Module 3 : Software Project Planning & Cost Estimation

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ILOC: Project Management (Autonomy)

Agenda : Software Project Planning

- Business Case
- Project selection and Approval
- Project charter
- Project Scope management
- Creating the Work Breakdown Structures (WBS)
- Networking and Scheduling techniques.
- PERT, CPM, GANTT chart
- Introduction to Project Management Information System (PMIS)

Overview of Planning Process

- **Business need** – RFP is needed
- **Project Manager** – Identified
- **Project Charter** – created that briefly gives statement of work, expected end items/ results, required resources.
- The purpose of **project charter** is to enable project Manager , senior management , functional manager to reach agreement about scope of project and resources they will commit to it.
- Plan – What has to be done? How it has to be done? When and in what order, for how much and by when? Project Team need to address these questions.

Overview of Planning Process

- **Project objectives**, requirement & scope- desired results, time, cost, performance targets
- **Specific work activities** – tasks, jobs to achieve objective are broken down, defined & listed(**What?**)
- **Project Organization** is created specifying department, subcontractors, managers responsible for work activities **(who?)**
- **A schedule** is prepared showing timing of work, activities, deadlines and milestones (**when, in what order?)**
- **Budget & Resource plan** is prepared showing amount & timing of resources & expenditures for work activities & related items **(How much and When?)**

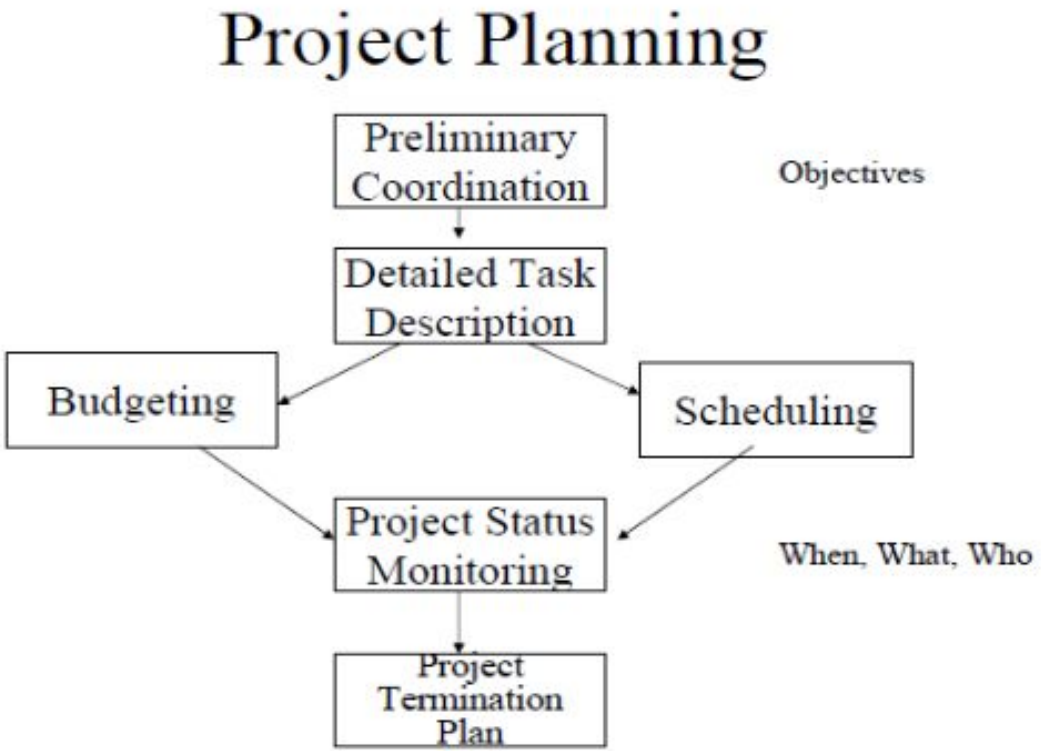
Overview of Planning Process

- A forecast is prepared of time, cost & performance. Projections for the completion of project(How much time is needed, what will it cost & when will project be finished)

In Planning...

- What will be performed? – **WBS**
- How will it be performed?- **determine process, procedure or methodologies used for completing project**
- Where it will be performed? – **physical location**
- Who will perform the work ?- **contract/ in-house**
- In What Sequence ? – **determine order in which activities will be performed to compete the project**

Project Planning…



Tools for Project Planning

- Work Breakdown structure and work packages – It is used to define the project work and break it down into specific tasks.
- Responsibility Matrix – Used to define project organization, key individuals, and their responsibilities.
- Events and milestones – used to identify critical points and major occurrences on the project schedule.
- Gantt charts – used to display the project master schedule and detailed task schedules.
- Additional planning tools such as networks, critical paths, PERT/CPM, cost estimating, budgeting and forecasted are also required.

Project Scope Management - Overview

- An overall goal statement
- A list of project objectives
- A list of deliverables
- A list of exclusions from scope
- A list of stakeholders, roles, & responsibilities
- A list of assumptions and constraints

Project Planning…

- The **first steps** in planning process
- Development of the **Work Breakdown Structure (WBS)**
- **Organizational Breakdown Structure (OBS)**
- Integration of WBS and OBS in creating the **Responsibility Assignment Matrix (RAM)**
- **Next step is Project Scheduling**

Work Breakdown Structure

- The process of dividing project into sub elements is called as Work Breakdown structure.
- Work - A WBS considers the work that needs to be performed
- Breakdown - Work is broken down (decomposed) into small pieces (activities)
  - Activities are eventually broken down into tasks
  - A task is something that takes less than a week to complete
  - Activities are normally assigned to individuals
- Structure - Each unit of work is broken down into a number of components
  - The result is a hierarchical structure
  - The lowest layers are tasks. e.g. A function that generates a polynomial collision-handling hash function is completed
  - The middle layers could be milestones. e.g. “Getting started” tutorial is completed
  - The highest layers are normally deliverables. e.g. Source code distribution, with configuration and makefiles, is completed

Work Breakdown Structure

For tasks to be well defined it must have **following properties:**

- Clear comprehensive statement of work
- Resource Requirements – labor, skills, equipment, facilities and materials for task are identified.
- Time – required to perform task is estimated
- Cost- cost for required resources management
- Responsibility – parties responsible for performing task
- Outcomes – the deliverables are identified
- Inputs – Preconditions necessary to begin task are identified
- Quality Assurance – Entry, process and exit conditions to which task must conform are identified.
- Other – additional information

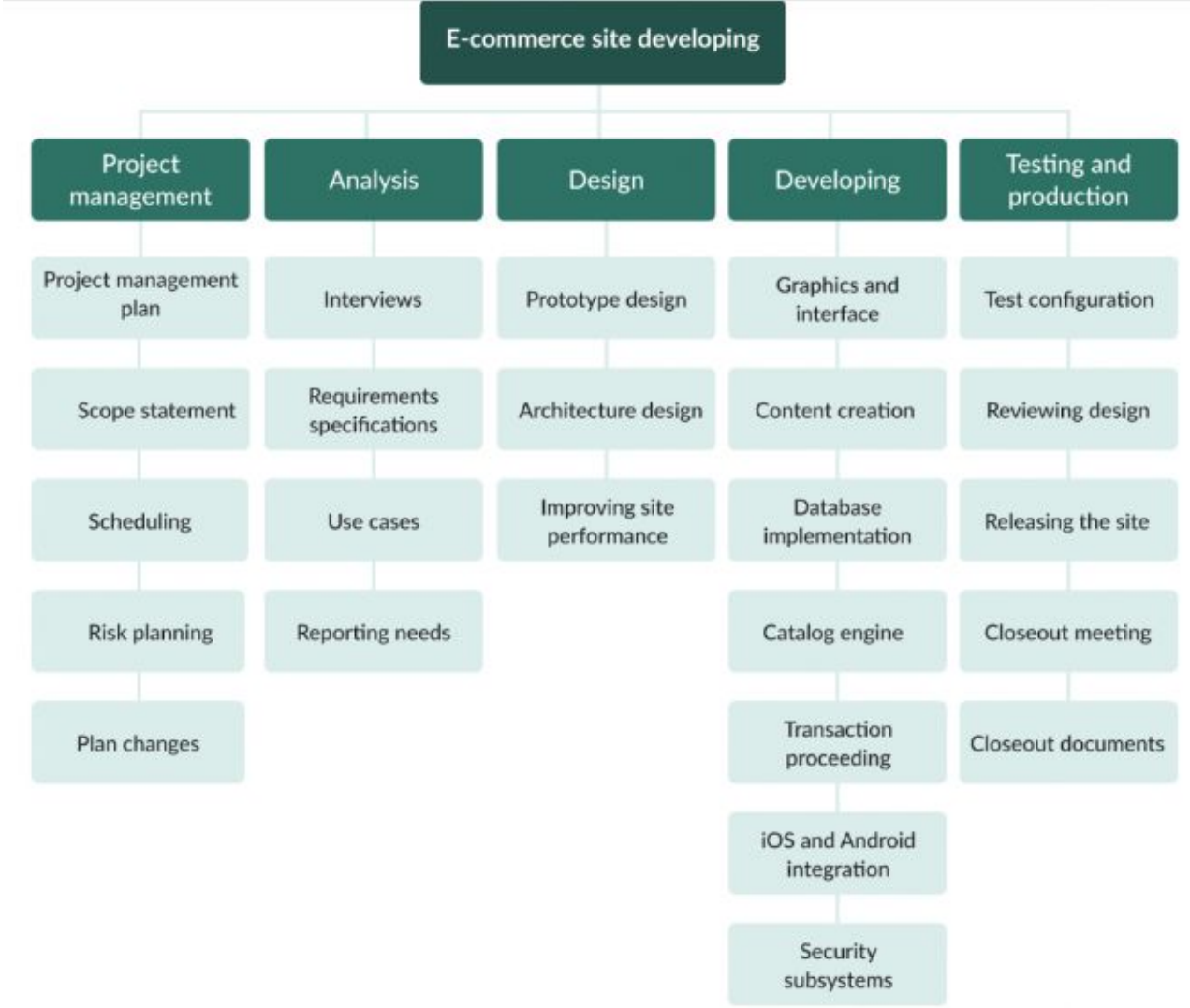
Work Packages

- Well defined tasks are called as work packages
- **Inputs :** Preconditions, Predecessors, Resources , Requirements/ specifications.
- **Tasks** - statement of work, time, cost, responsibility, quality assurance
- **Outcomes** – deliverables , results

