progress against the plan. If significant differences are observed, then the scheduling and resources allocation decisions are changed to update and revise the uncompleted part of the project. It consists of following steps:

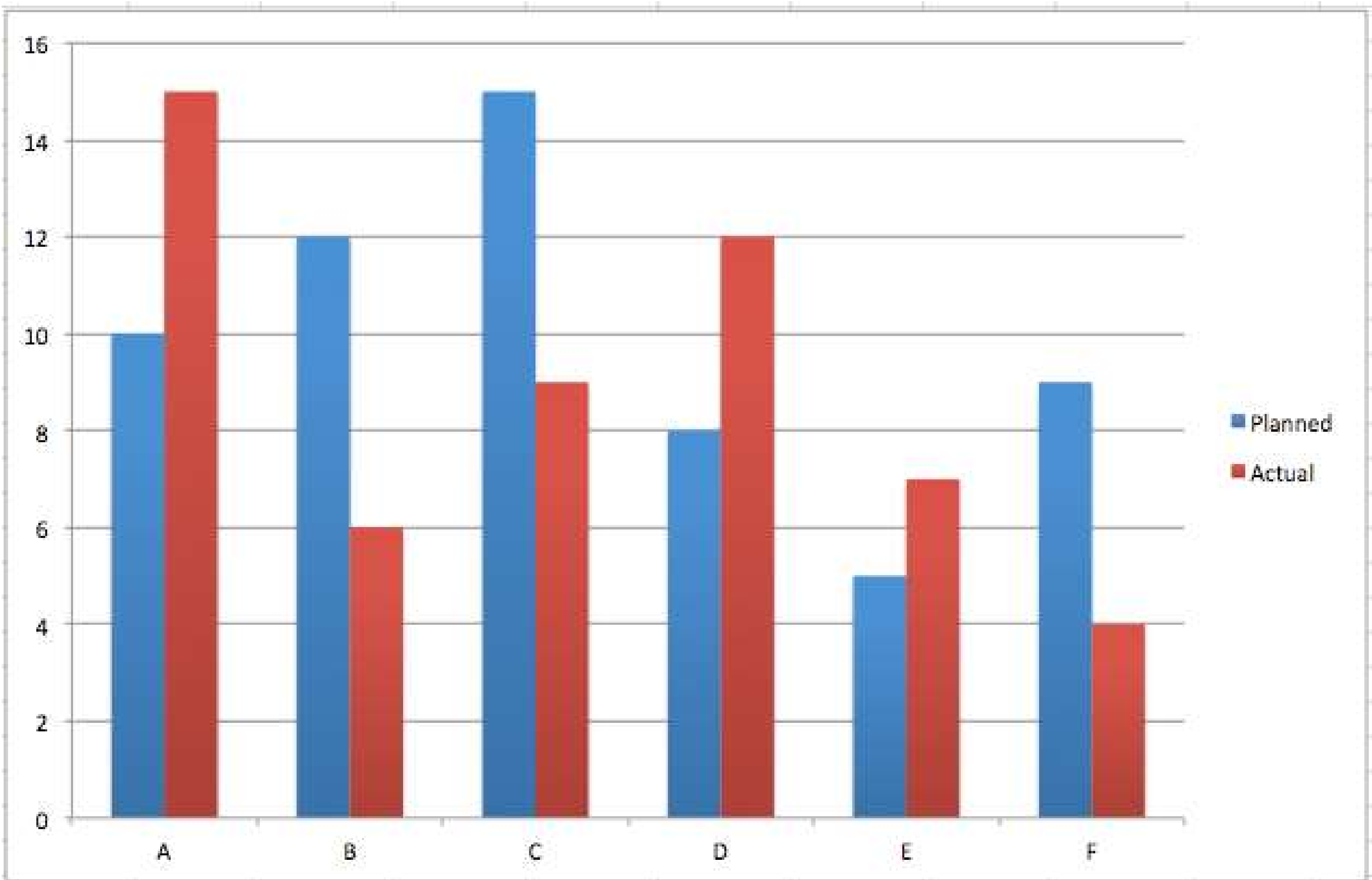
1. **Setting standard and targets with regard to time and cost of the project.**
2. **Reviewing the progress by comparing the work accomplished to the work scheduled at different stages of time and finding deviations.**
3. **Evaluating the effects of deviations on the project plan.**
4. **Updating the project schedule.**
5. **Suggesting the corrective measures to rectify the deviations from the plan.**

Basic tools and techniques of project management

- The various tools and techniques of project management are grouped into the following two heads:

1. **Bar Charts, Milestone charts and velocity diagrams**
2. **Network techniques.**

