Industrial Management and Engineering Economics

Chapter 5

Project Management and Resource Allocation

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What is project ?

- ✓ Project is a unique, one-time temporary endeavor designed to accomplish a specific set of objectives within constraints of time and budget.
- ✓ An endeavor-(treat or legate) in which human, (or machine) material and financial resources are organized to achieve set of objectives.
- ✓ Project is a unique set of interconnected activities,
    - ➢ with definite starting and finishing points
    - ➢ undertaken by an individual or organization
    - ➢ to meet specific objectives
    - ➢ within defined schedule, cost and performance parameters

Cont.…

Examples of projects include:

- ✓Designing new products or services
- ✓Designing information systems
- ✓Reengineering a process
- ✓Designing databases
- ✓Software development
- ✓Designing advertising campaigns

Project Management (PM)

- What is project management?
- Project management (PM) is the process of integrating resources in order to meet the project's objectives.
- A project management tries to balance competing demands for
  - ✓Project scope
  - ✓Time and cost
  - ✓Quality level of the outcome and requirements

✓PM is the application of knowledge, skills, tools and techniques to project activities to meet objectives of a project.

The Project Manager

- The project manager bears the ultimate responsibility for the success or failure of the project.
- In the planning stage, the project manager must prepare:
    - a scope statement that spells out the deliverables and goals
    - determine required skills and resources needed
    - develop a schedule and budget, and
    - develop plans for managing the scope, the schedule, the budget, and quality and risk.

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The project manager is responsible to manage the following:

1. The **work:** activities are accomplished in the desired sequence, and performance goals are met.

2. The **human resources:** people working on the project have direction and motivation.

3. **Communications,** so that everybody has the information needed to do the work.

4. **Quality:** performance objectives are realized.

5. **Time:** the project is completed on schedule.

6. **Costs:** the project is completed within budget.

7. **Scope:** the project stays within the prescribed scope, and “scope creep” doesn’t occur without commensurate changes to the schedule (if needed) and the budget.

Cont.…

- Several of these responsibilities are often portrayed in what is known as a “project management triangle.”

Figure: The Project Management Triangle

Project Life Cycle

- All projects have something in common.
- They are generally be sub-divided into several stages or phases to provide better management control.
- Collectively, the project phases are called the **Project Life Cycle**, which typically consists of five phases:
    - ✓ Initiating and Scoping the project
    - ✓ Planning the project
    - ✓ Executing & Launching the plan
    - ✓ Monitoring & Controlling the progress
    - ✓ Closing out the project

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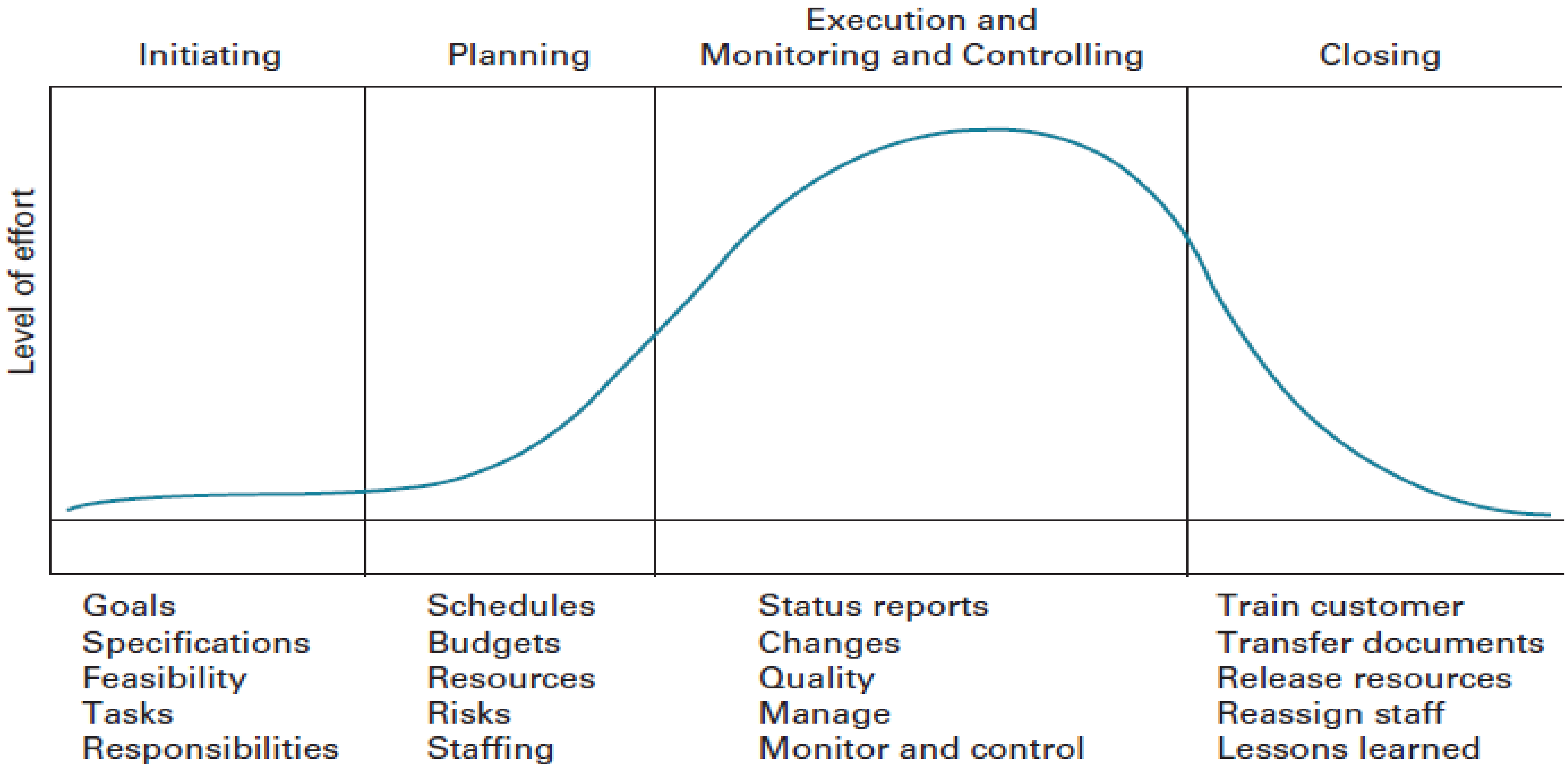