Creating a WBS: Top-Down approach

- **The top-down approach:**
  - Start with the project's overall goal
  - Decompose the goal into deliverables
  - Decompose the deliverables into modules
  - ...
  - When you are finished you have tasks
  - Tasks should be a few days work or less
- **This is an iterative technique to creating a WBS**
  - WBS iterations might produce only a part of the next level while requirements are still being worked out
  - However, it should produce some tasks, so that work can begin

WBS: Example


E-commerce site developing
Project management
Analysis
Design
Developing
Testing and production
Project management plan
Scope statement
Scheduling
Risk planning
Plan changes
Interviews
Requirements specifications
Use cases
Reporting needs
Prototype design
Architecture design
Improving site performance
Graphics and interface
Content creation
Database implementation
Catalog engine
Transaction proceeding
iOS and Android integration
Security subsystems
Test configuration
Reviewing design
Releasing the site
Closeout meeting
Closeout documents

WBS: Advantages

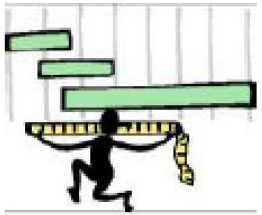
- Gives you a somewhat **complete list of tasks**
- Later, this can be a checklist to show how much is still to be done, and how much is done
- Allows you to **easily assign work to team members**
- Requires you to **solidify things** that are still vague, even after requirements analysis
- Generating a WBS enables you to **methodically decompose the work, exposing new risks and resource requirements**

Project Scheduling

- Scheduling determines the **timing of operations** in the project
- Schedule will determine the **specific start and completion date** for project and **all project activities**
- Scheduling includes the project **start and completion dates** for all activities**, project deliverables and milestones dates**, needed to successfully complete the project

Project Scheduling

- Scheduling can be developed after **WBS** is established and the time estimation for each activity is done.
- Scheduling is the most important step in planning because it is the basis for
  - ✓ allocating resources,
  - ✓ estimating revenue and spending
  - ✓ controlling the cash flow
  - ✓ monitoring project performance



Project Scheduling

The scheduling process will integrate:

- ✓ The estimated duration of activities.
- ✓ The technological precedence relations among activities.
- ✓ Constraints imposed by the availability of resources and budget.
- ✓ Due-date requirements

Project Scheduling

Definition – Activity (task)

- **Activity** – any task, any job or any operation which **must be completed to finish the project.**
- It requires time (for people to work or to wait) and may require resources.
- Have to consider logical relationships between activities.

Project Scheduling

Definition – Calendar

- **Calendar/ Workpattern** » the days on which the works are scheduled.
- Like what days of the week will be working or How many days a week (e.g. 5 days per week, 8 hours per day).
- The work pattern allows the activity durations to be related to calendar dates.

How to start a schedule

- **How to start a schedule?**
  - **Top down** - define major task (milestones or phases) and then decompose each milestone/phase into more detailed activities.
  - **Bottom up** - list all the activities in a project in any order. Group the list into phases/milestones based on the required sequence, constraints, and assumptions.

Schedule Presentation

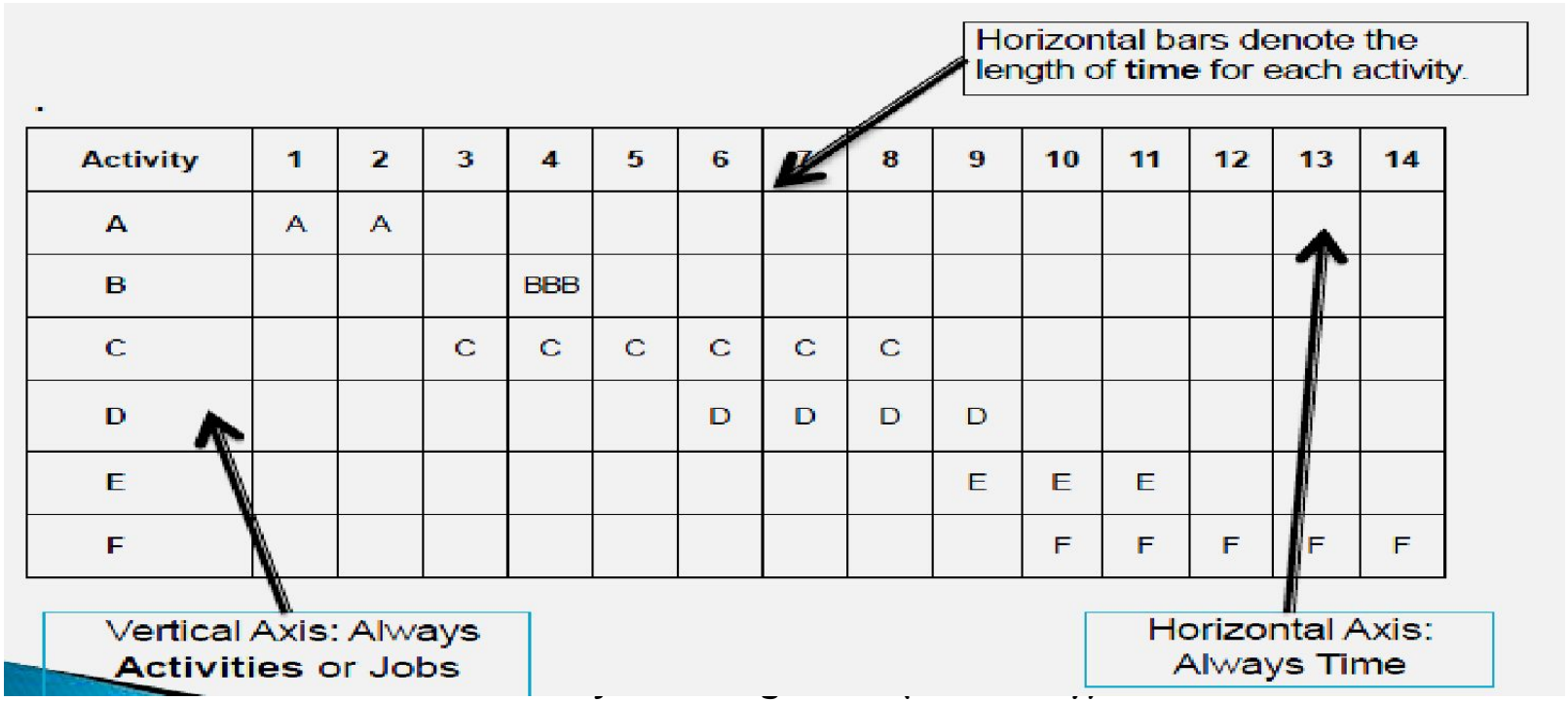
- Schedules can be presented in several different **ways to match the needs of the user.**
  - Chart
    - ✓ Milestone chart
    - ✓ Gantt chart
- **Networks either AOA (Activity on arrow) or** AON (activity-on-node) method.
  - ✓ Critical Path Method (CPM) .
  - ✓ Program Evaluation and Review Technique (PERT).

Types of Project Schedules

- **Project Schedules** – Used by PM & upper management for planning and reviewing entire project. Shows major project activities.
- **Task Schedules** – Show specific activities necessary to complete task.

Gantt Chart

- A graphical representation of a Project that shows each task as a horizontal bar whose length is proportional to its time for completion.
- Visual representation can help when a project manager needs an overview:



Activity	1	2	3	4	5	6	7	8	9	10	11	12	13	14
A	A	A												
B				BBB										
C			C	C	C	C	C	C						
D						D	D	D	D					
E									E	E	E			
F										F	F	F	F	F

Gantt Chart

- A GANTT Chart is a **horizontal bar chart** that illustrates a Project schedule.
- In the GANTT Chart, **time is displayed on the horizontal axis and the Tasks/ Activities are arranged vertically from top to bottom**, in order of their start dates.
- Most widely used as **management tool for project scheduling and control**.
- It is particularly useful to **manage "critical" and scarce" resources**.
- A detailed GANTT Chart for a **large project might be quite complex** and **hard to understand.** To simplify the chart, Project manager can combine related activities into one Task.

Gantt Chart

- GANTT CHART **do not show how tasks must be ordered (precedence)** but simply show **when a task should begin and should end**
- GANTT Chart is often **more useful to for depicting relatively simple projects** or sub projects of a large project, the activities of a single worker, or **for monitoring the progress of activities** compared to scheduled completion dates..

Gantt Chart

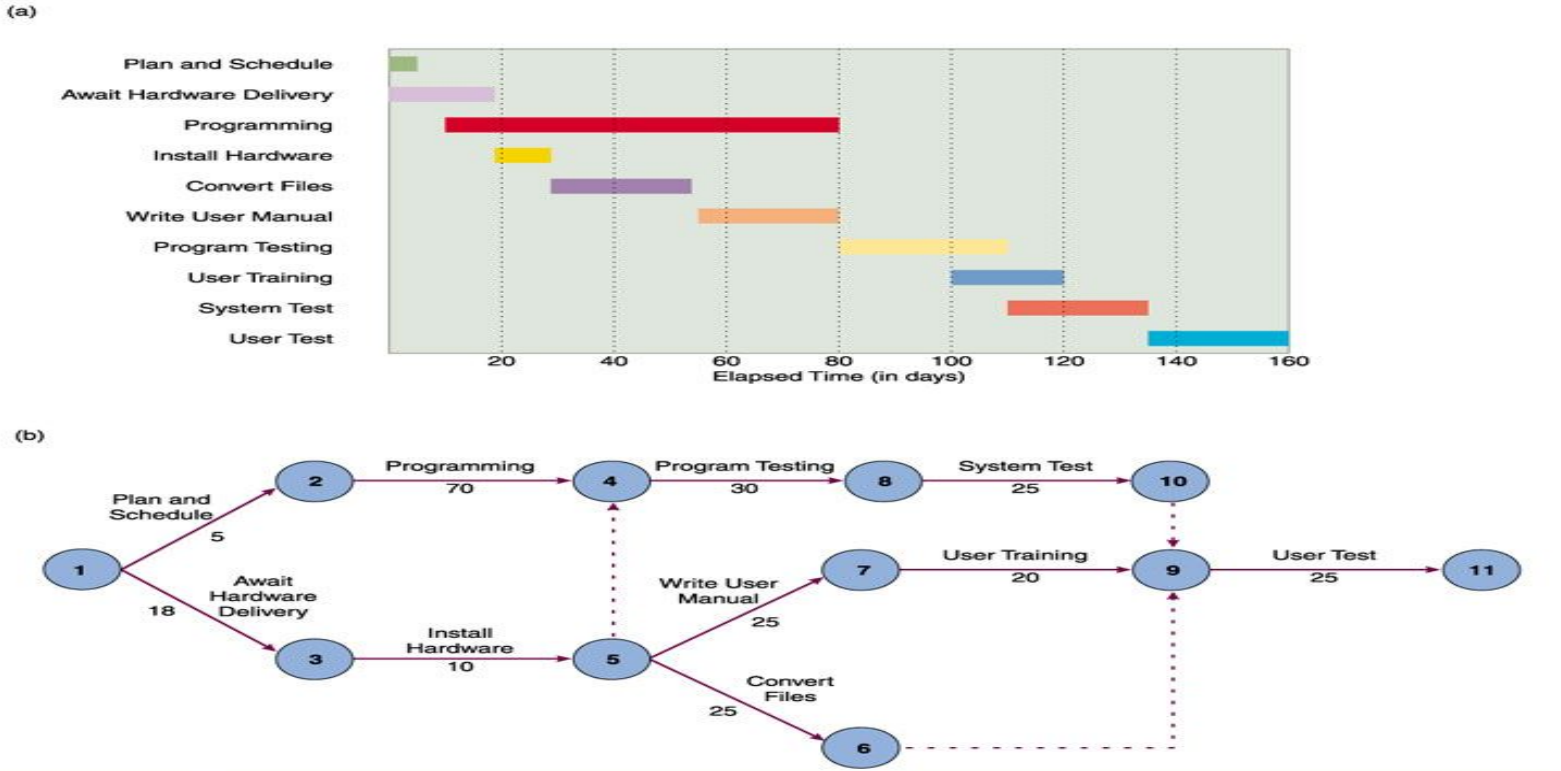


FIGURE TK 3-10 A Gantt chart and a PERT/CPM chart for the implementation phase of the same project shown in Figure TK 3-5 on page TK 3.7.