Bar Chart



Gantt chart

Critical Path Method

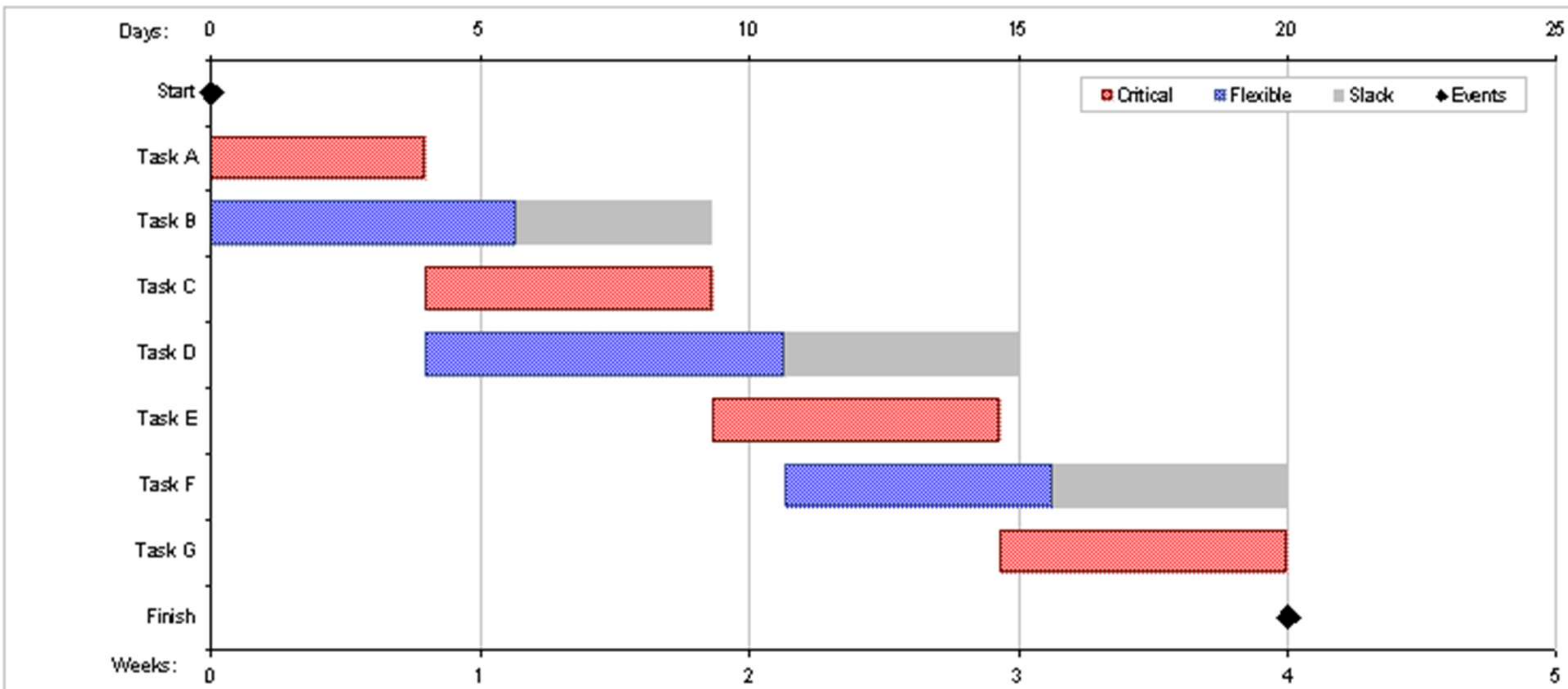
HELP

Start Date
1/11/2010
Finish Date
2/5/2010

Days to Completion
20.00

Times (in Days)
Time Distribution: Triangular

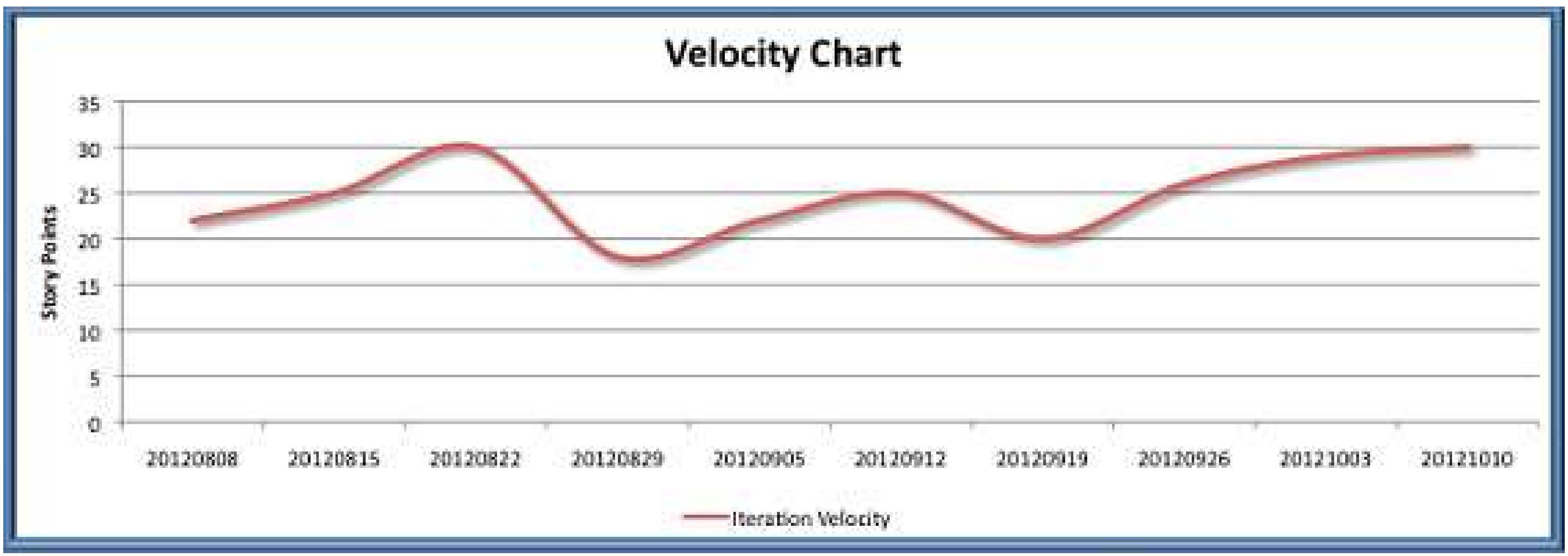
ID	Task Name	Predecessors (Enter one ID per cell)	O (min)	M (most likely)	P (max)	Duration (exp.time)	ES	EF	LS	LF	Slack
10	**Start**					0.00	*0.00*	0.00	0.00	0.00	0.00
20	**Task A**	10	2	4	6	4.00	0.00	4.00	0.00	4.00	0.00
30	Task B	10	3	5	9	5.67	0.00	5.67	3.67	9.33	3.67
40	**Task C**	20	4	5	7	5.33	4.00	9.33	4.00	9.33	0.00
50	Task D	20	4	6	10	6.67	4.00	10.67	8.33	15.00	4.33
60	**Task E**	30 40	4	5	7	5.33	9.33	14.67	9.33	14.67	0.00
70	Task F	50	3	4	8	5.00	10.67	15.67	15.00	20.00	4.33
80	**Task G**	60	3	5	8	5.33	14.67	20.00	14.67	20.00	0.00
90	**Finish**	70 80				0.00	20.00	20.00	20.00	*20.00*	0.00



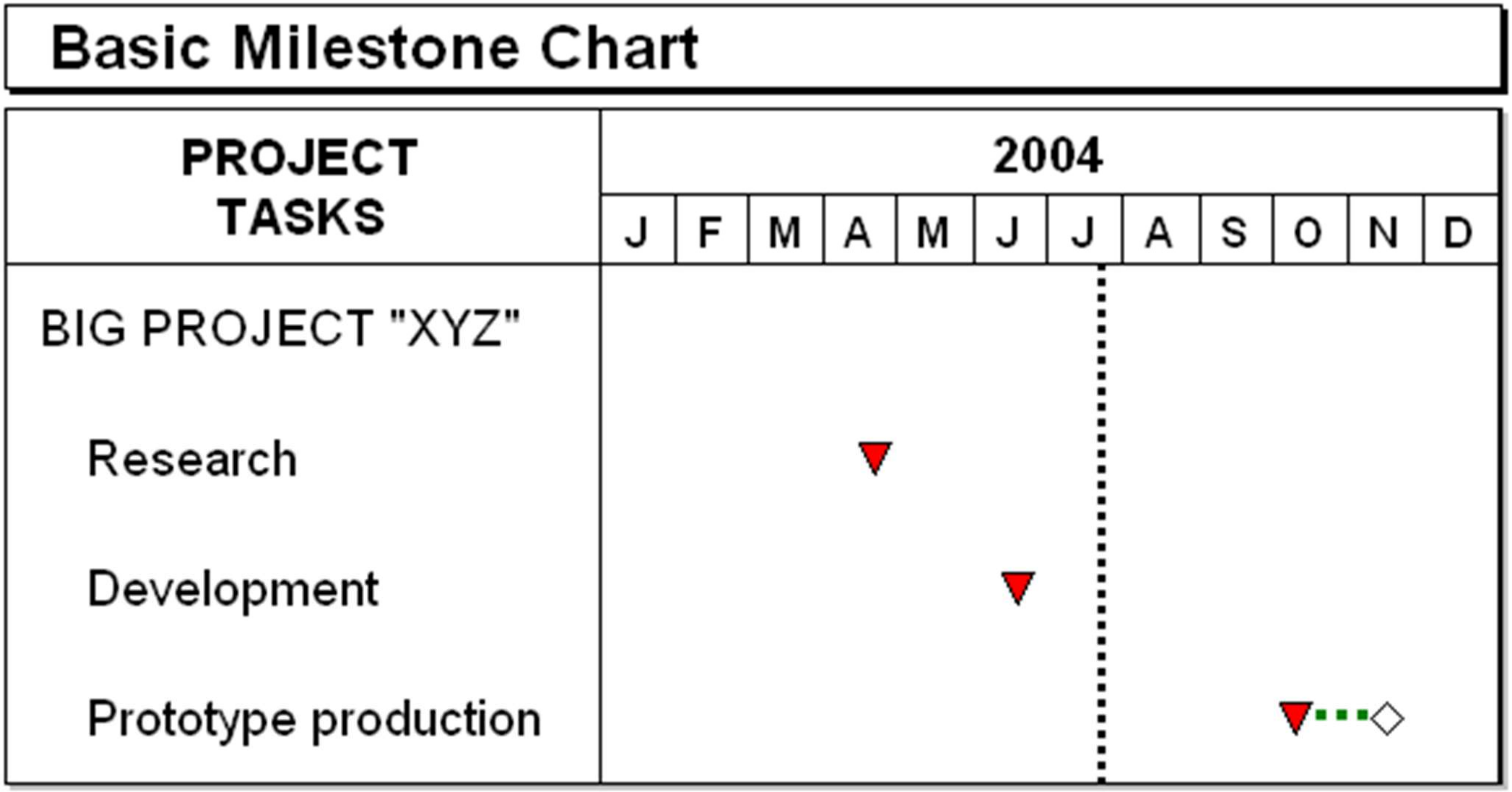
Velocity Chart

The Velocity Chart shows the amount of value delivered in each sprint, enabling you to predict the amount of work the team can get done in future sprints. It is useful during your sprint planning meetings, to help you decide how much work you can feasibly commit to.

You can estimate your team's velocity based on the total Estimate (for all completed stories) for each recent sprint. This isn't an exact science — looking at several sprints will help you to get a feel for the trend. For each sprint, the Velocity Chart shows the sum of the Estimates for complete and incomplete stories. Estimates can be based on story points, business value, hours, issue count, or any numeric field of your choice.



Milestone chart



Network techniques

- A network also called as network diagram or network technique is a symbolic representation of the essential characteristics of a project. PERT and CPM are two most widely applied techniques.

1. Program evaluation and review technique(PERT):

- It uses event oriented network in which successive events are joined by arrows.
- It is preferred for projects that are non repetitive and in which time for various activities can not be precisely pre determined.
- There is no significant past experience to guide.
- Launching a new product in the market by company, research and development of new war weapon, launching of satellite, sending space craft to mars are PERT projects.
- **Three time estimates** – the optimistic time estimate, pessimistic time estimate and the most likely time estimate are associated with each and every activity to take into account the uncertainty in their times.

Network techniques

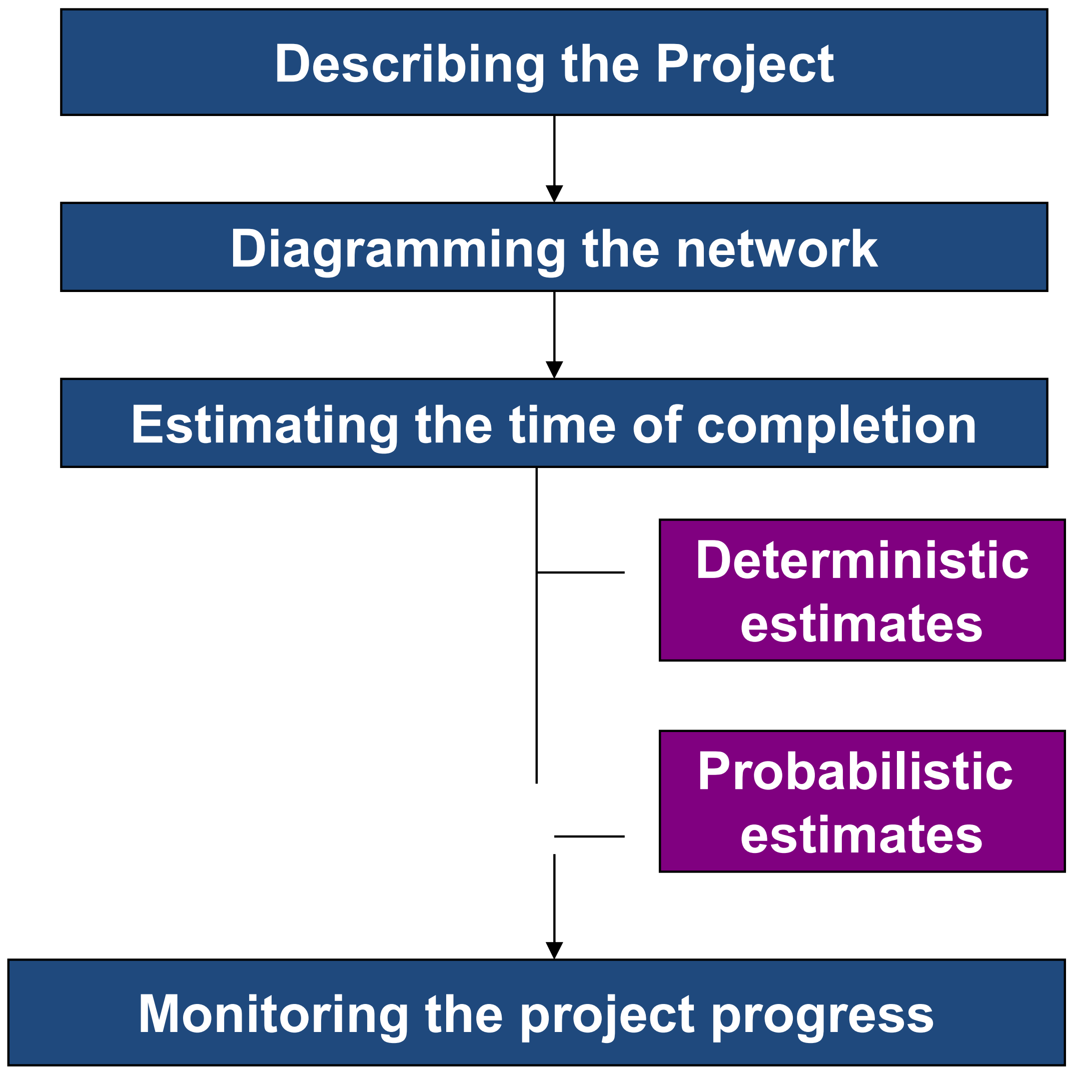
2. **Critical Path Method (CPM):**

- It uses activity oriented network which consists of a number of well recognized jobs, tasks or activities.
- Each activity is represented by arrow and activities are joined together by events.
- CPM is generally used for simple, repetitive types of projects for which the activity times and costs are certainly and precisely known.
- Projects like construction of building, road, bridge, physical verification of store, yearly closing of accounts by a company can be handled by CPM.
- Thus it is deterministic rather than probabilistic model.