Figure: Project life cycle

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1. Initiating

- State the problem/opportunity
- Establish the project goal goals and choosing a project manager
- Define the project objectives
- Identify the success criteria
- Outline the expected costs, benefits, and risks & obstacles associated with a project.

2. Planning the project

This phase provides details on deliverables

- ➢ The scope of the project
- ➢ Identify project activity
- ➢ Estimate activity duration
- ➢ Determine resource requirements
- ➢ Construct/ analyze the project network
- ➢ Prepare the project proposal

Cont.…

3. Executing

- The actual work of the project is carried out.
- The project is managed as activities are completed and resources are consumed.
- Recruit and organize project team
- Establish team operating rules.
- Schedule work packages.
- Document work packages

4. Monitoring and Controlling

- This phase occurs at the same time as project execution.
- Monitor project progress versus plan.
- Undertakes corrective action if needed
- Establish progress reporting system
- Revise project plans.

5. Closing

- This phase ends the project.
- Obtain client/customer acceptance.
- Install project deliverables.
- Complete project documentation.
- Complete post-implementation audit
- Issue final project report.

Cont.....

- ❖ Collectively, these project phases are called the **Project Life Cycle.**

- ❖ Along with the project life cycle the other special project management techniques which form part of the project management integrative process are:

  - ✓**Work Breakdown Structure (WBS),**

  - ✓**Net work scheduling consisting CPM & PERT**

  - ✓**Resource smoothing or allocation, etc.**

1. Work Breakdown Structure (WBS)

- Large projects usually involve a very large number of activities.
- WBS is a method of breaking down a project into individual elements (components, subcomponents, activities and tasks) in a hierarchical structure.
- WBS is a hierarchical listing of what must be done during a project.
- WBS facilitates resource allocation, assignment of responsibilities and measurement and control of the project.
- The WBS is the basis for developing time and cost estimates.

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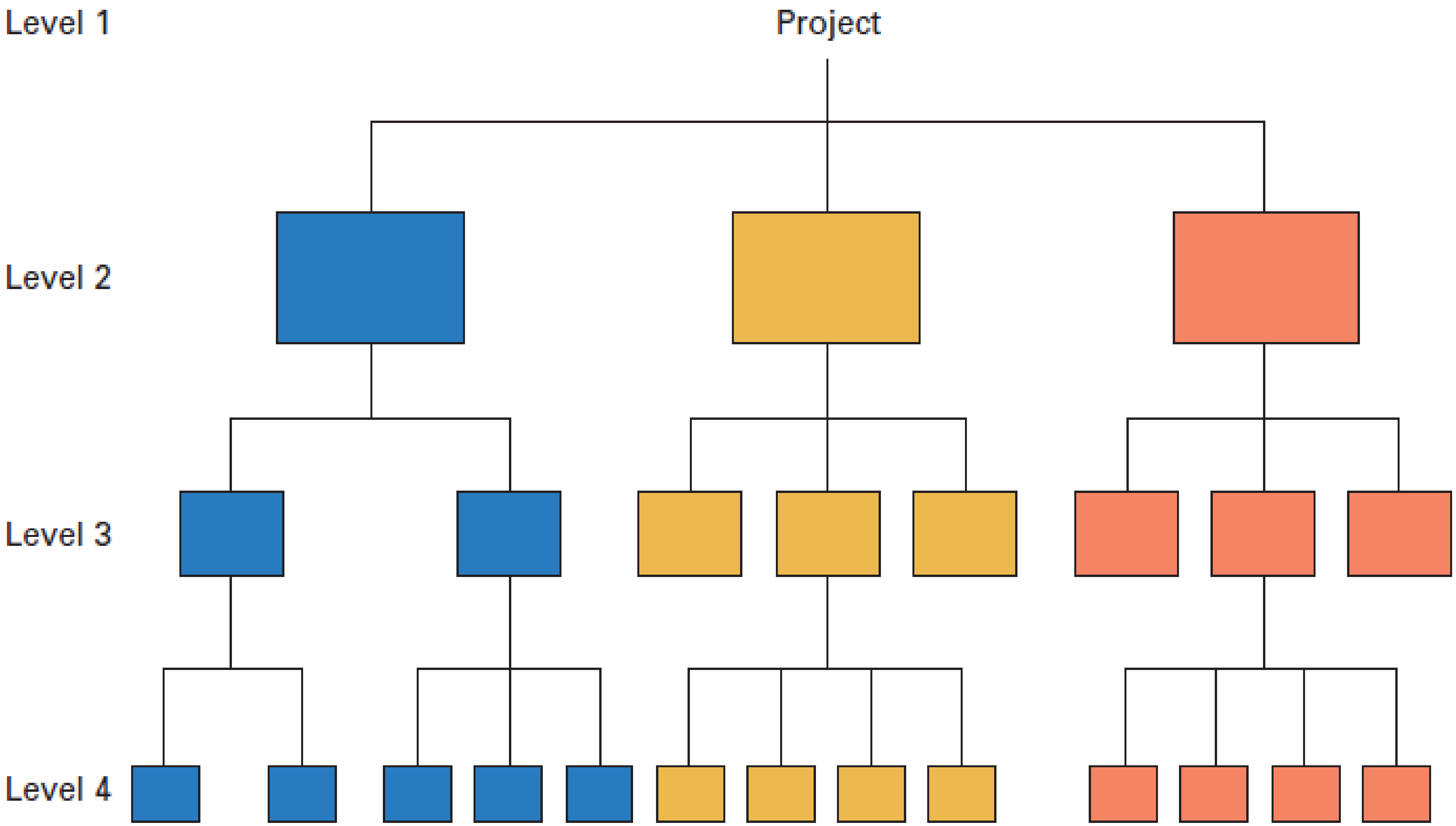