Advantages of Gantt Chart

- Gives clear pictorial model of project
- Simple for planner and user
- Easy to construct & understand
- Must be updated on daily/ weekly basis.
- Advantageous for small projects

Two Approaches : Gantt Chart

- Early start or late start approach.

  - **The early start approach** - each activity is initiated as early as possible without violating the precedence relations.

  - **The late start approach** - each activity is delayed as much as possible as long as the finish time of the project is not compromised.

Gantt Chart : how to read table

Activity	Immediate Predecessors	Duration (weeks)
A	--	5
B	--	3
C	A	8
D	A,B	7
E	--	7
F	C, D, E	4
G	F	5

- Activities, A, B and E do not have any predecessors and thus can start at any time.
- Activity C can start only after A finishes, while D can start after the completion of A and B.
- F can start only after C, D and E are finished, and G must follow F.

Gantt Chart : procedures

1. Generate the *early start schedule* using activity list given and its precedence relationships - the duration of the whole project will be obtained,
2. Using the *duration* of the *whole project obtained*, the late start schedule can be generated by shifting each activity to the right as much as possible without violation of precedence relationships.
   - When the late start is completed, make sure that the starting date of the whole project is day (week) 1.
3. With applying a *combination* of early and late start approaches, a range of schedules can be generated on *Gantt chart* - Slack management!

1. Early Start

Activity	Immediate Predecessors	Duration (weeks)
A	--	5
B	--	3
C	A	8
D	A,B	7
E	--	7
F	C, D, E	4
G	F	5

- For early start:
  Count from the beginning!
- Activities, A, B and E do not have any predecessors and thus can start at Week 1.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
A	A	A	A	A	A																	
B	B	B	B																			
C																						
D																						
E	E	E	E	E	E	E	E															
F																						
G																						

2. Early Start

Activity	Immediate Predecessors	Duration (weeks)
A	--	5
B	--	3
C	A	8
D	A,B	7
E	--	7
F	C, D, E	4
G	F	5

- Activity C can start only after A finishes, While D can start after the completion of both A and B.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
A	A	A	A	A	A																	
B	B	B	B																			
C						C	C	C	C	C	C	C	C									
D						D	D	D	D	D	D											
E	E	E	E	E	E	E	E															
F																						
G																						

3. Early Start

Activity	Immediate Predecessors	Duration (weeks)
A	--	5
B	--	3
C	A	8
D	A,B	7
E	--	7
F	C, D, E	4
G	F	5

- F can start only after C, D and E are finished, and G must follow F - early start Gantt chart finished. Duration is 22 weeks.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
A	A	A	A	A	A																	
B	B	B	B																			
C						C	C	C	C	C	C	C	C									
D						D	D	D	D	D	D	D										
E	E	E	E	E	E	E	E															
F														F	F	F	F					
G																		G	G	G	G	G

1. Late Start

Activity	Immediate Predecessors	Duration (weeks)
A	--	5
B	--	3
C	A	8
D	A,B	7
E	--	7
F	C, D, E	4
G	F	5

- For Late start
  Count form the End!
- Compare activity list and predecessor column -find any missing activity
  - start of LS (in here G)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
A																						
B																						
C																						
D																						
E																						
F																						
G																		G	G	G	G	G

2. Late Start

- Activity F is required by only G.

Activity	Immediate Predecessors	Duration (weeks)
A	--	5
B	--	3
C	A	8
D	A,B	7
E	--	7
F	C, D, E	4
G	F	5

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
A																						
B																						
C																						
D																						
E																						
F														F	F	F	F					
G																		G	G	G	G	G

3. Late Start

Activity	Immediate Predecessors	Duration (weeks)
A	--	5
B	--	3
C	A	8
D	A,B	7
E	--	7
F	C, D, E	4
G	F	5

Activity C, D, & E are required by only F.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
A																						
B																						
C						C	C	C	C	C	C	C	C									
D							D	D	D	D	D	D	D									
E							E	E	E	E	E	E	E									
F														F	F	F	F					
G																		G	G	G	G	G

4. Late Start

Activity	Immediate Predecessors	Duration (weeks)
A	--	5
B	--	3
C	A	8
D	A,B	7
E	--	7
F	C, D, E	4
G	F	5

Activity B is required by only D.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
A																						
B				B	B	B																
C						C	C	C	C	C	C	C	C									
D							D	D	D	D	D	D	D									
E							E	E	E	E	E	E	E									
F														F	F	F	F					
G																		G	G	G	G	G

5. Late Start

Activity	Immediate Predecessors	Duration (weeks)
A	--	5
B	--	3
C	A	8
D	A,B	7
E	--	7
F	C, D, E	4
G	F	5

Activity A is required by both C & D.
You have to follow the earlier one!

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
A	A	A	A	A	A																	
B				B	B	B																
C						C	C	C	C	C	C	C	C									
D							D	D	D	D	D	D	D									
E							E	E	E	E	E	E	E									
F														F	F	F	F					
G																		G	G	G	G	G

6. Late Start

Activity	Immediate Predecessors	Duration (weeks)
A	--	5
B	--	3
C	A	8
D	A,B	7
E	--	7
F	C, D, E	4
G	F	5

Remember!! The starting date of the starting date of the schedule should be “week 1”.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
A	A	A	A	A	A																	
B				B	B	B																
C						C	C	C	C	C	C	C	C									
D							D	D	D	D	D	D	D									
E							E	E	E	E	E	E	E									
F														F	F	F	F					
G																		G	G	G	G	G

ES and LS- Differences

ES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
A	A	A	A	A	A																	
B	B	B	B																			
C						C	C	C	C	C	C	C	C									
D						D	D	D	D	D	D	D										
E	E	E	E	E	E	E	E															
F														F	F	F	F					
G																		G	G	G	G	G

LS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
A	A	A	A	A	A																	
B				B	B	B																
C						C	C	C	C	C	C	C	C									
D							D	D	D	D	D	D	D									
E							E	E	E	E	E	E	E									
F														F	F	F	F					
G																		G	G	G	G	G

Total Slacks: Differences between two Gantt charts

- Total Slack (float) of activity - the difference between the start (or the end) times of an activity on the two schedules.

ES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
A	A	A	A	A	A																	
B	B	B	B																			
C						C	C	C	C	C	C	C	C									
D						D	D	D	D	D	D	D										
E	E	E	E	E	E	E	E															
F														F	F	F	F					
G																		G	G	G	G	G

LS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
A	A	A	A	A	A																	
B				B	B	B																
C						C	C	C	C	C	C	C	C									
D							D	D	D	D	D	D	D									
E							E	E	E	E	E	E	E									
F														F	F	F	F					
G																		G	G	G	G	G

A(0), B(3), C(0), D(1), E(6), F(0), G(0)

Question

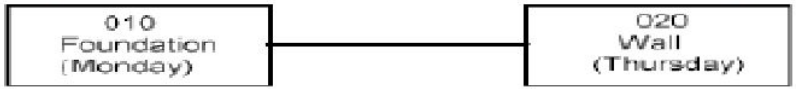
- Construct Gantt chart
  - Task – A, B, C, D, E, F, G
  - Start time – 0,6,7,7,8,9,12
  - Duration – 5,3,4,9,2,8,7
- When will last task be completed?

Precedence relations among the activities

- Precedence relations – technological constraints of the project that limit the availability of resources to perform activities.
- How to arrange "the order of activities".
  - Finish-to-start relationship
  - Start-to-start relationship
  - Finish-to-finish relationship
  - Start-to-finish relationship.

Finish-to-Start relationship

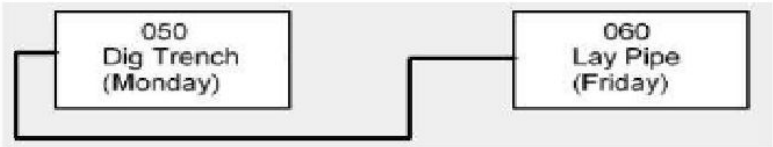
- **Finish-to-start relationship:** typical, generic relationship mostly used in scheduling. Requires that an activity can start only after its predecessor has been completed.
  - Activity 020 can not start until activity 010 is finished.



  - Space shuttle can be launched after all payloads are in place.
  - Shipment can begin after the quality inspection is done.

Start-to-Start relationship

- **Start to start relationship** - exists when an activity can start only after a specified activity has already begun.
- Sequential activities can be worked in parallel and concurrently.
  - activity 060 can start after activity 050 has started.



  - In the construction of a house, the foundation work can be started even though the final design is not finished. Usually, only the initial design plan is required for the foundation work.

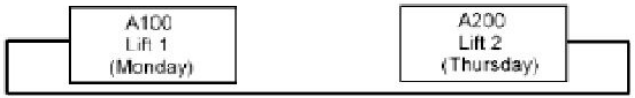
Finish-to-Finish relationship

- **Finish-to-finish relationship** – The finish of one activity depends on the finish of another activity.
  - Activity 2000 can finish, after activity 1000 is completed.