Difference between PERT & CPM

PERT	CPM
A probability model with uncertainty in activity duration . The duration of each activity is computed from multiple time estimates with a view to take into account time uncertainty.	A deterministic model with well known activity times based upon the past experience.
It is applied widely for planning & scheduling research projects.	It is used for construction projects & business problems.
PERT analysis does not usually consider costs.	CPM deals with cost of project schedules & minimization.

Methodology Involved in Network Analysis



Advantages

- Planning & controlling projects
- Flexibility
- Designation of responsibilities
- Achievement of objective with least cost
- Better managerial control

Limitations of PERT /CPM

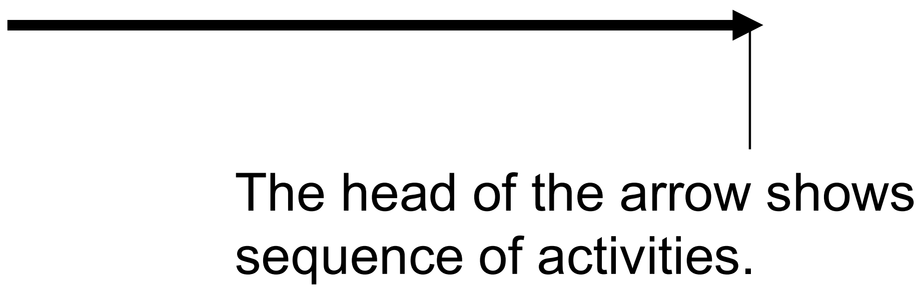
- Network diagrams should have clear starting & ending points, which are independent of each other which may not be possible in real life.
- Another limitation is that it assumes that manager should focus on critical activities.
- Resources will be available when needed for completion for an activity is again unreal.

Difficulties

- Difficulty in securing realistic time estimates.
- The planning & implementation of networks requires trained staff.
- Developing clear logical network is troublesome.

Key terminology

- **Activity :** All projects may be viewed as composed of activities. It is the smallest unit of work consuming both time& resources that project manager should schedule & control.
- An activity is represented by an arrow in network diagram



Classification of activities

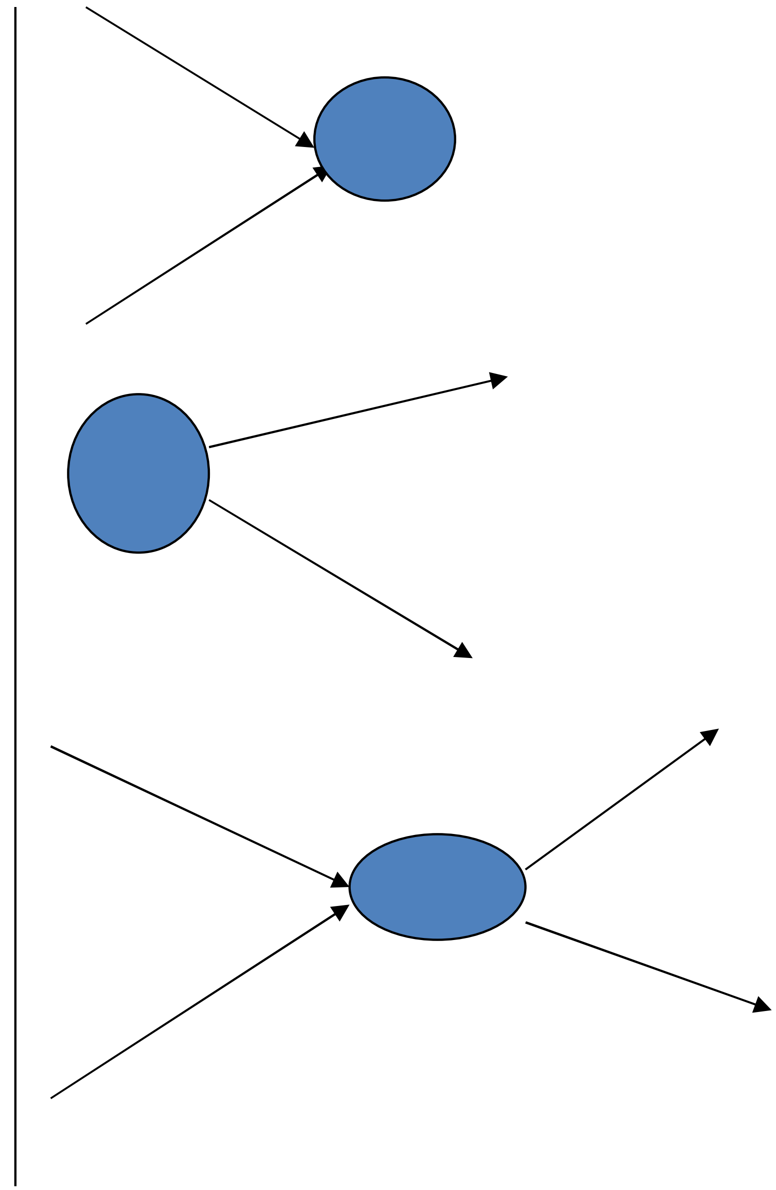
- **Predecessor activity**: Activities that must be completed immediately prior to the start of another activity are called predecessor activities.
- **Successor activity** : activities that cannot be started until one or more of other activities are completed but immediately succeed them are called successor activities.
- **Concurrent activities**: activities that can be accomplished together are known as concurrent activities.
- **Dummy activity**: An activity which does not consume any resource but merely depicts the dependence of one activity on other is called dummy activity. It is introduced in a network when two or more parallel activities have the same start and finish nodes.

Event

- The beginning & end of an activities are called as **events** .
- Events are represented by numbered circles called **nodes**.

Types of Events

- Merge event
- Burst event
- Merge & Burst Event



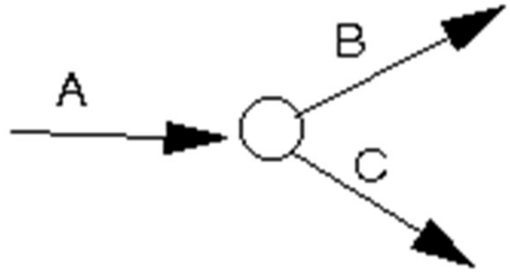
Path & Network

- An unbroken chain of activity arrows connecting the initial event to some other event is called **a path**.
- **A network** is the graphical representation of logically & sequentially connected arrows & nodes representing activities & events of a project . It is a diagram depicting precedence relationships between different activities.

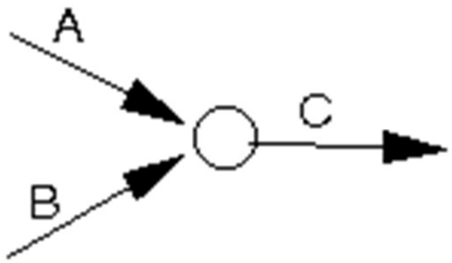
Guidelines for Network Construction

- A complete network diagram should have one start point & one finish point.
- The flow of the diagram should be from left to right.
- Arrows should not be crossed unless it is completely unavoidable.
- Arrows should be kept straight & not curved or bent.
- Angle between arrows should as large as possible.
- Each activity must have a tail or head event. No two or more activities may have same tail & head events.
- Once the diagram is complete the nodes should be numbered from left to right. It should then be possible to address each activity uniquely by its tail & head event.