Figure: A hierarchical structure

Gantt Charts

- The Gantt chart is a popular visual tool for planning and scheduling projects.
- It enables a manager to initially schedule project activities and then to monitor progress over time by comparing planned progress to actual progress.
- As the project progressed, the manager able to see which activities were on schedule and which were behind schedule.
- To prepare the chart:
  - Identify the major activities
  - Time estimates for each activity
  - Determine the sequence of activities.

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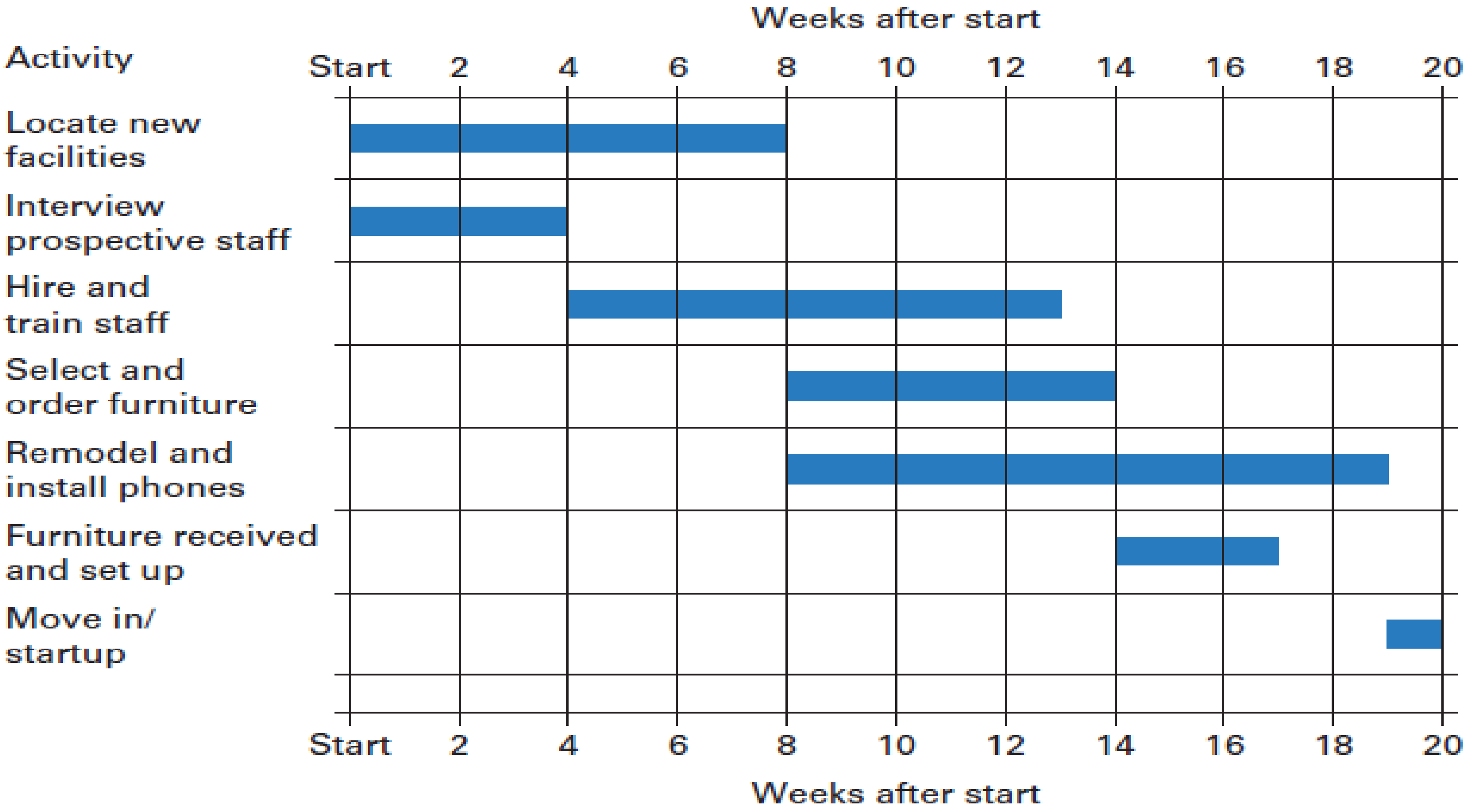