  - For example, if you have two tasks, "Add wiring" and "Inspect electrical," the "Inspect electrical" task cannot be completed until the "Add wiring" task is completed

Start-to-finish relationship

- **Start-to-finish relationship** – an activity cannot finish until another activity has begun (Overlap).
  - After activity A100 starts, A200 can finish



  - For example, the roof trusses for your construction project are built off-site. Two of the tasks in your project are "Truss delivery" and "Assemble roof." The "Assemble roof" task cannot be completed until the "Truss delivery" task begins.
  - A security guard's shift cannot end until the next guard has commenced his/her shift.

Limitations of Gantt Chart

- It does not explicitly show interrelationships among work elements.
- It doesn't reveal effect of one work element falling behind schedule on other element.

Network Techniques

- Program Evaluation and Review Technique, developed by the US Navy
- on the Polaris Missile/Submarine program 1958

Critical Path Method
Developed by El Dupont for Chemical Plant Shutdown

✔Both use same calculations, almost similar

✔Main difference is probabilistic and deterministic in time estimation

✔Gantt Chart also used in scheduling

Network Techniques

- 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

Simple Network - Example

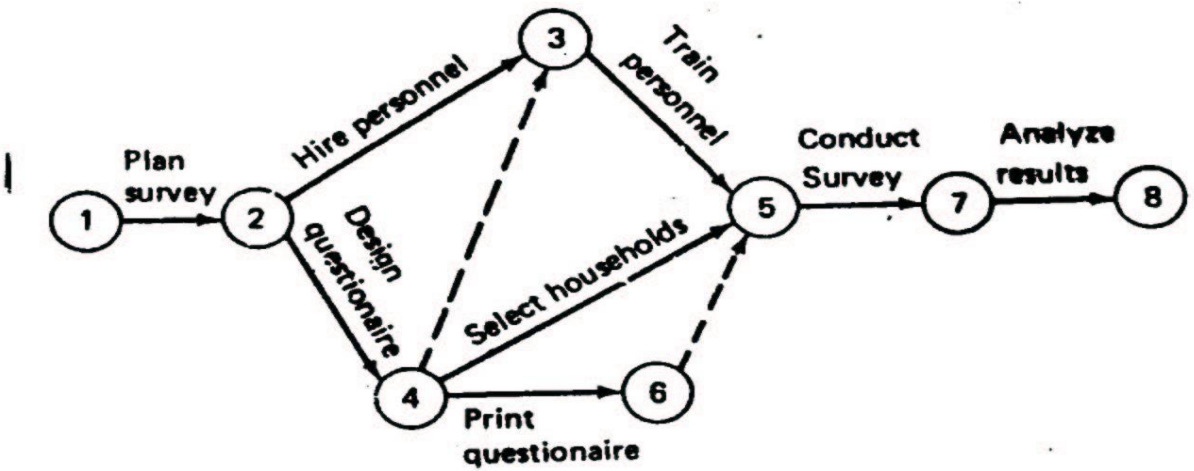


Figure 2-18

Complex Network - Example

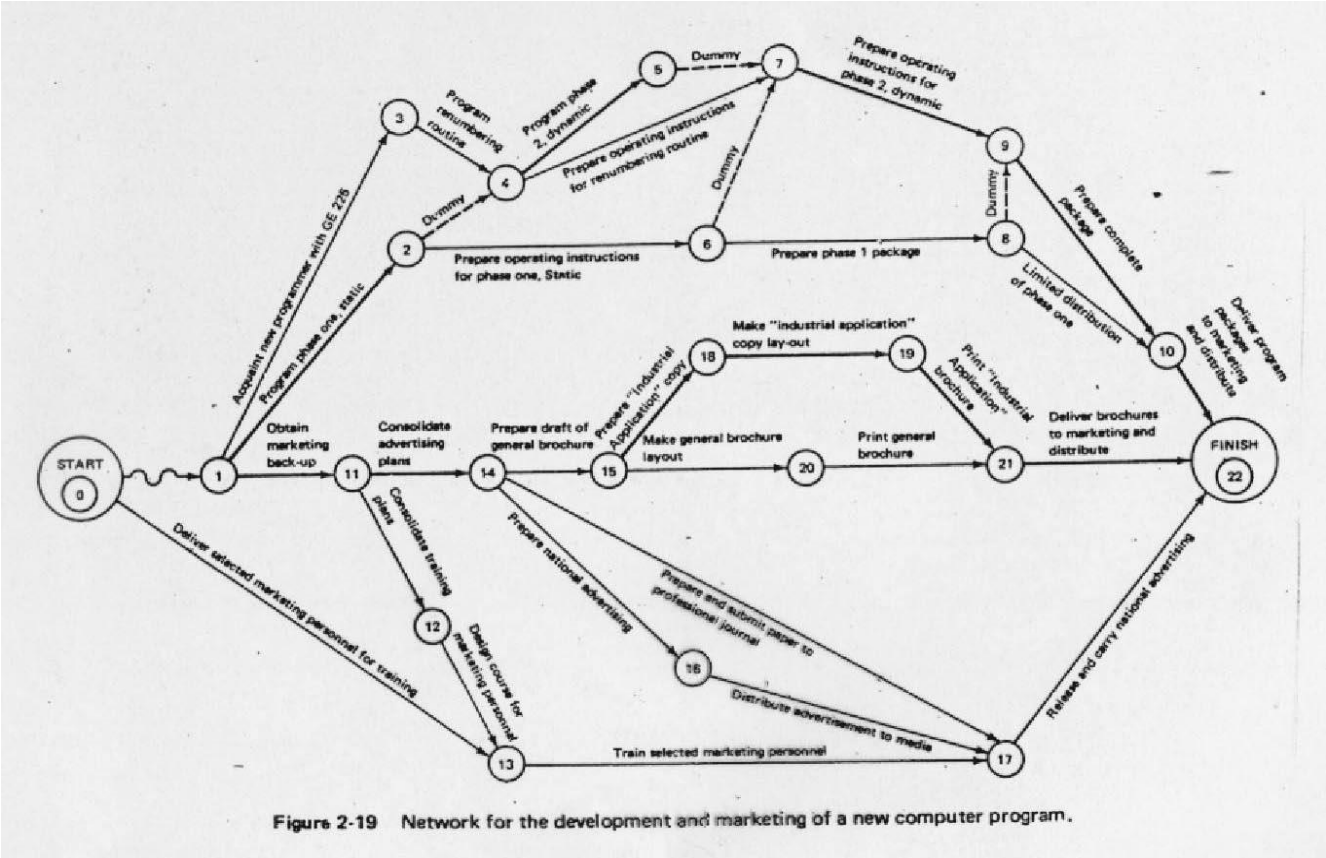
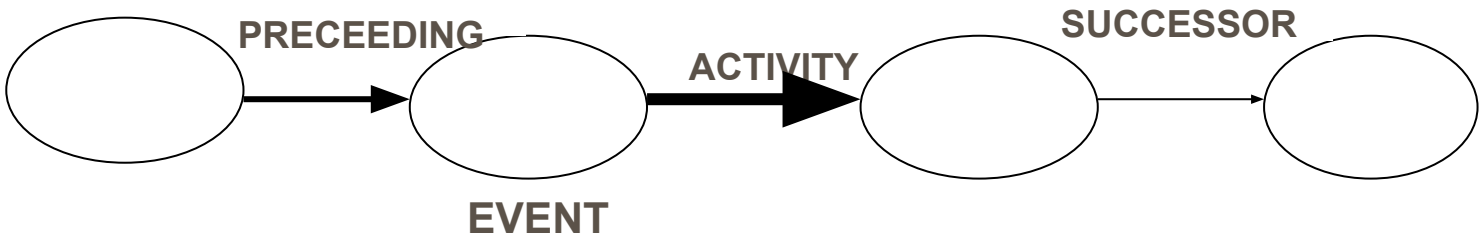


Figure 2-19 Network for the development and marketing of a new computer program.

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

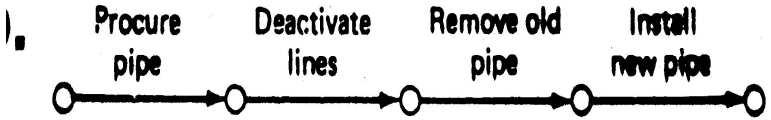


Figure 2-5a

WRONG !!!

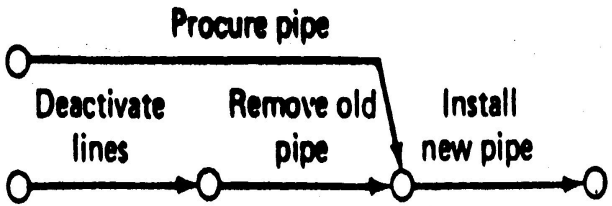


Figure 2-5b

CORRECT

Example 1 - Simple Network

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

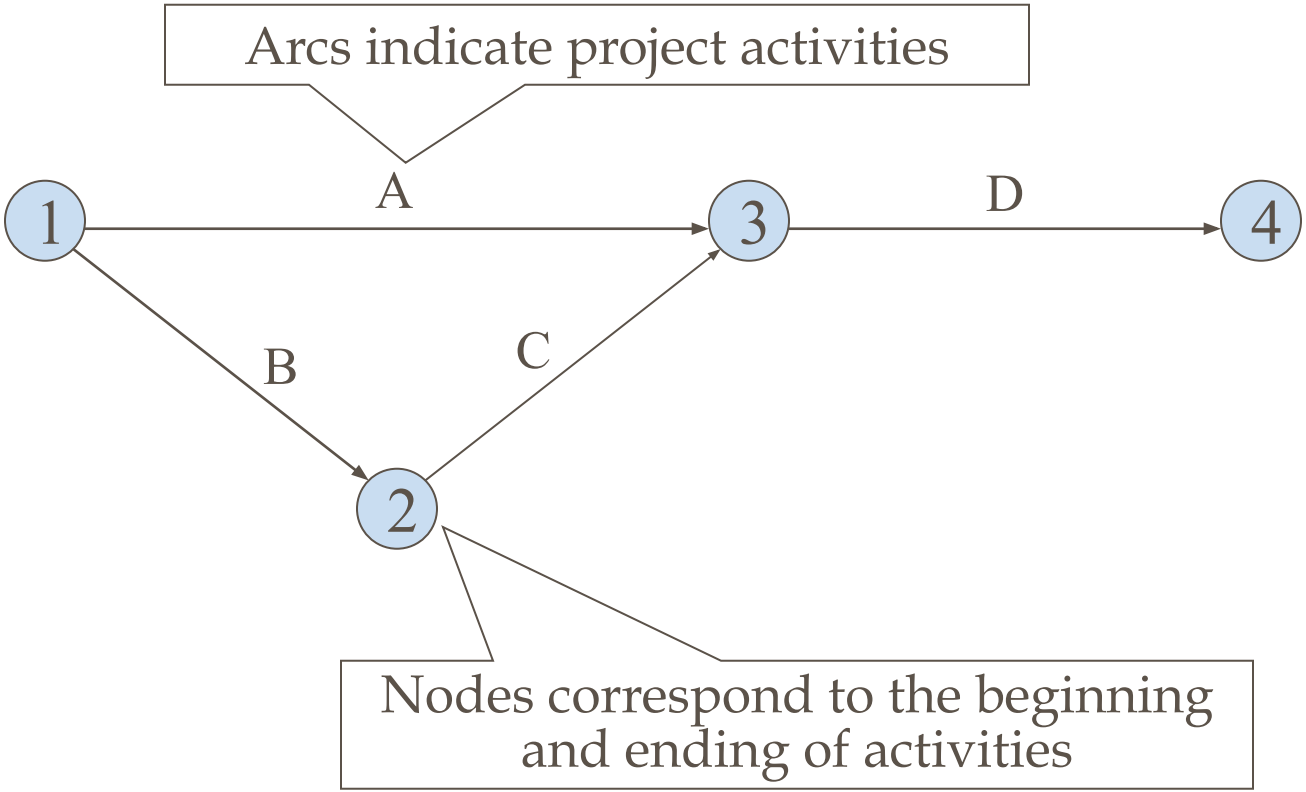
Activity	Description	Immediate predecessors
A	Buy Plastic Body	-
B	Design Component	-
C	Make Component	B
D	Assemble product	A,C

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

Example 1 - 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.