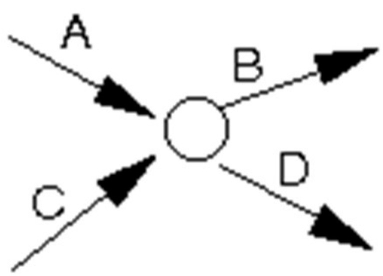
Dependency Relationship



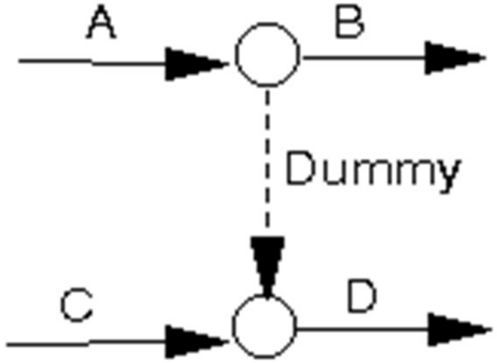
A must finish before either B or C can start



both A and B must finish before C can start



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



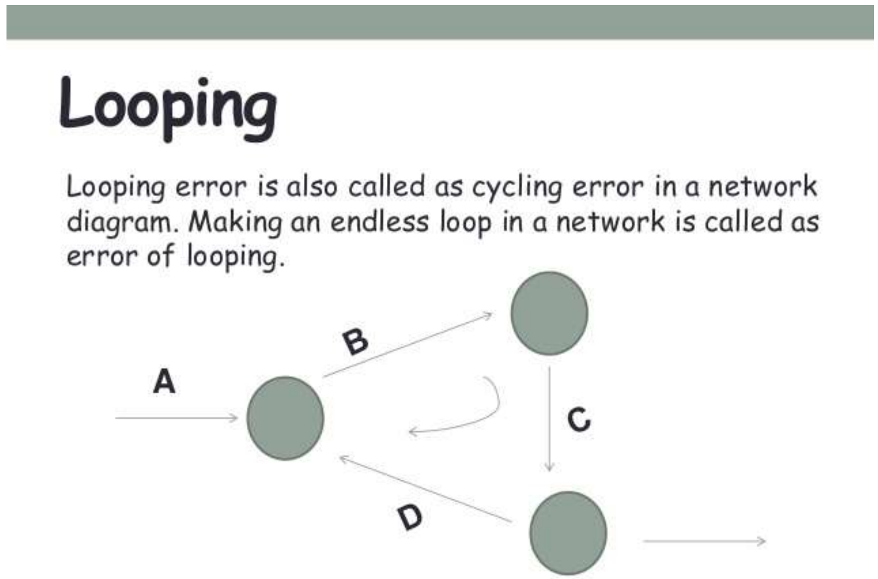
A must finish before B can start

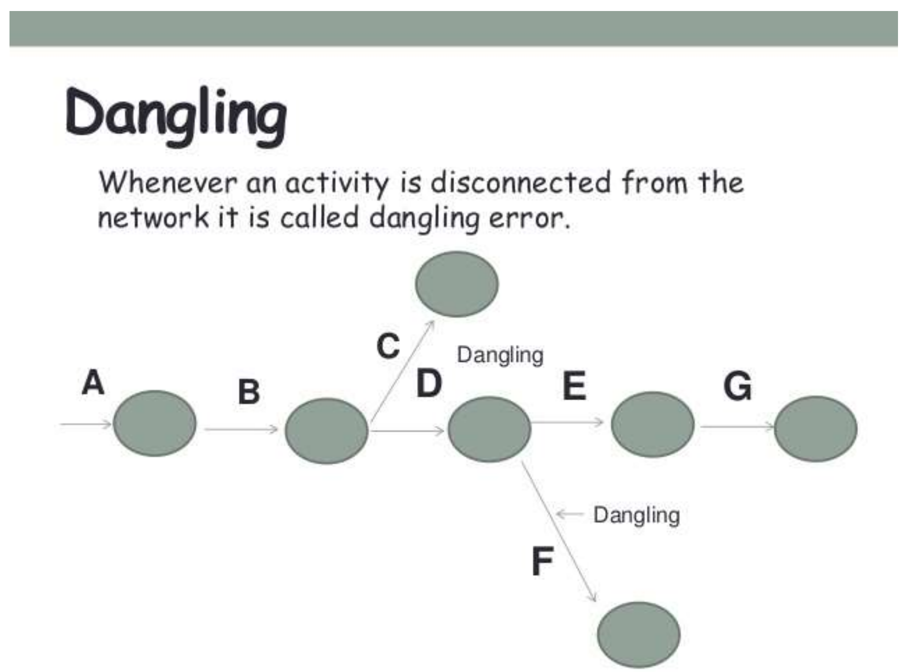
both A and C must finish before D can start

Errors in network logic

- Looping : looping is known as cycling error and creates an impossible situation and it appears that none of the activities could ever be completed.

- Dangling : sometimes a project network includes an activity which does not fit into the end objective of the project and is carried out without any result related with completion of the project . Such an error in network is called dangling





ERRORS TO BE AVOIDED IN CONSTRUCTING A NETWORK

a. Two activities starting from a tail event must not have a same end event. To ensure this, it is absolutely necessary to introduce a dummy activity, as shown in Figure 8.6.

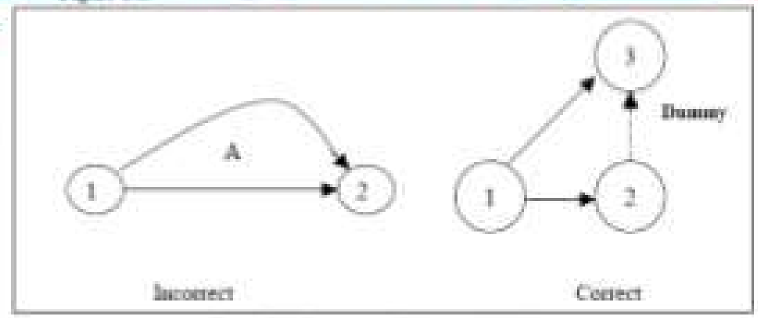


Figure 8.6: Correct and Incorrect Activities

b. Looping error should not be formed in a network, as it represents performance of activities repeatedly in a cyclic manner, as shown below in Figure 8.7.

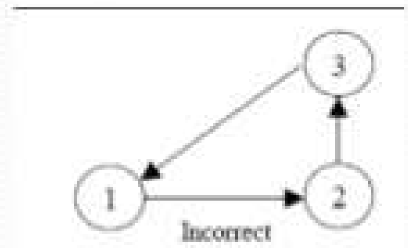


Figure 8.7: Looping Error

c. In a network, there should be only one start event and one ending event as shown below, in Figure 8.8.

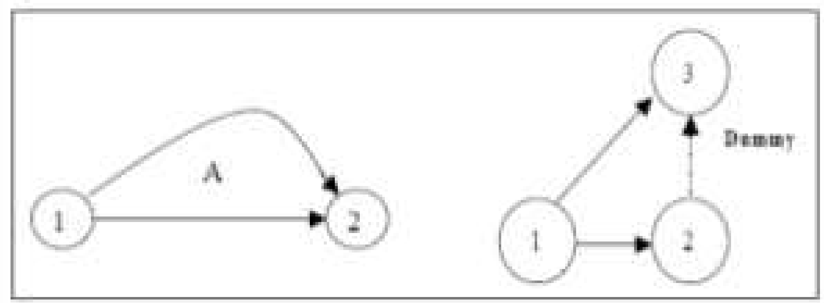


Figure 8.8: Only One Start and End Event

d. The direction of arrows should flow from left to right avoiding mixing of direction as shown in Figure 8.9.

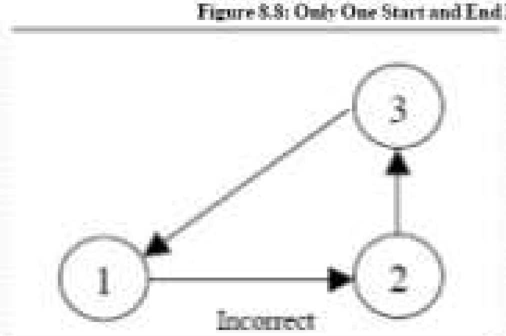


Figure 8.9: Wrong Direction of Arrows

Example 1- A simple network

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

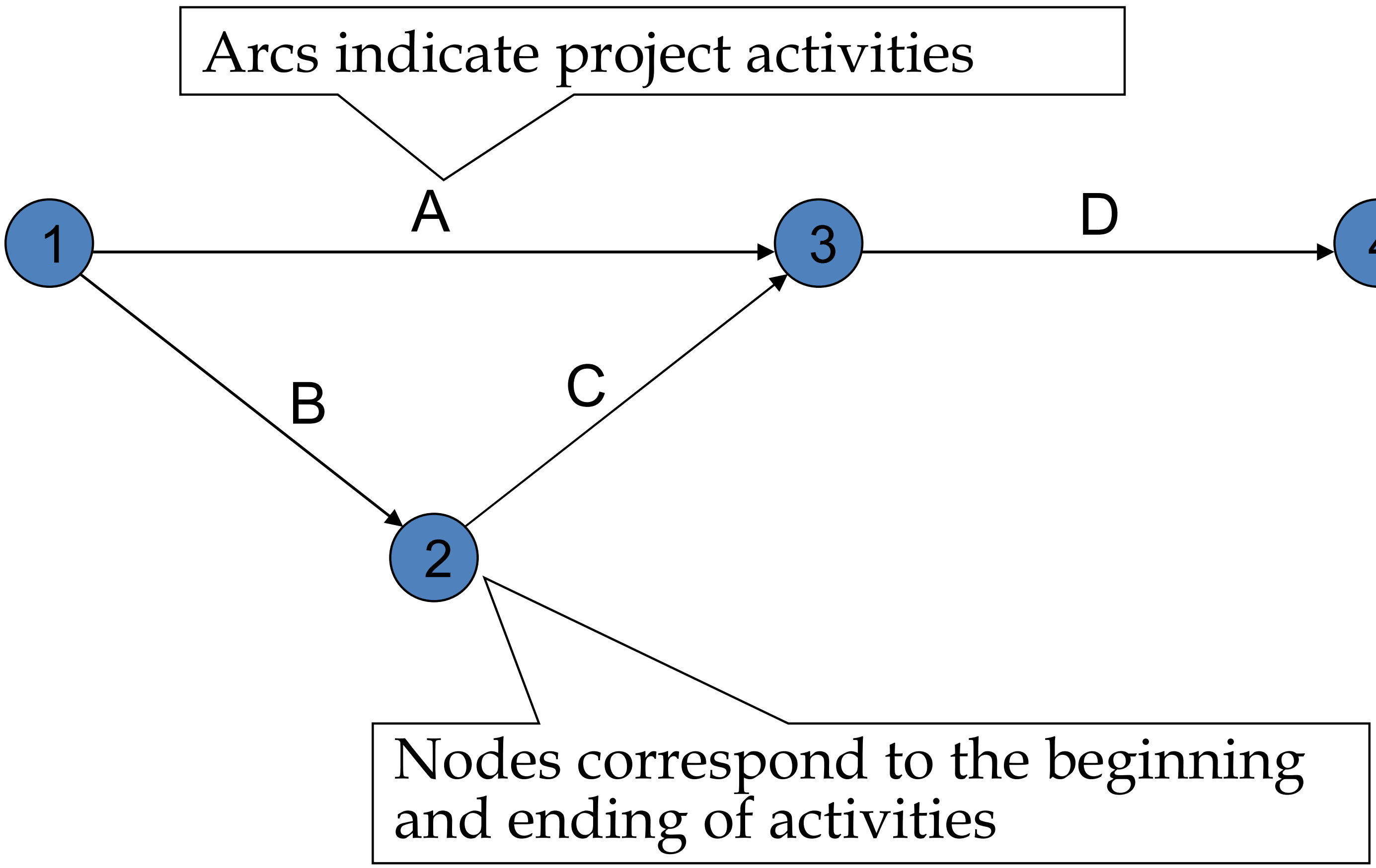
Activity	Description	Immediate predecessors
A	Buy Plastic Body	-
B	Design Component	-
C	Make Component	B
D	Assemble product	A,C