E.g. Gantt chart for bank’s plan to establish a new direct marketing department.

Cont.…

- ✓However, Gantt charts fail to reveal certain relationships among activities.
- ✓ Do not give a clear indication of interrelation ship between the separate activities
- ✓For instance, if one of the early activities in a project suffers a delay, it would be difficult to easily determine which later activities would result in a delay.
- ✓On more complex projects, Gantt chart is often used in conjunction with a network diagram for scheduling purposes.

2. Network Scheduling

- Network scheduling uses WBS to convert action plan into operating time table.
- The following project **management procedures** are important in network scheduling, i.e.:
  - ✓ Activity definition
  - ✓ Activity sequencing
  - ✓ Activity resource estimating
  - ✓ Activity duration estimating
  - ✓ Schedule development and
  - ✓ Schedule control.

The project management procedures

- **Activity definition**: Identifying the specific activities required to produce the project deliverables.
- **Activity sequencing**: Identifying and documenting the relationships between the project activities.
- **Activity resource estimating**: Estimating level of resources used to perform project activities.
- **Activity duration estimating**: Estimating work periods that are needed to complete individual activities.
- **Schedule development**: Analyzing activity sequences, activity resource estimates, and activity duration estimates to create the project schedule.
- **Schedule control**: Controlling and managing changes to the project schedule.

The network techniques

CPM

- Critical Path Method

PERT

-Program Evaluation and Review Technique

✓Both use the same calculations, almost similar

✓Main difference is deterministic & probabilistic in time estimation

Cont.…

By using PERT or CPM, managers are able to obtain

- ✓A graphical display of project activities.
- ✓Shows dependency relationships between tasks/activities in a project.
- ✓An estimate of how long the project will take.
- ✓An indication of which activities are the most critical to timely project completion.

I. Critical path method

- **CPM** is a network diagramming technique used to predict total project duration.
  - ✓ **Deterministic model.**
  - ✓ **Single time estimate for each activity.**
  - ✓ **No uncertainty is considered.**
  - ✓ **No determination of success/failure probability**

Cont.…

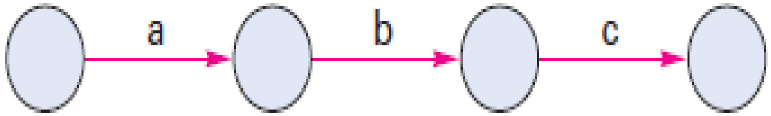
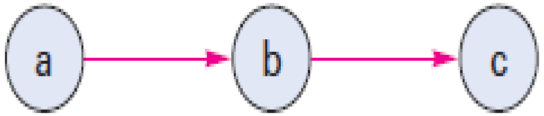
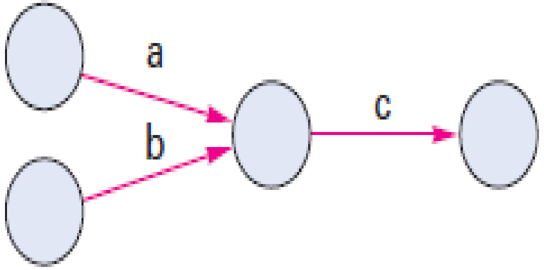
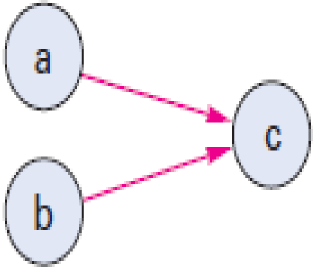
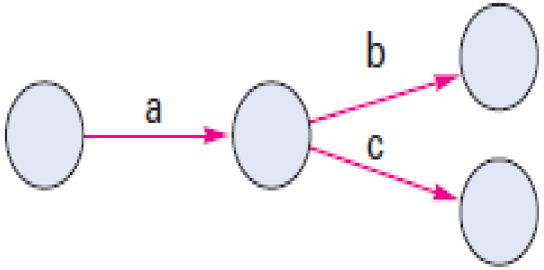
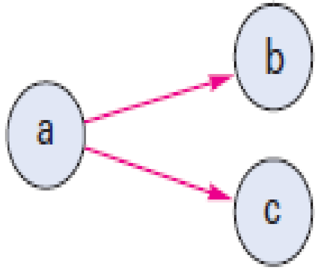
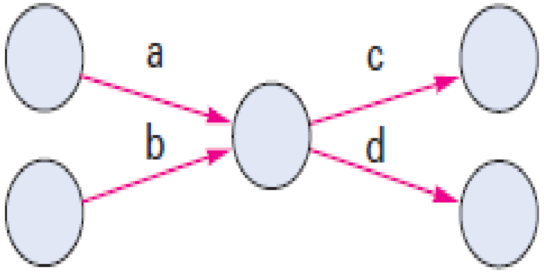
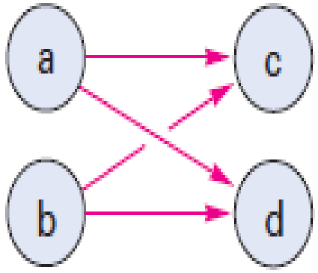
- The critical path for a project is the longest path through the network diagram and determines the earliest time by which the project can be completed.
- CPM is:
  - Single estimate of activity time
  - Deterministic activity times
- CPM can be used in Production management - for the jobs of repetitive in nature where the activity time estimates can be predicted with considerable certainty due to the existence of past experience.