Example 1 - Simple Network with 4 Activities

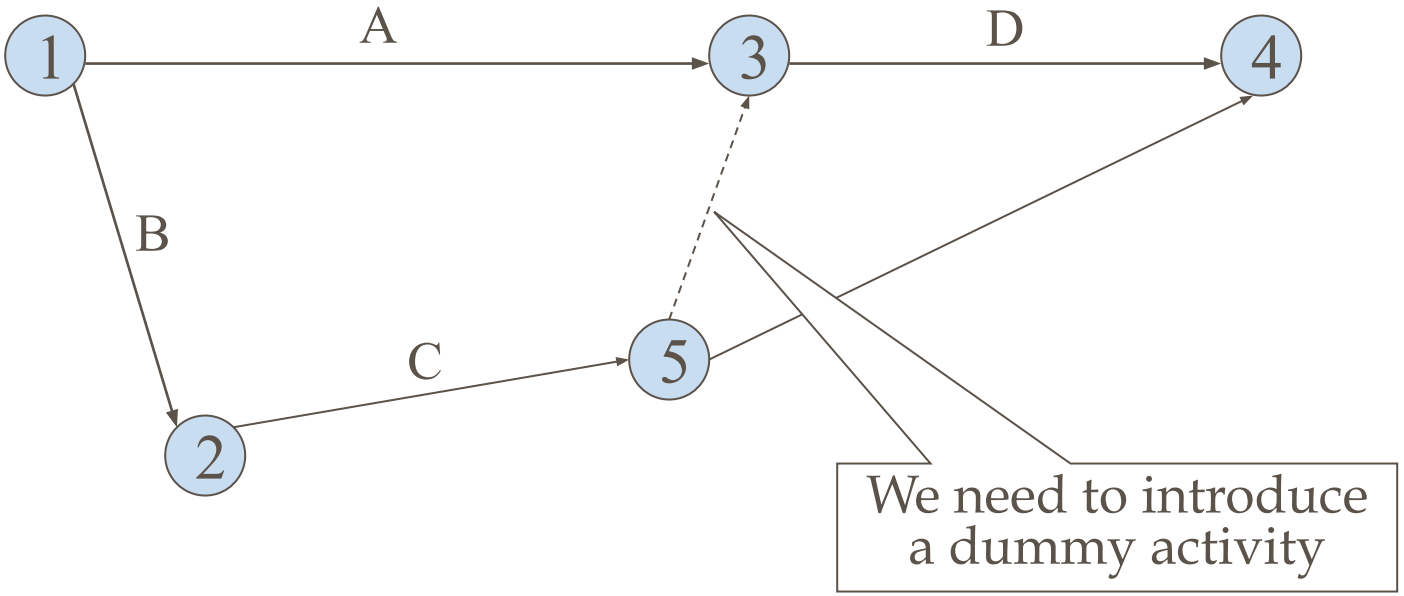


Example 2 - Network

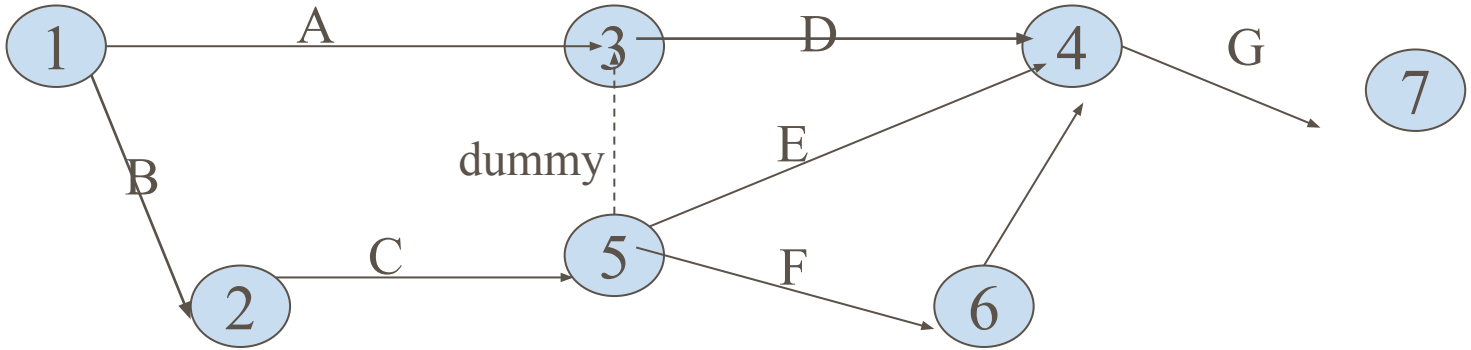
- Develop the network for a project with following activities and immediate predecessors:

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

Example 2- Network with 5 Activities

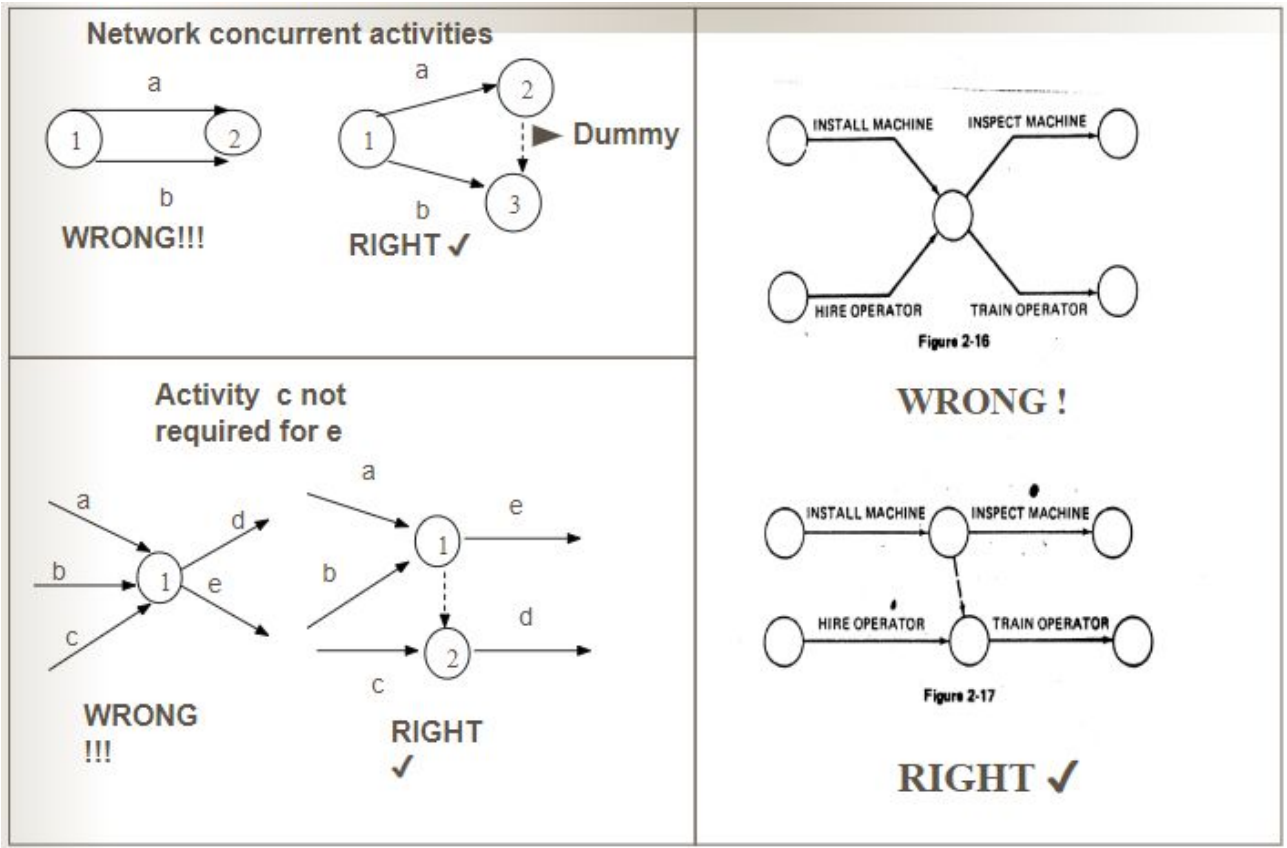


Example 3- Network with 7 Activities



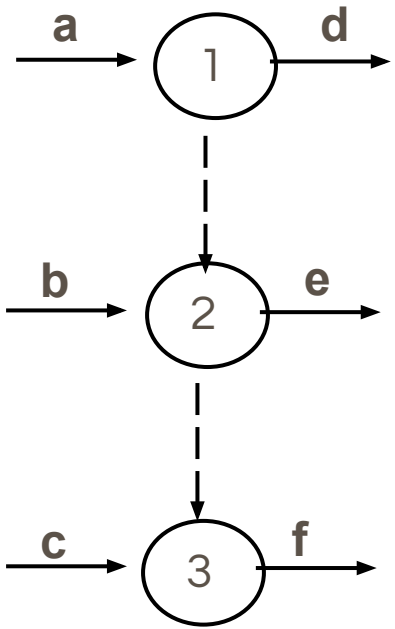
- Note how the network correctly identifies **D, E, and F as the immediate predecessors for activity G.**
- Dummy activities is used to identify precedence relationships correctly and to eliminate possible confusion of two or more activities having the same starting and ending nodes
- **Dummy activities have no resources** (time, labor, machinery, etc) – purpose is to PRESERVE LOGIC of the network