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

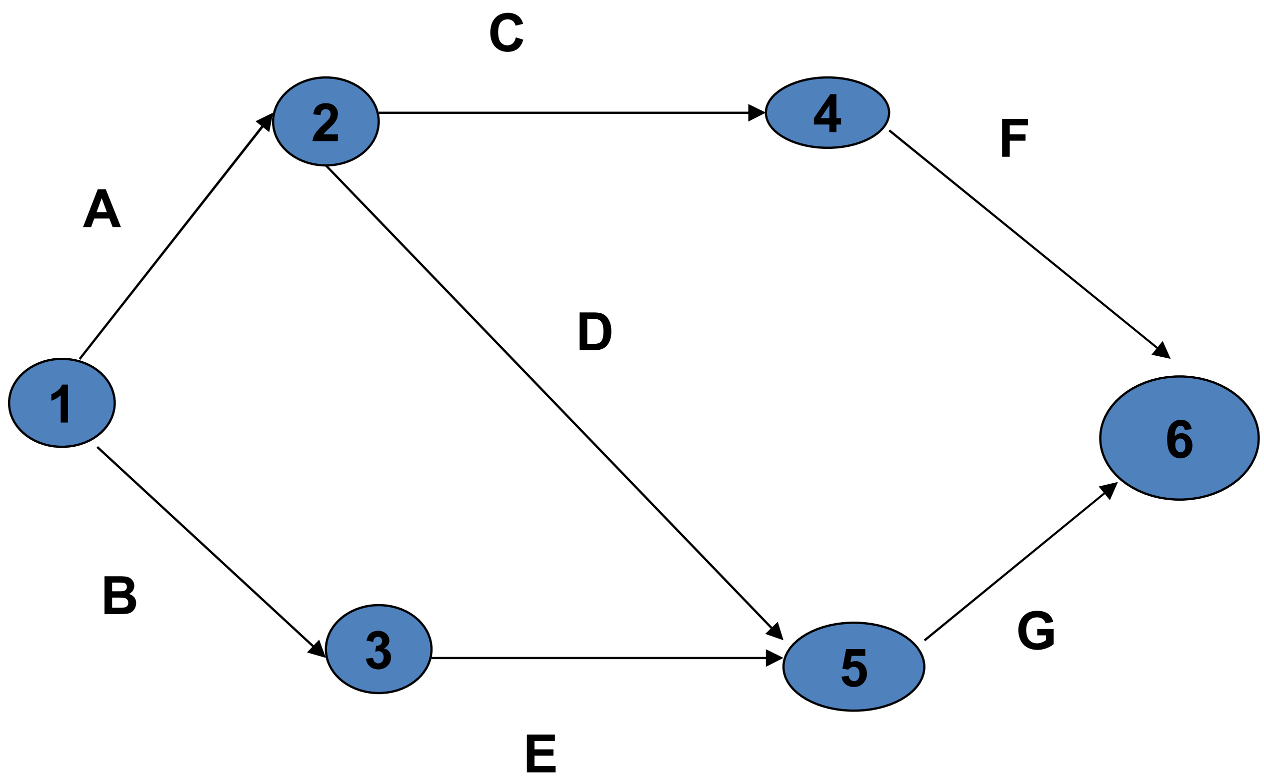


Example 2

Activity	Predecessor activity
A	none
B	none
C	A
D	A
E	B
F	C
G	D & E

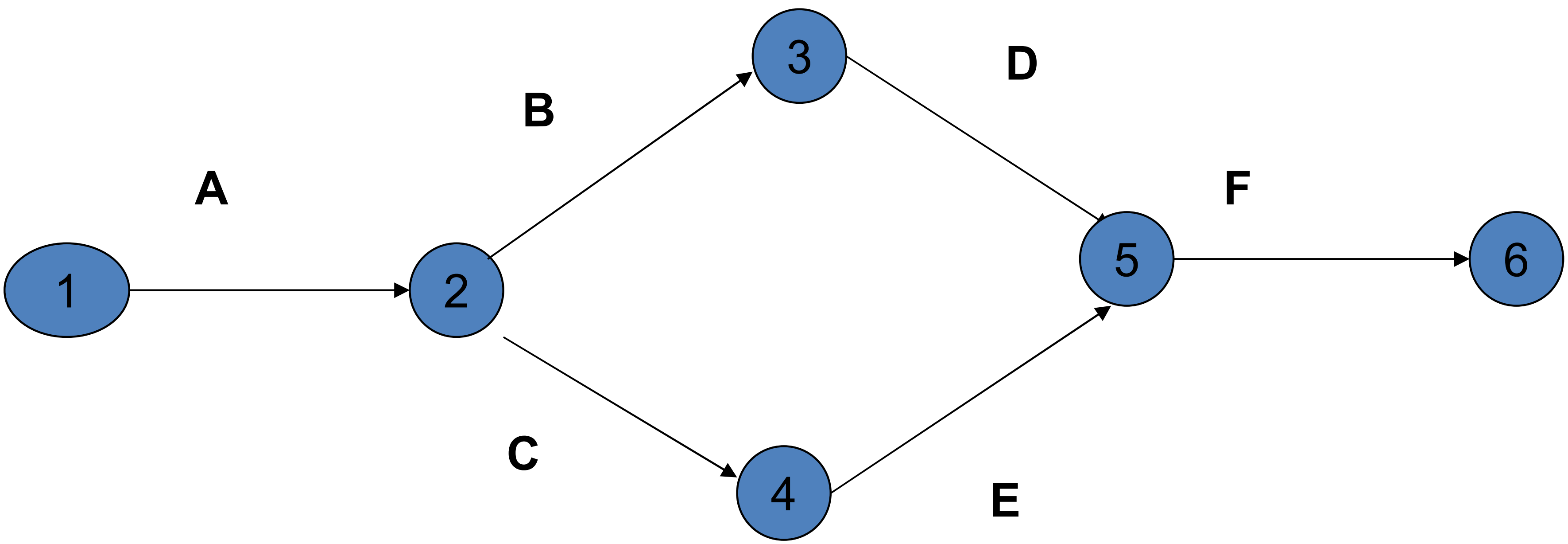
Example 2

Activity	Predecessor activity
A	none
B	none
C	A
D	A
E	B
F	C
G	D & E



Example 3

Activity	Predecessor activity
A	none
B	A
C	A
D	B
E	C
F	D ,E



A
B
C
D
E
F
1
2
3
4
5
6

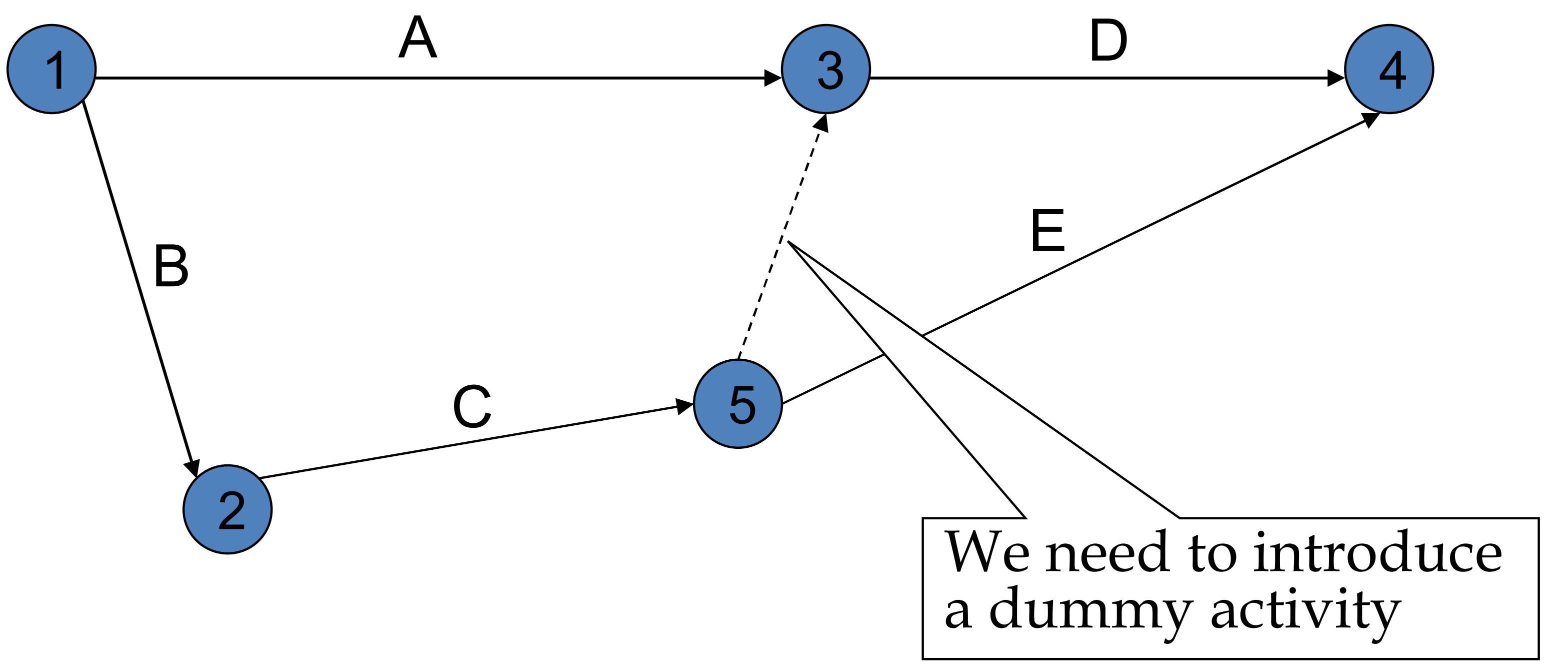
Example 4

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

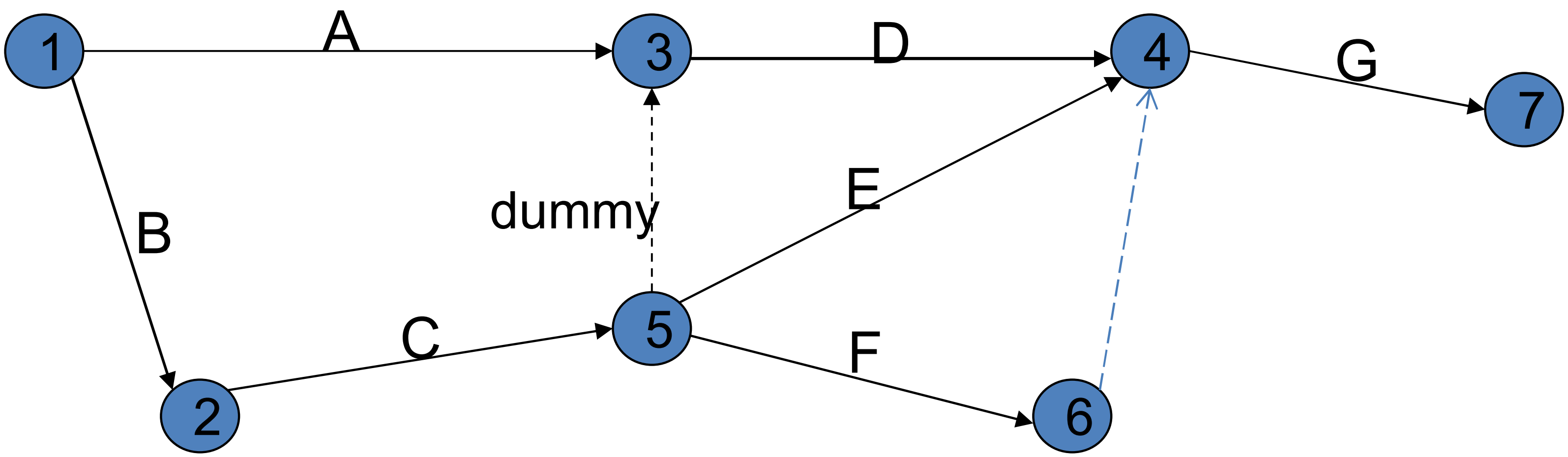
Activity	**Immediate predecessors**
A	-
B	-
C	B
D	A, C
E	C
F	C
G	D,E,F

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

Network of first five activities



Network of Seven Activities



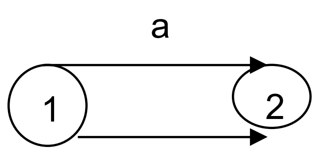
- Note how the network correctly identifies D, E, and F as the immediate predecessors for activity G.

- 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

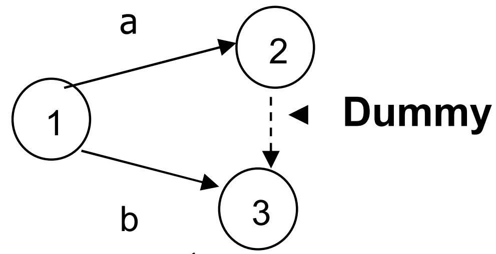
- Dummy activities have no resources (time, labor, machinery, etc) – purpose is to PRESERVE LOGIC of the network

EXAMPLES OF THE USE OF DUMMYACTIVITY

Network concurrent activities

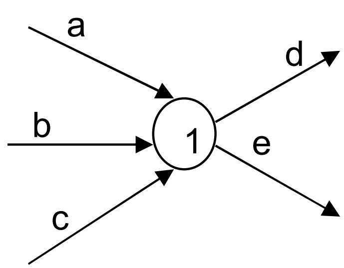


WRONG!!!

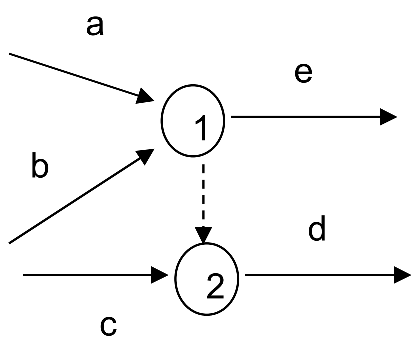


RIGHT ✓

Activity c not required for e



WRONG !!!



RIGHT ✓

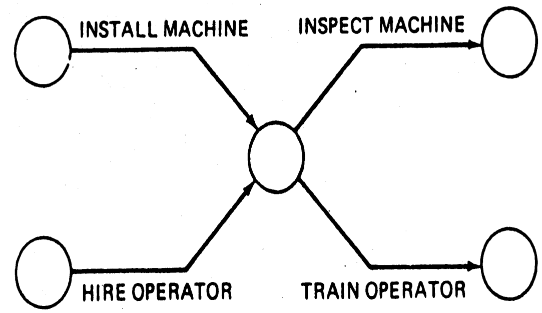


Figure 2-16

WRONG !

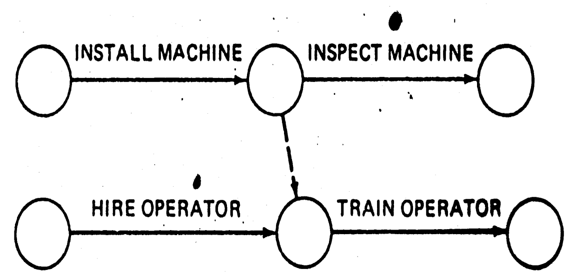