Procedures

i. Determine the activities of the project
ii. Identify the predecessors and successor activities
iii. Allocate resource and time for each activity
iv. Draw the network diagram
v. Find the critical path
vi. Determine the early start and finish times
vii. Determine the latest start and finish times
viii. Find the slack time for each non-critical activities

The Network Diagram

- **Network (precedence) diagram** shows the sequential relationships of activities by use of arrows and nodes.
- There are two slightly different conventions for constructing these network diagrams.
  - **Activity-on-arrow (AOA):** The arrows in an AOA diagram represent activities.
  - **Activity-on-node (AON):** The nodes in an AON diagram represent activities.
- **AOA:** the arrows represent activities and they show the sequence in which certain activities must be performed, i.e. arrows designate activities.
- **AON:** the arrows show only the sequence in which certain activities must be performed while the nodes represent the activities, i.e. nodes designate activities.

AOA	Interpretation	AON
	Activities must be completed in sequence: first *a*, then *b*, and then *c*.	
	Both *a* and *b* must be completed before *c* can start.	
	Activity *a* must be completed before *b* or *c* can start.	
	Both *a* and *b* must be completed before *c* or *d* can start.	

Cont.…

- **Activities:** Project steps that consume resources and/or time.
- **Nodes:** consume neither resources nor time. In the AOA approach, the nodes represent the activities' starting and finishing points.
- Of particular interest to managers are the *paths* in a network diagram.
- A **path** is a sequence of activities that leads from the starting node to the ending node.

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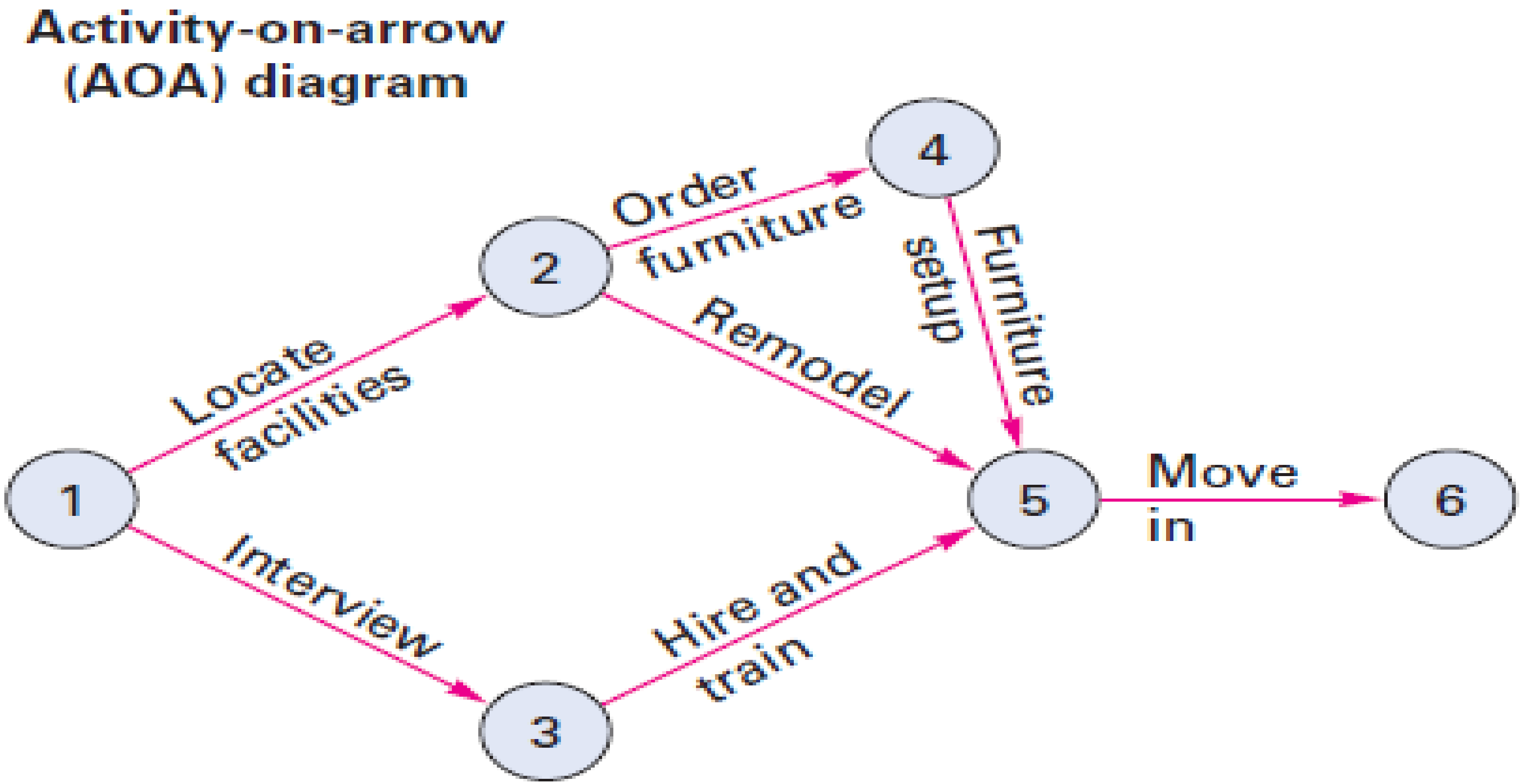