Use of Dummy Activity

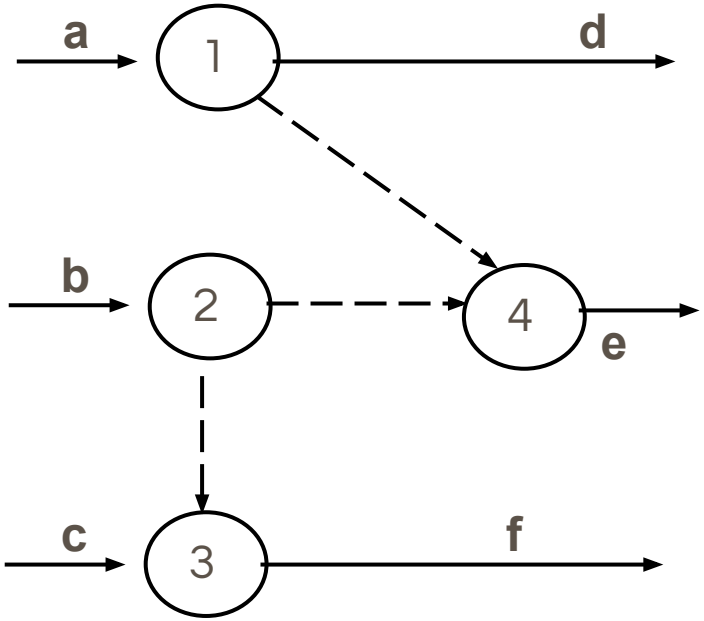


Use of Dummy Activity

WRONG!!!



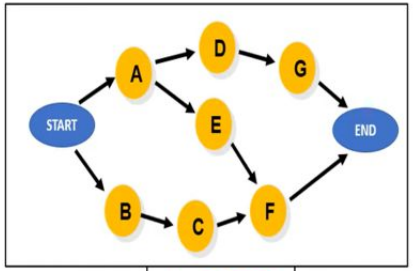
RIGHT!!!



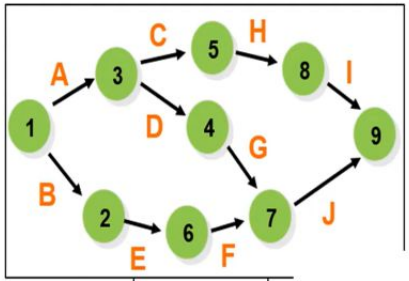
a precedes **d.**
a and **b** precede **e,**
b and **c** precede **f** (**a** does not precede **f**)

Network Diagram – AOA & AON

- *AOA networks were more popular in the 1960s and 1970s.*
- *AON focus on Tasks while AOA focus on Events*
- *AON diagrams are generally easier to Create as compared to AOA diagrams*
- *AON diagrams are generally easier to Understand as compared to AOA diagrams*
- *AOA shows only Finish to start relationship, while AON can show any type of relationship (Finish to Start, Finish to Finish, Start to Start, Start to Finish).*
- *AON is widely used network diagram technique and supported by most of the project management software's.*

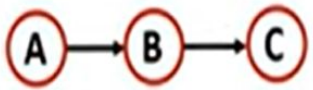
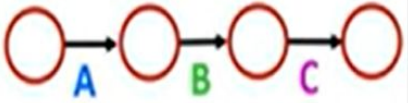
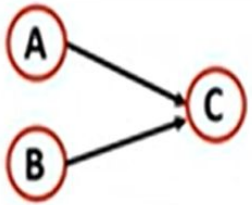
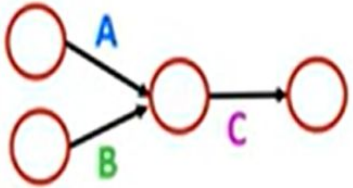
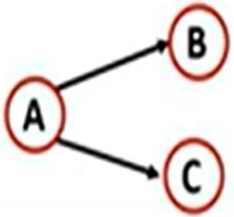
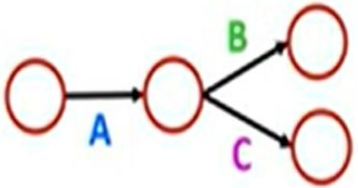


AON

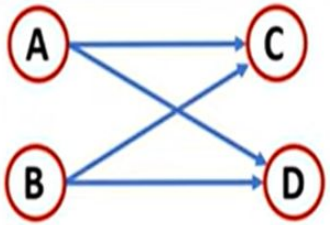
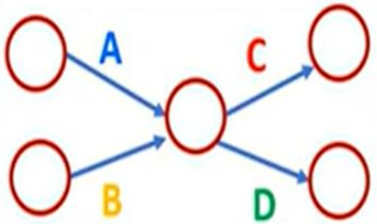
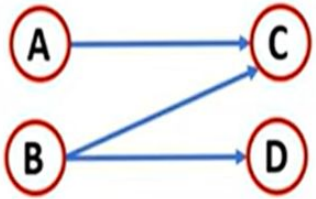
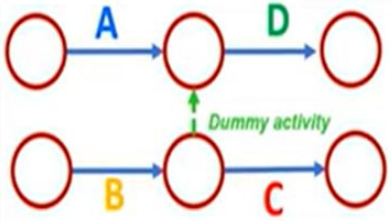
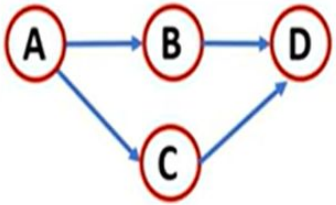
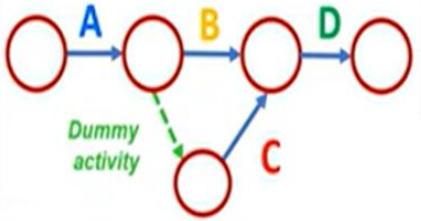


AOA

Network Diagram – AOA & AON

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

Network Diagram – AOA & AON

Activity on Node (AON)	Activity Meaning	Activity on Arrow (AOA)
	C and D cannot begin until A and B have both been completed	
	C cannot begin until both A and B are completed; D cannot begin until B is completed. A dummy activity is introduced in AOA	
	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	

Scheduling with Activity Time

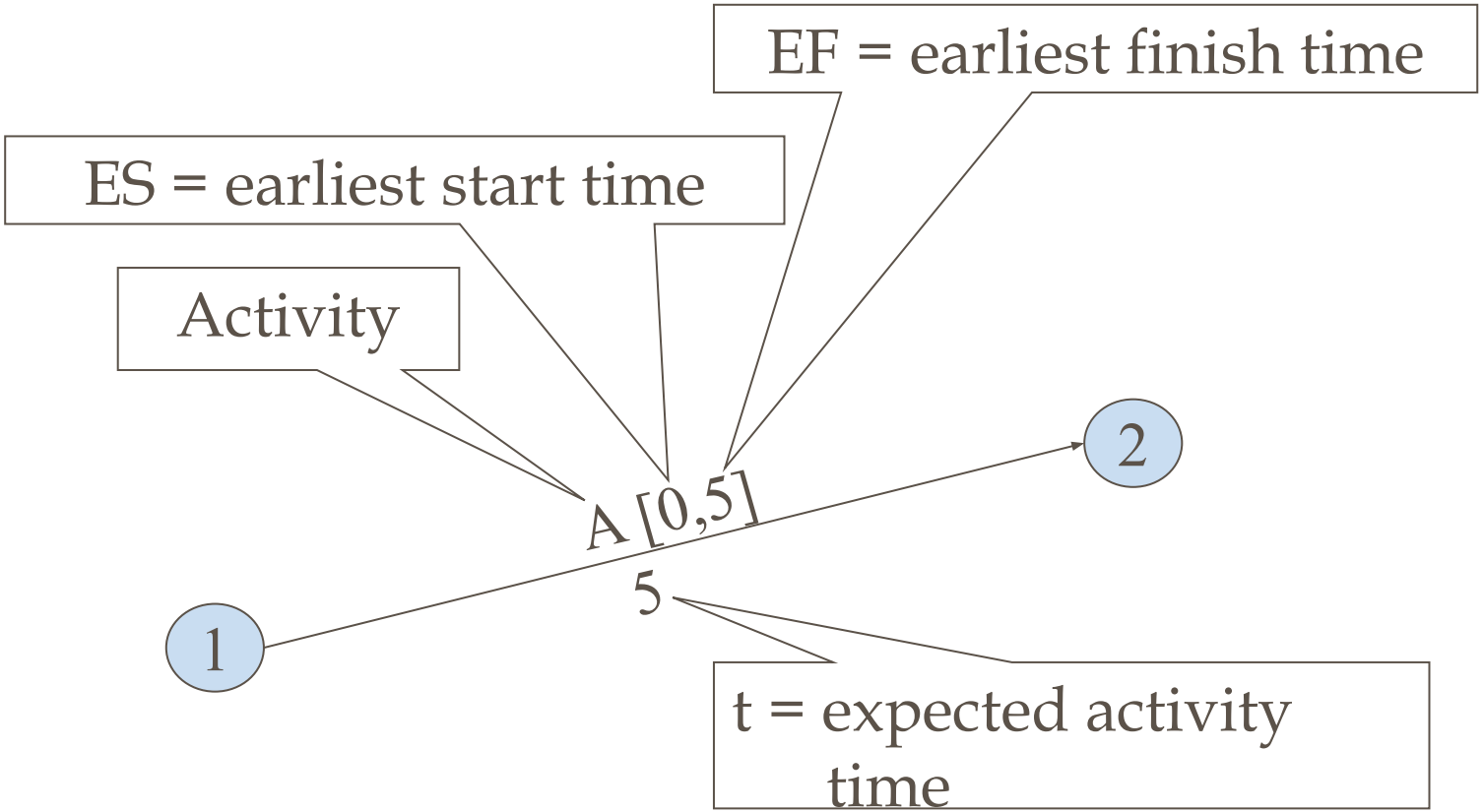
Activity	Immediate Predecessors	Completion Time (Week)
A	-	5
B	-	6
C	A	4
D	A	3
E	A	1
F	E	4
G	D,F	14
H	B,C	12
I	G,H	2
	Total :	51

ILOC: Project Management (Autonomy)