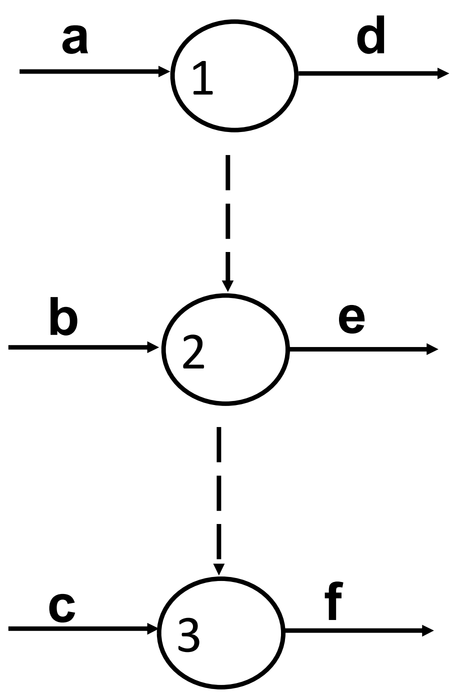


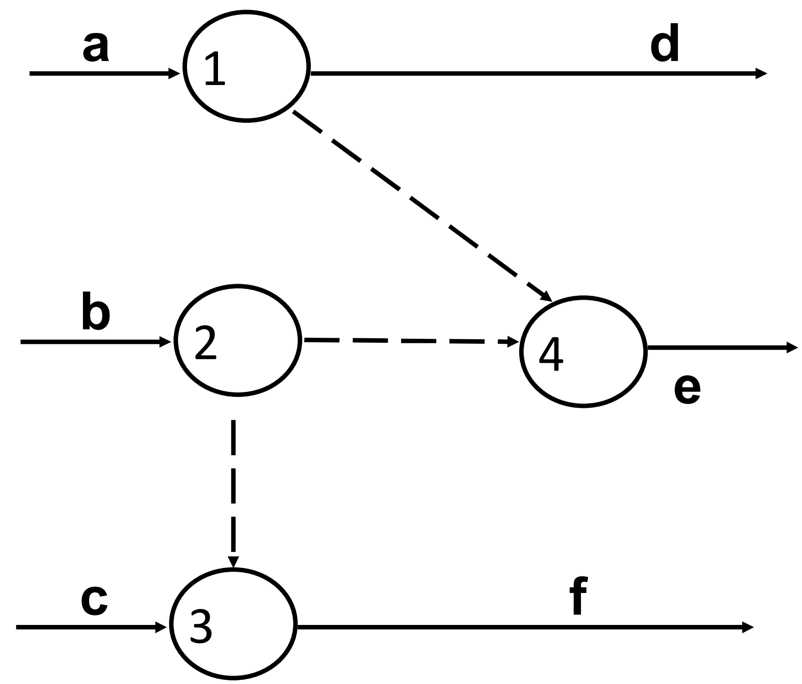
Figure 2-17

RIGHT ✓

WRONG!!!



RIGHT!!!



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

Float : **There are many activities where the maximum time available to finish the activity is more than the time required to complete the activity. The difference between the two times is known as float available for the activity.**

There are three types of float:

- **Total float** : **It is the spare time available when all preceding activities occur at earliest possible times & all succeeding activities occur at latest possible times.**

  Total float = Ls – Es or Lf – Ef

- **Free float** : time available when all preceding activities occur at the earliest possible time &all succeeding activities also occur at the earliest possible times.
- **Free float** = total float - head event slack
- **Independent Float** : it may be defined as the amount of time by which the start of an activity can be delayed without affecting the earliest start time of any successor activity , assuming that preceding activity has finished at its latest finish time.
- Independent Float = free float – tail event slack

Critical path

- Those activities which contribute directly to the overall duration of the project constitute critical activities, the critical activities form a chain running through the network which is called critical path.