- For example, there are three paths in this diagram.
- The sequence 1-2-4-5-6 is a path.

Cont.…

- The length of any path can be determined by summing the expected times of the activities on that path.
- The longest path is referred to as the **critical path ,** and its activities are referred to as **critical activities.**
- **Critical path:** The longest path; determines expected project duration and governs project completion time.
- **Critical activities:** Activities on the critical path.

Cont.…

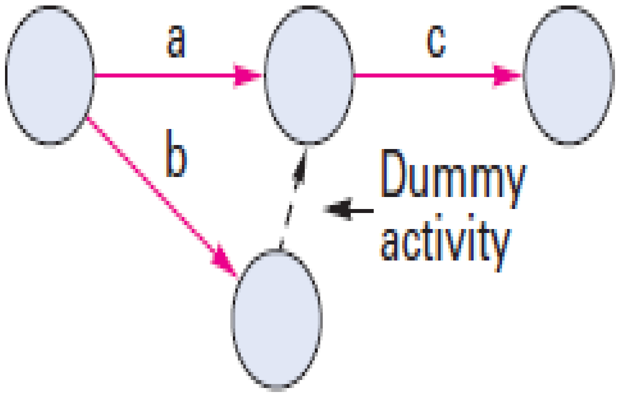
- Paths that are shorter than the critical path can experience some delays, but still not affect the overall project completion time as long as the ultimate path time does not exceed the length of the critical path.
- The allowable slippage for any path is called **slack.**
- **Slack:** the difference between the length of a path and the length of the critical path.
- The critical path, then, has zero slack time.

Rules of networking

- Each activity must have a preceding and/or a succeeding event.
- There should be no loops in the project network.
- Not more than one activity can have the same preceding and succeeding events.
  - ✓ This means that each activity is represented by a uniquely numbered arrow.
  - ✓ To ensure that each activity is uniquely numbered it may be necessary some times to introduce dummy activities.
  - ✓ A dummy activity is an imaginary activity which can be accomplished in zero time and which does not consume resources. It is represented by a dashed arrow.

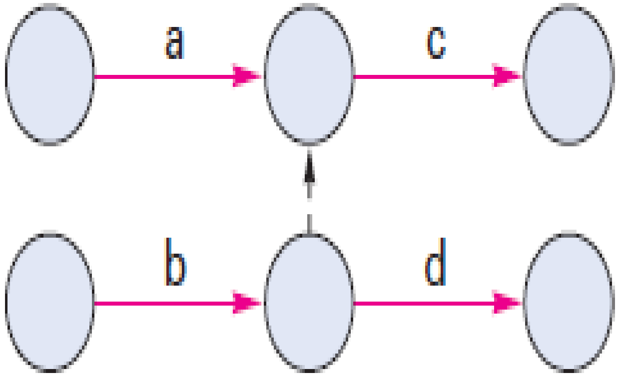
Cont….

Use a dummy activity to clarify relationships:



1. To separate two activities that have the same starting and ending nodes.

(No dummy needed)