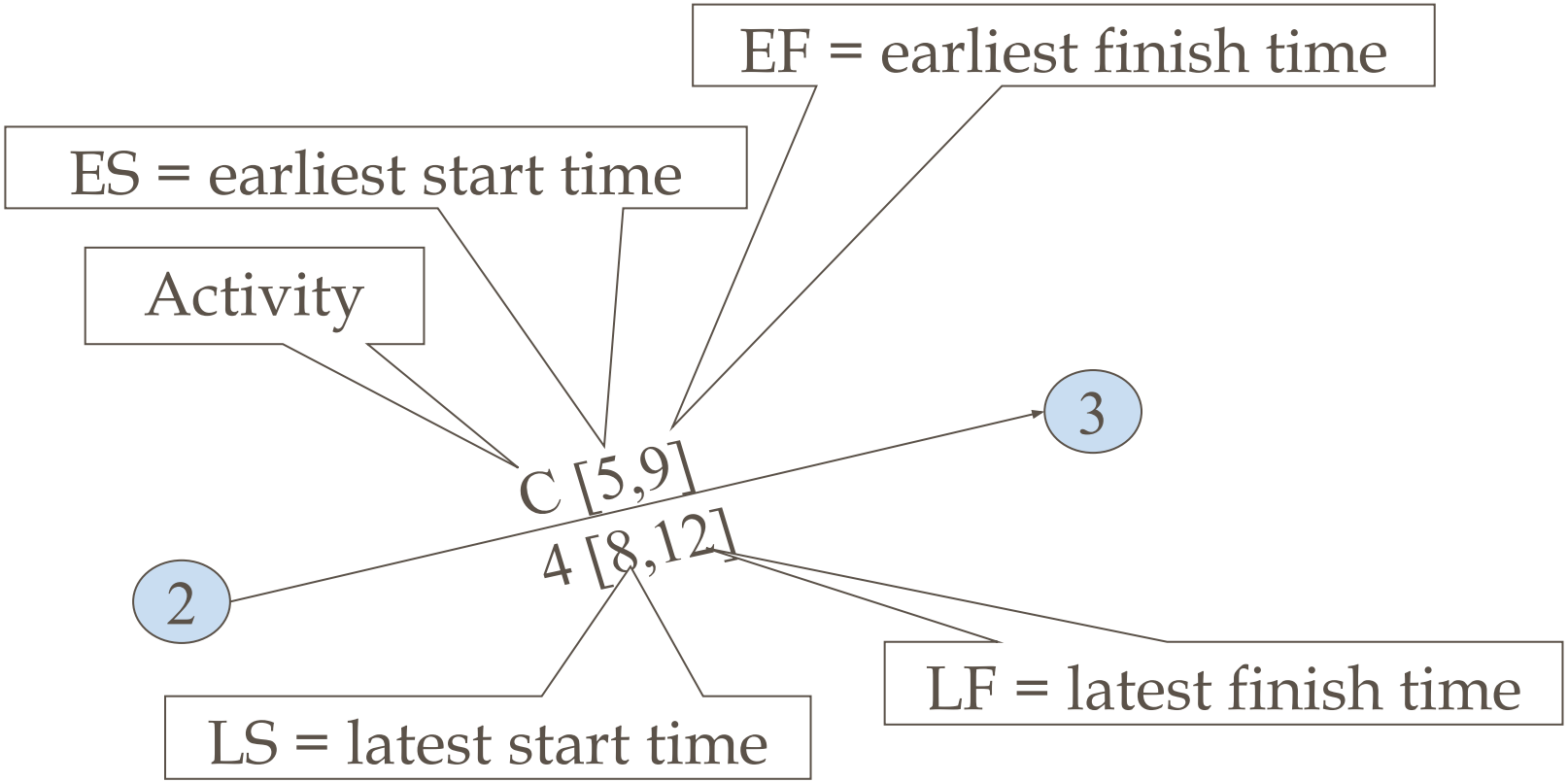
Earliest Start and Earliest Finish Time

- 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 and EF time



Activity with Duration, ES, LS and EF, LF time

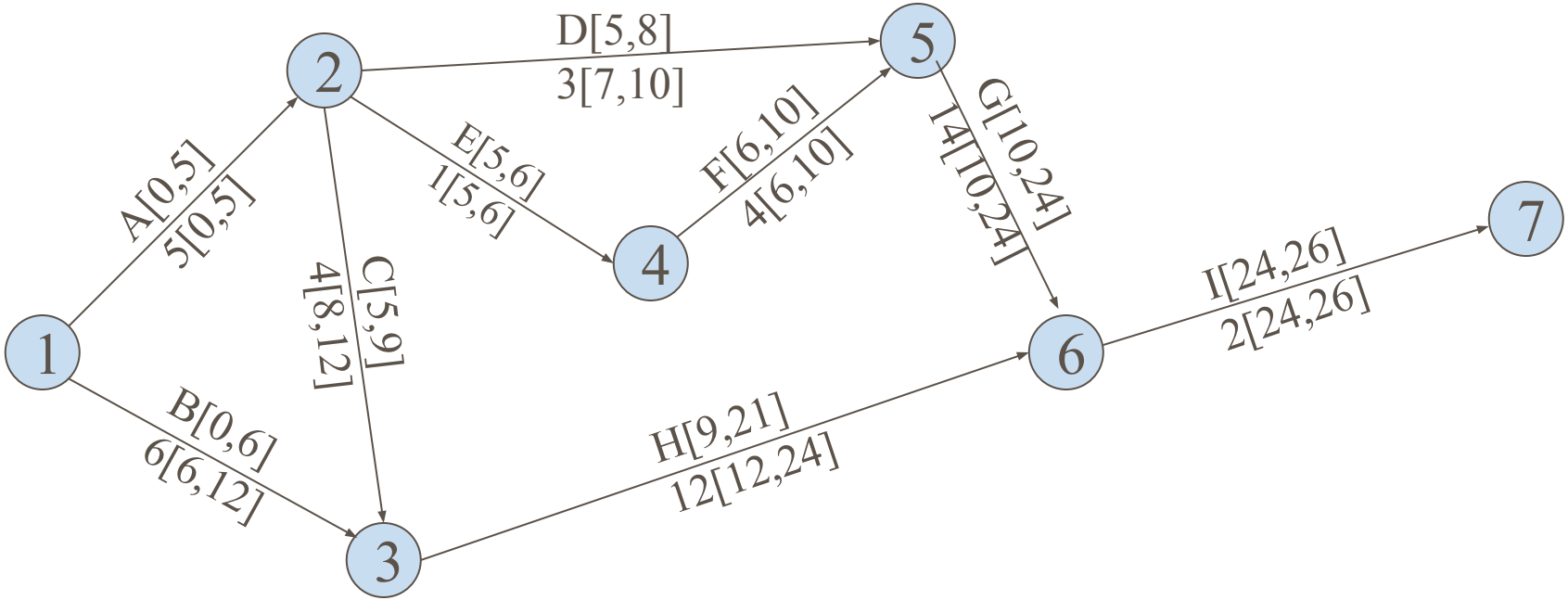


Latest Start and Latest Finish Time

- 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

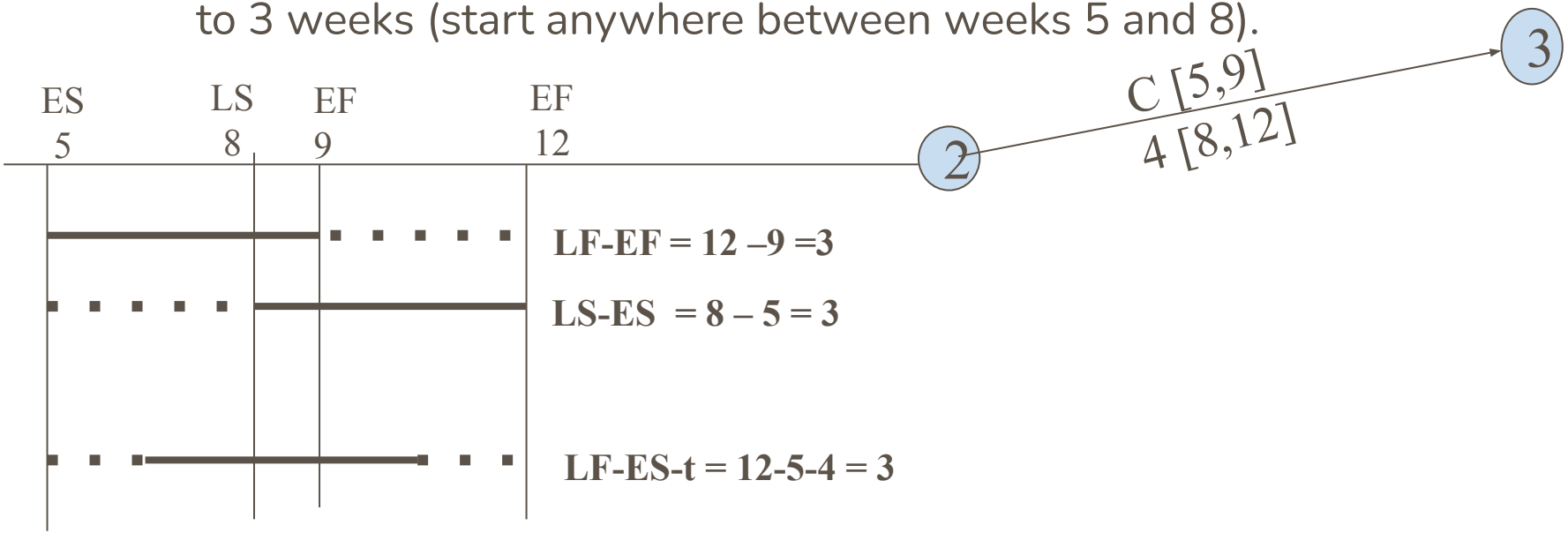
$$LS = 26 - 2 = 24$$

Network Diagram



Slack Period

- 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).



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

Sample 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.

Critical Path

- Slack or Float shows how much allowance each activity has, i.e how long it can be delayed without affecting completion date of project
- Critical path is a sequence of activities from start to finish with zero slack. Critical activities are activities on the critical path.
- Critical path identifies the minimum time to complete project
- If any activity on the critical path is shortened or extended, project time will be shortened or extended accordingly

Critical Path

- 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.
- If can spend resources to speed up some activity, do so only for critical activities.
- Don’t waste resources on non-critical activity, it will not shorten the project time.
- If resources can be saved by lengthening some activities, do so for non-critical activities, up to limit of float.
- Total Float belongs to the path

PERT Method

- PERT is designed for scheduling complex projects that involve many interrelated tasks. it improves planning process because:
- It forms planner to define the projects various components activities.
- It provides a basis for normal time estimates & yet allows for some measure of optimism or pessimism in estimating the completion dates.
- It shows the effects of changes to overall plans they contemplated.
- It provides built in means for ongoing evaluation of the plan.