- **Critical event** : the slack of an event is the difference between the latest & earliest events time. The events with zero slack time are called as critical events.

- **Critical activities** : The difference between latest start time & earliest start time of an activity will indicate amount of time by which the activity can be delayed without affecting the total project duration. The difference is usually called total float. Activities with 0 total float are called as critical activities

Critical path

- The critical path is the longest path in the network from the starting event to ending event & defines the minimum time required to complete the project.

- The critical path is denoted by darker or double lines.

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 & earliest finish time

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

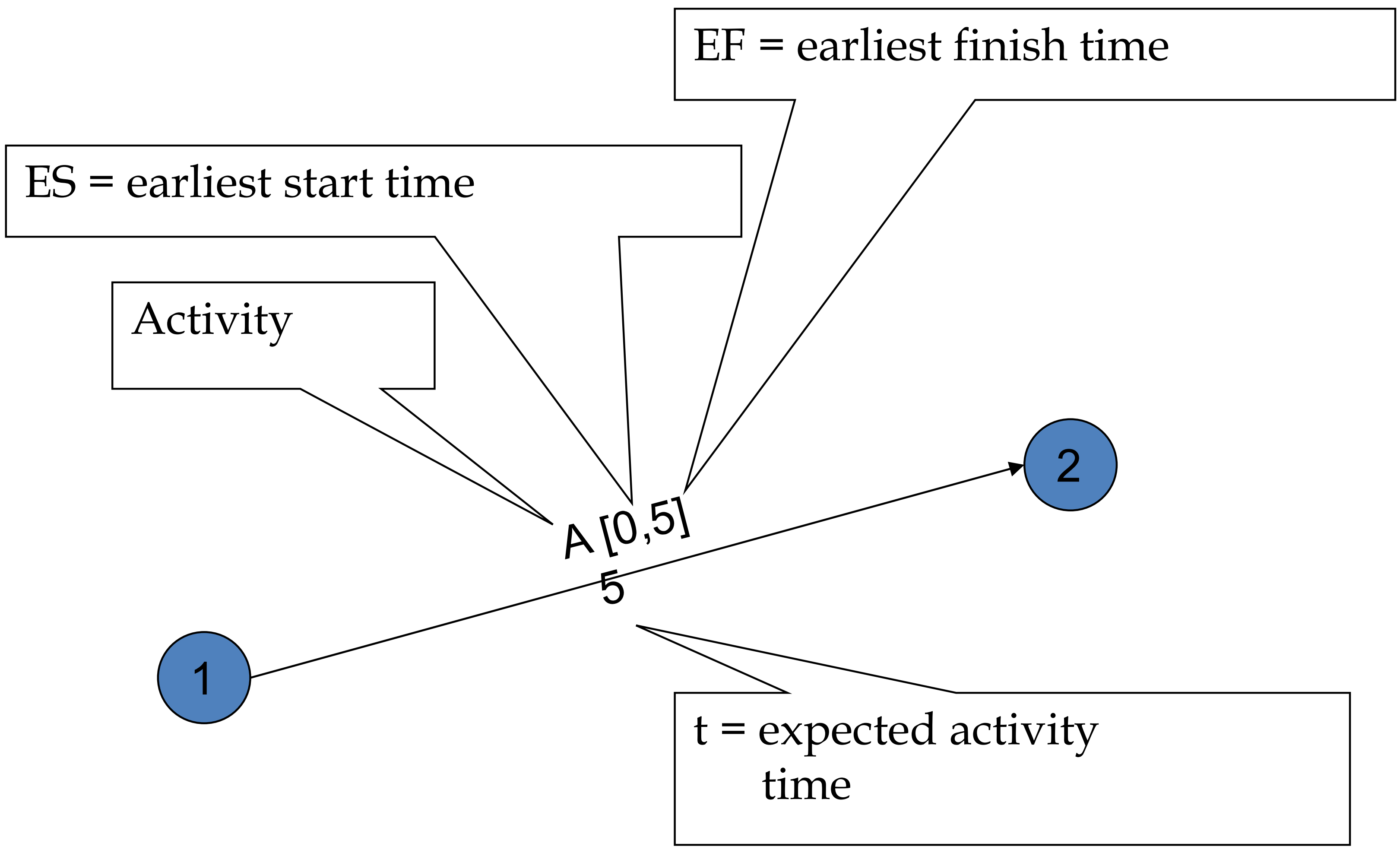
- Starting at the network's origin (node 1) and using a starting time of 0, we compute an ***earliest start*** (ES) and ***earliest finish*** (EF) time for each activity in the network.

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

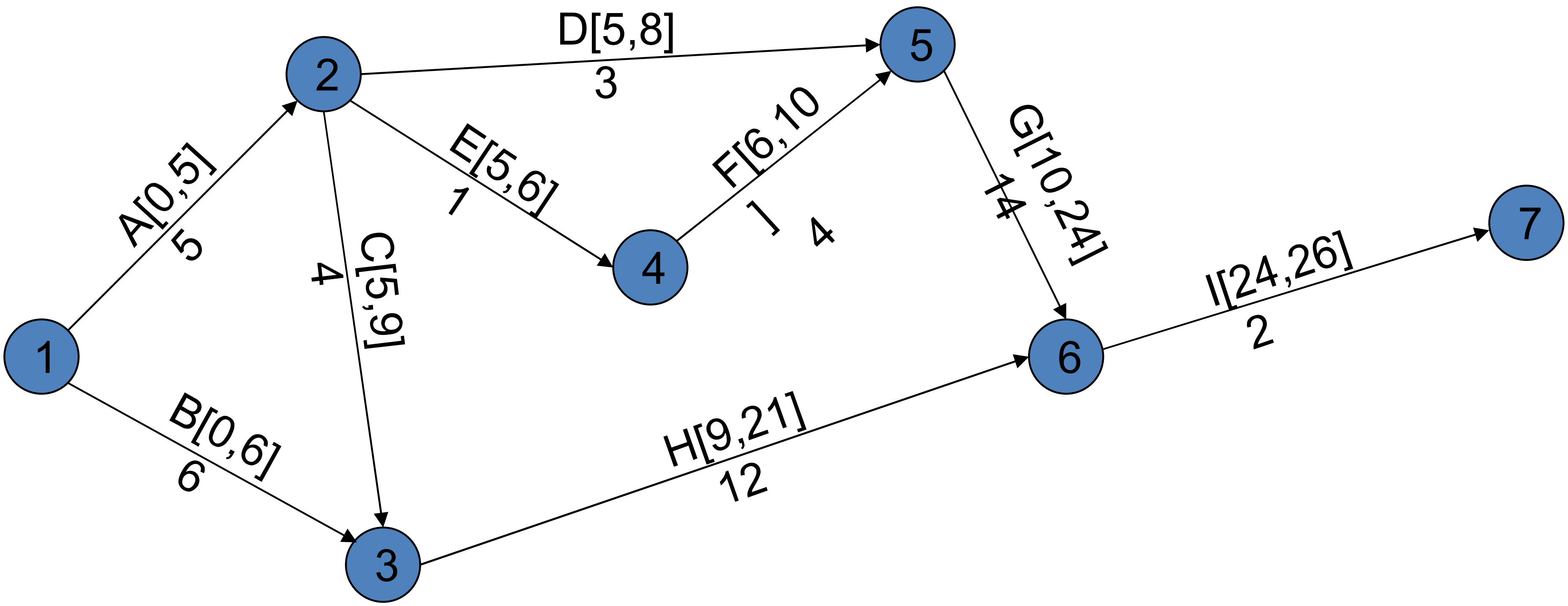
  For example, for activity A, ES = 0 and t = 5; thus the earliest finish time for activity A is