PERT Method to deal 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.expected time required to complete activity

  a = optimistic time estimate, minimum time in which activity will be completed

  b = pessimistic time estimate, worst case scenario (maximum time in which an activity can or should be completed)

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

  Variance (V) = ((b – a) / 6) ^{2}

  Std Deviation (δ) = SQRT (V)

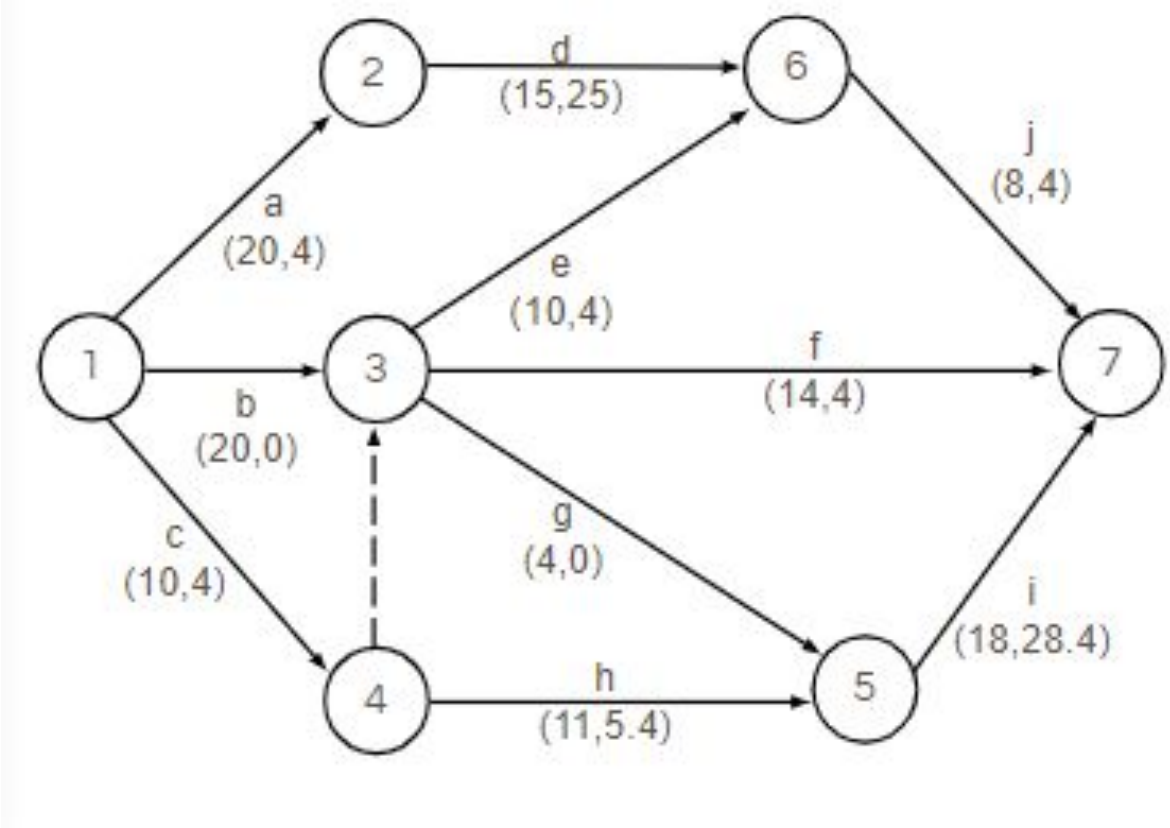
Steps involved in PERT

- Develop list of activities.
- A rough network for PERT is drawn.
- Events are numbered from left to right.
- Time estimates for each activity are obtained.
- Expected time for each activity is calculated : to+4tm+tp / 6
- Using these expected times calculate earliest & latest finish & start times of activities.
- Estimate the critical path.
- Using this estimate compute the probability of meeting a specified completion date by using the standard normal equation
- $$Z = \frac{\text{Due date – expected date of completion}}{\text{standard deviation of critical path}}$$

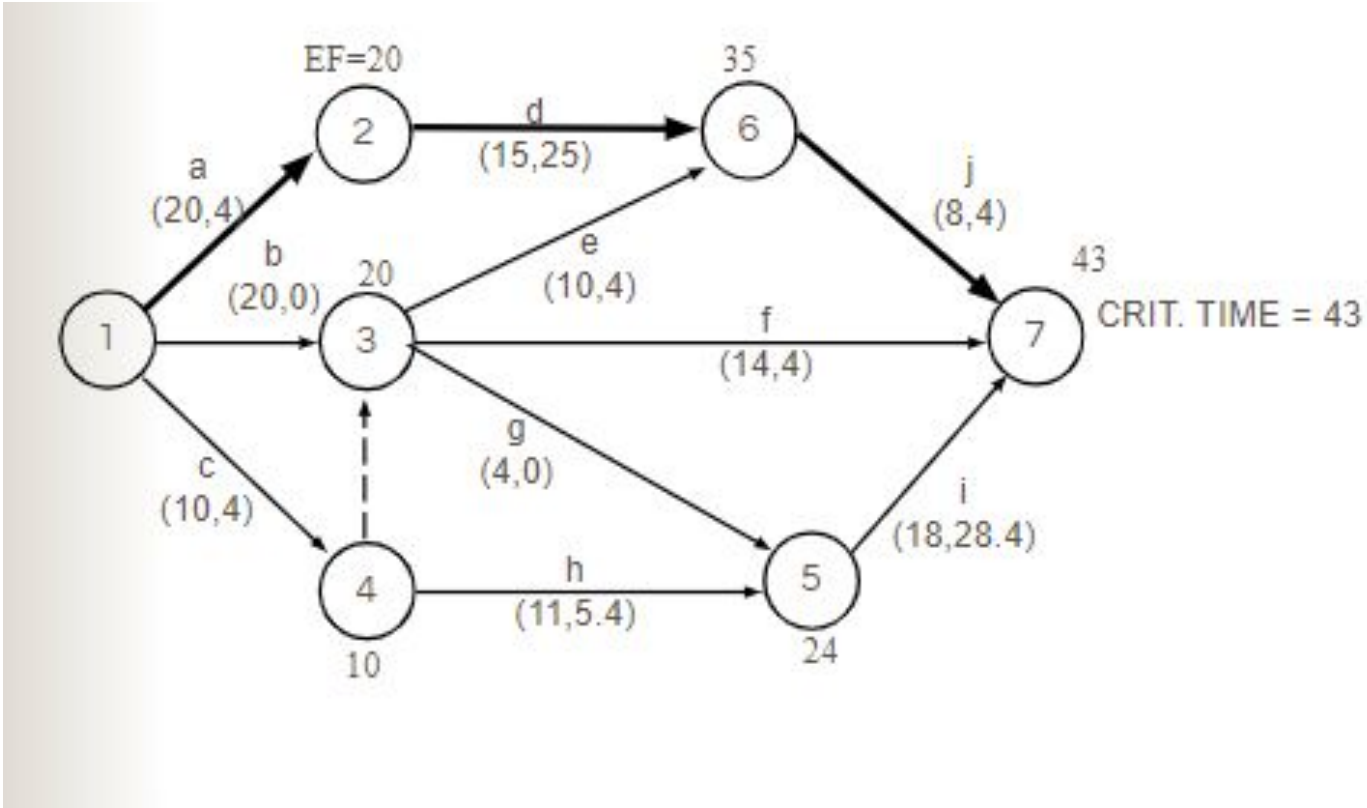
Precedences And Project Activity Times

Activity	Immediate Predecessor	Optimistic Time (a)	Most Likely Time(m)	Pessimistic Time(b)	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

Solution



Solution


EF=20
35
2
d
(15,25)
6
a
(20,4)
j
(8,4)
b
(20,0)
20
e
(10,4)
43
1
3
f
(14,4)
7
CRIT. TIME = 43
g
(4,0)
c
(10,4)
i
(18,28.4)
4
h
(11,5.4)
5
10
24

Solution

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**

Solution

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

Solution

What deadline are you 95% sure of meeting

Z value associated with 0.95 is 1.645

D = S + 5.745 (1.645)
= 43 + 9.45
= 52.45 days

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

Example

JOB	OPTIMISTIC	MOST LIKELY	PESSIMISTIC
1-2	1	4	7
1-3	5	10	15
2-4	3	3	3
2-6	1	4	7
3-4	10	15	26
3-5	2	4	6
4-5	5	5	5
5-6	2	5	8

Question

1. Draw the network & find expected project completion time.

2. What is the probability that it would be completed in 41 days?

Solution

Activity	To	Tp	variance
1-3	5	15	2.77
3-4	10	26	7.11
4-5	5	5	0
5-6	2	8	1
			Total= 10.88

Solution

- So, standard deviation = 3.30
- Probability for completing the job in 41 days.
- Z = DUE DATE – EXPECTED DATE OF COMPLETION
  S.D. OF CRITICAL PATH

  $= \frac{41 - 36}{3.30}$

  $= 1.51$

- The tabulated value of corresponding to calculated value i.e. 1.51 is .4345
- So probability is .5 + .4345 = .9345 i.e. 93.45% that project will be completed on 41 day.

Exercise

Activity	Preceding activity	to	tm	tp
A	-	2	3	10
B	-	2	3	4
C	A	1	2	3
D	A	4	6	14
E	B	4	5	12
F	C	3	4	5
G	D,E	1	1	7

Question

- Find the expected duration and variance of each activity.
- What is the expected project length?
- Calculate the variance & standard deviation of the project length.

Solution

Activity	to	Tm	tp	te	Variance
A	2	3	10	4	16/9
B	2	3	4	3	1/9
C	1	2	3	2	1/9
D	4	6	14	7	25/9
E	4	5	12	6	16/9
F	3	4	5	4	1/9
G	1	2	7	2	1

Solution

- Various paths & expected project length

  A-C-F = 4+2+4 = 10

  A-D-G = 4+7+2 = 13 CRITICAL PATH

  B-E-G = 3+6+2 = 11

- Thus critical path is A-D-G with an expected length of 13 days. Hence the expected project length is 13 days.
- **Project variance = 16/9 + 25/9 + 1 = 50/9**

Comparison of 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

Project Management Information System (PMIS)

- WBS & Work packages – to define all work to be done
- An Organization Structure –to integrate people with functional areas with WBS and assign responsibilities
- Project Schedules – to provide basis for work package resource allocation and work timing
- Cost accounts – to provide basis for project cost aggregation and control
- Budgets – to define expected cost for each cost account and work package.
- PMS activities which utilize this information includes – collecting and storing project management information, means for reporting information, means for management direction, decisions and corrective action.