$$EF = 0 + 5 = 5$$

Arc with ES & EF time



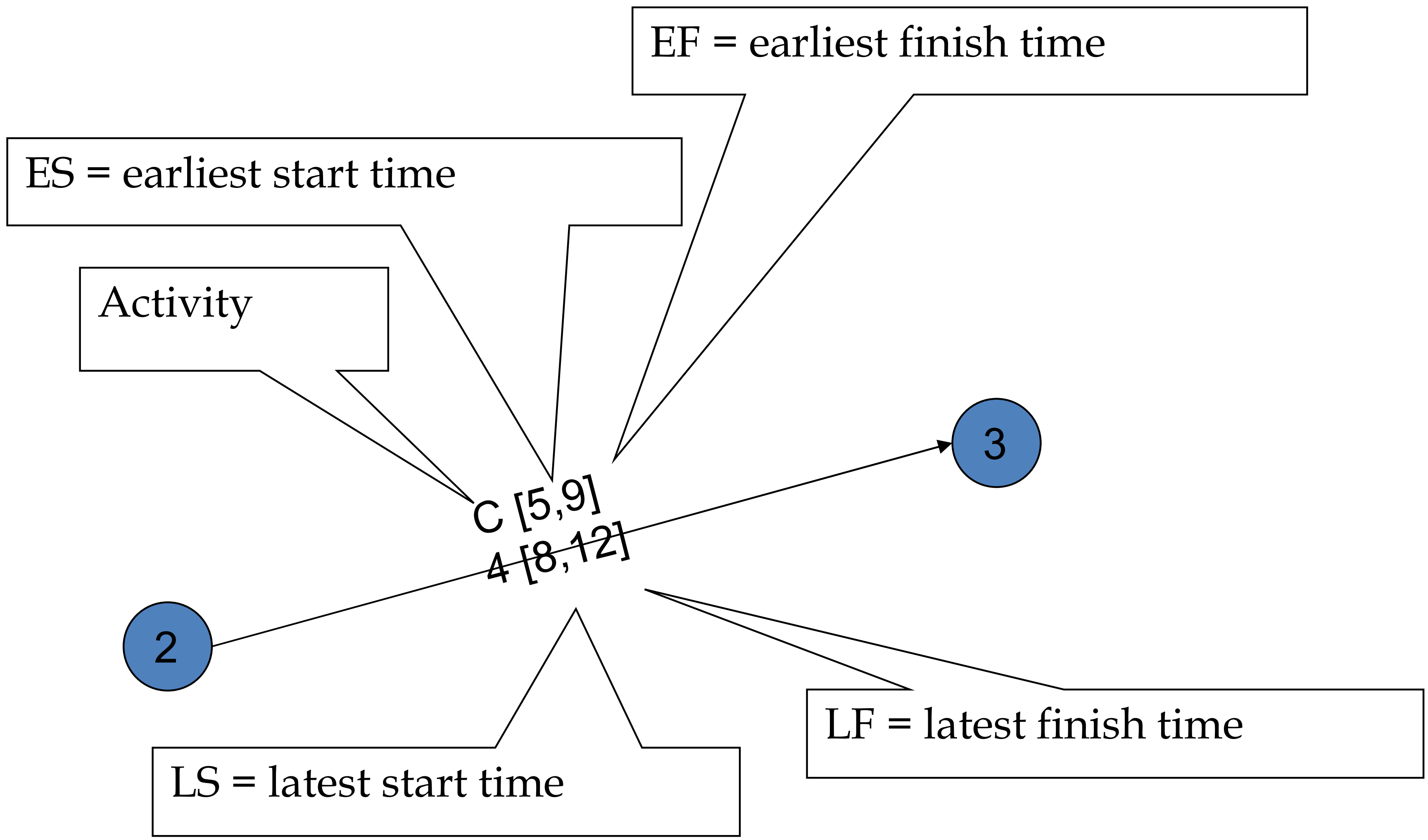
Network with ES & EF time



<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

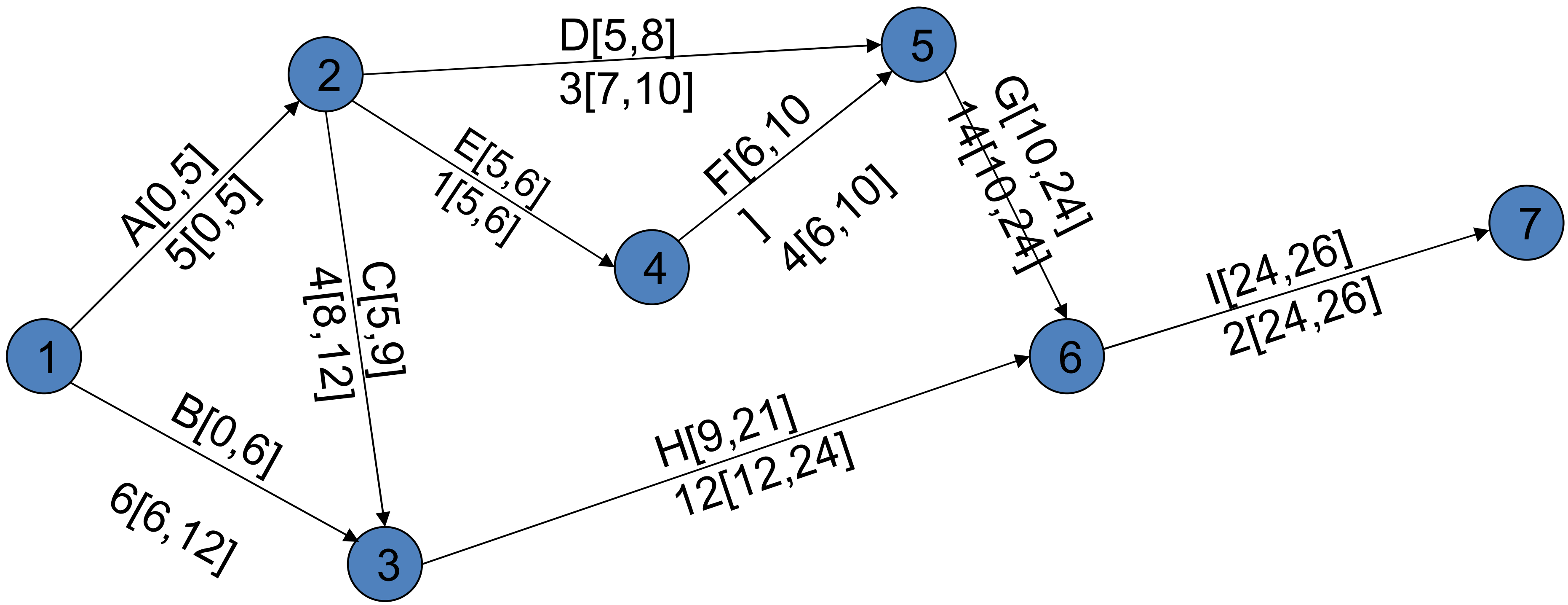


Latest start & latest finish time

- To find the critical path we need a backward pass calculation.
- Starting at the completion point (node 7) and using a ***latest finish*** time (LF) of 26 for activity I, we trace back through the network computing a ***latest start*** (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



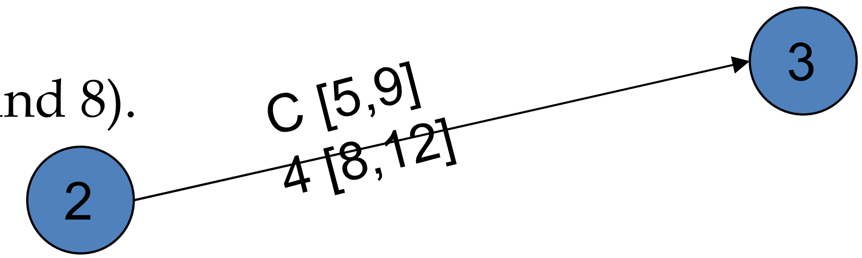
<u>Latest finish time rule</u>:
The latest finish time for an activity entering a particular node is equal to the **smallest** of the latest start times for all activities leaving the node.

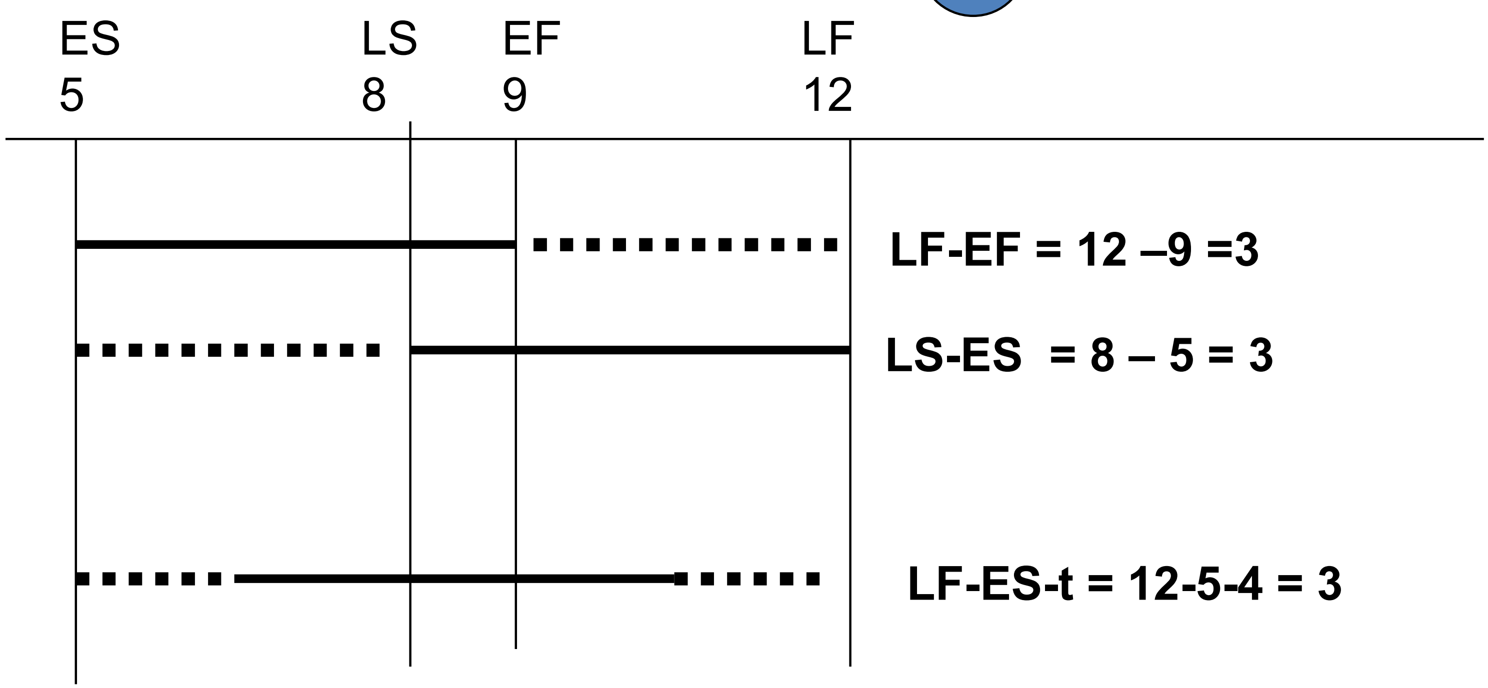
Slack or Free Time or Float

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	Duration	Earliest start (ES)	Latest start (LS)	Earliest finish (EF)	Latest finish (LF)	Slack (LS-ES)	Critical path
A	**5**	0	**0**	5	**5**	0	Yes
B	**6**	0	**6**	6	**12**	6	
C	**4**	5	**8**	9	**12**	3	
D	**3**	5	**7**	8	**10**	2	
E	**1**	5	**5**	6	**6**	0	Yes
F	**4**	6	**6**	10	**10**	0	Yes
G	**14**	10	**10**	24	**24**	0	Yes
H	**12**	9	**12**	21	**24**	3	
I	**2**	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