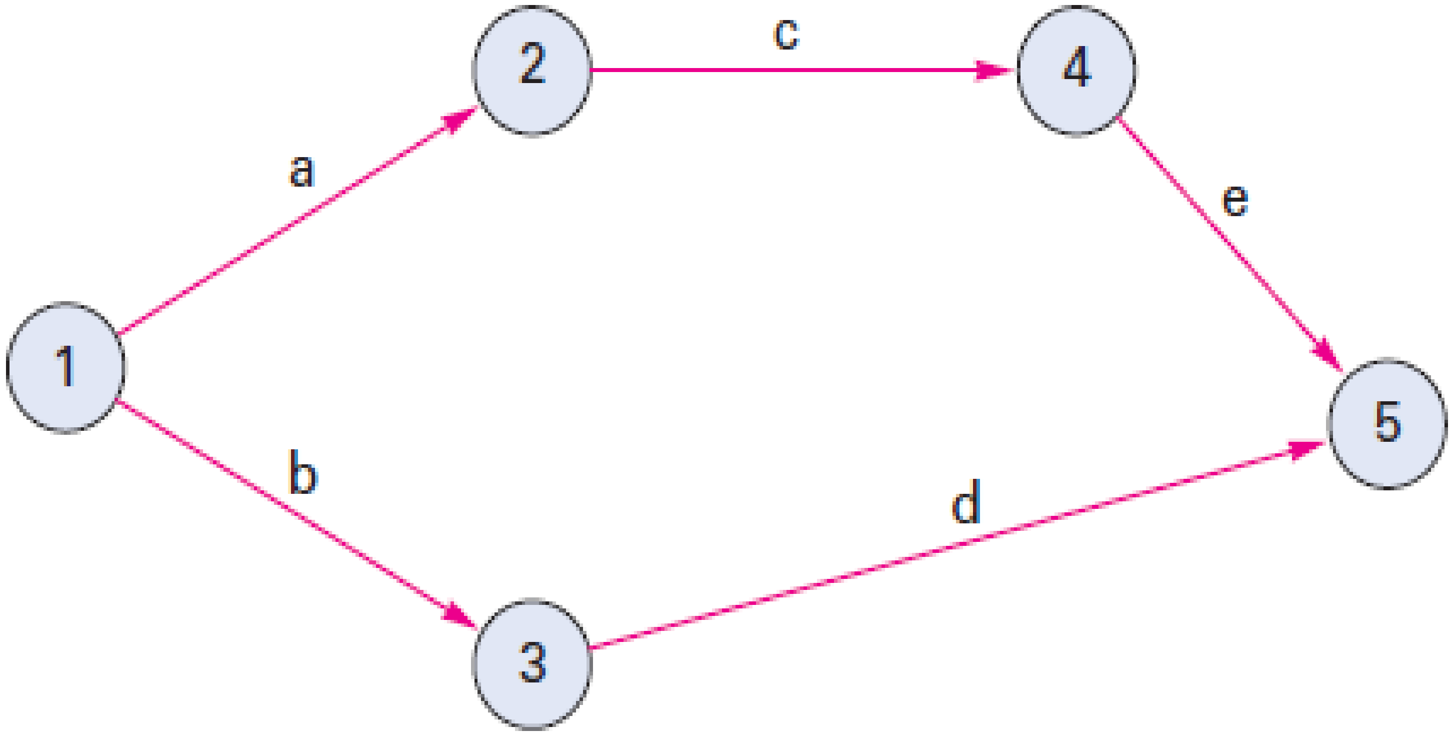


2. When activities share some, but not all, preceding activities. Here, activity *c* is preceded by activities *a* and *b*, while activity *d* is only preceded by activity *b*.

(No dummy needed)

Cont.…

- For reference purposes, nodes are numbered typically from left to right, with lower numbers assigned to preceding nodes and higher numbers to following nodes:



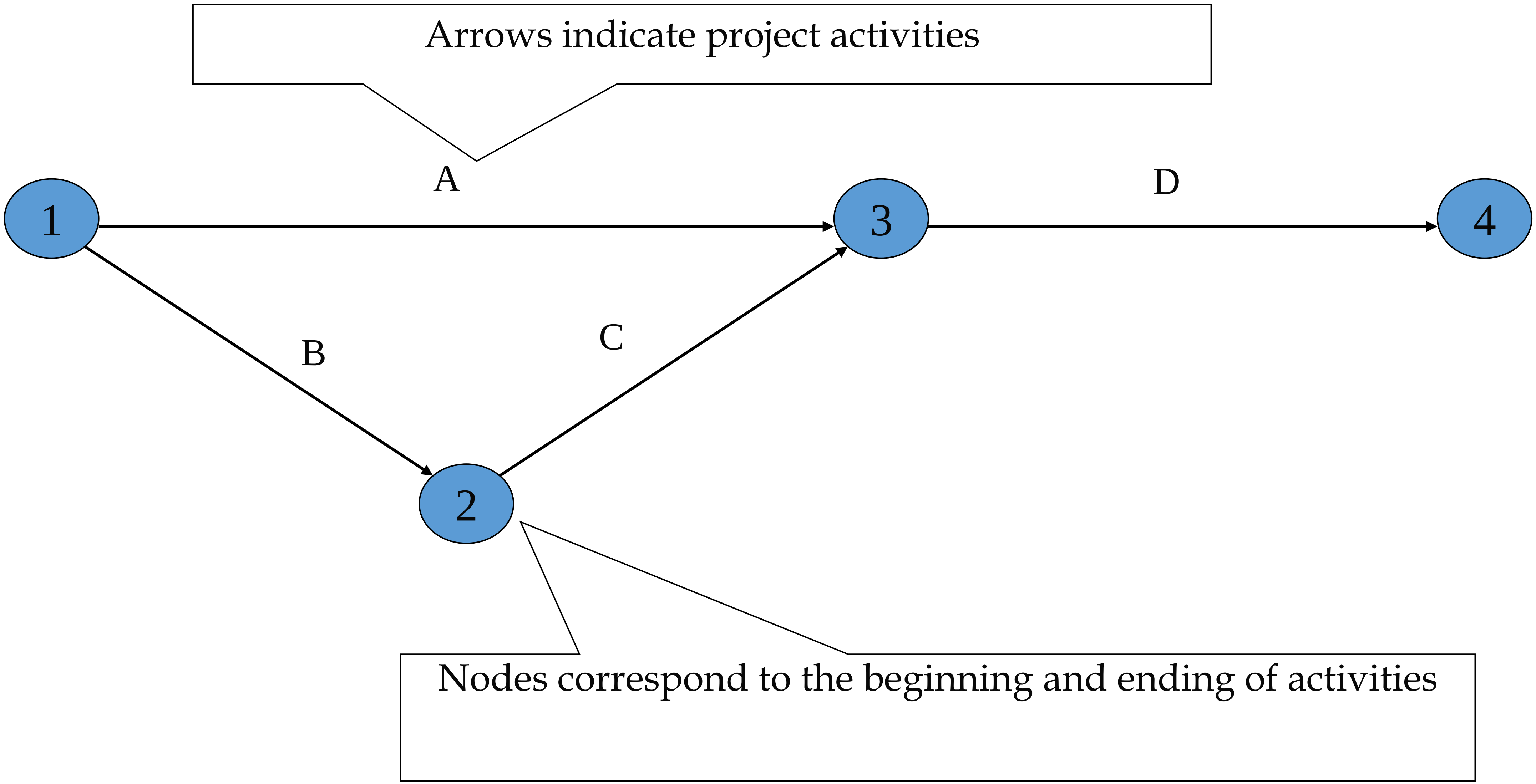
Example:

- Consider the list of four activities for making a simple product, draw the network diagram.

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.

Cont….



Arrows indicate project activities
A
D
1
3
4
B
C
2
Nodes correspond to the beginning and ending of activities

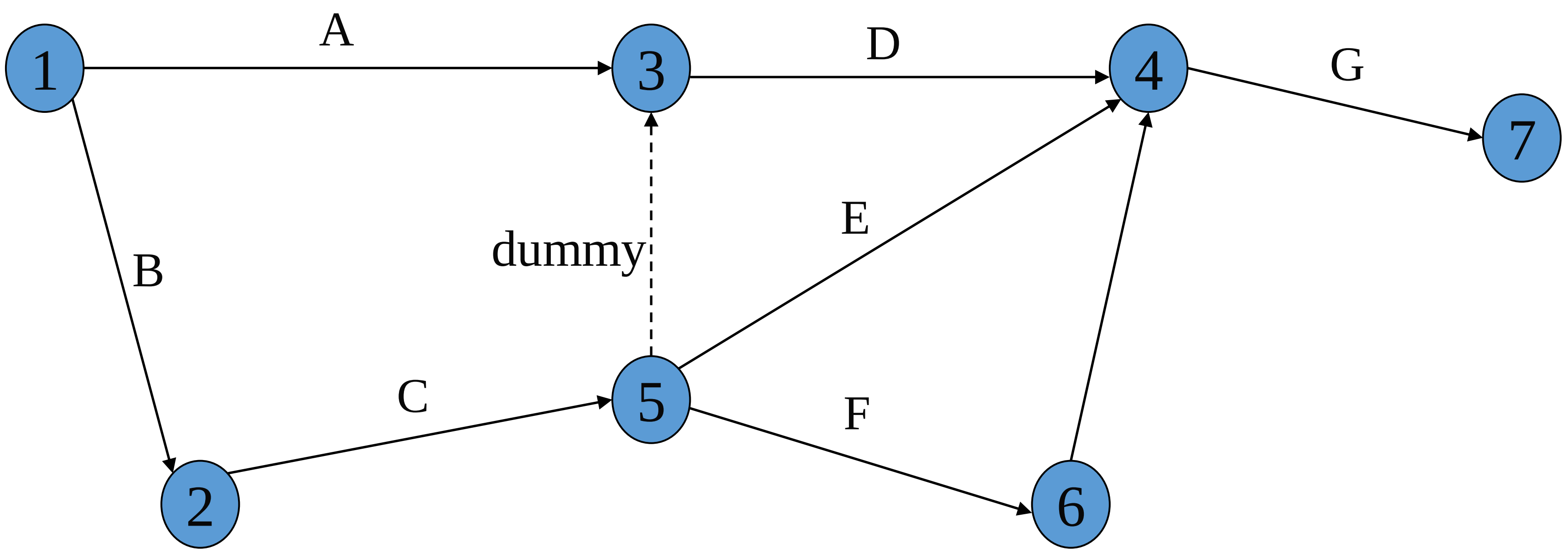
Example 2:

- 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

Cont.…

- Note how the network correctly identifies D, E, and F as the immediate predecessors for activity G.
- Dummy activities have no resources (time, labor, machinery, etc.) – purpose is to PRESERVE LOGIC of the network



Deterministic Time Estimates

- The main determinant of the way PERT and CPM networks are analyzed and interpreted is whether activity time estimates are probabilistic or deterministic.
- If time estimates can be made with a high degree of confidence that actual times are fairly certain, we say the estimates are **deterministic.**
- If actual times are subject to variation, we say the estimates are **probabilistic.**
- **CPM is deterministic** activity times.
- **PERT is probabilistic** activity times.

CPM example:

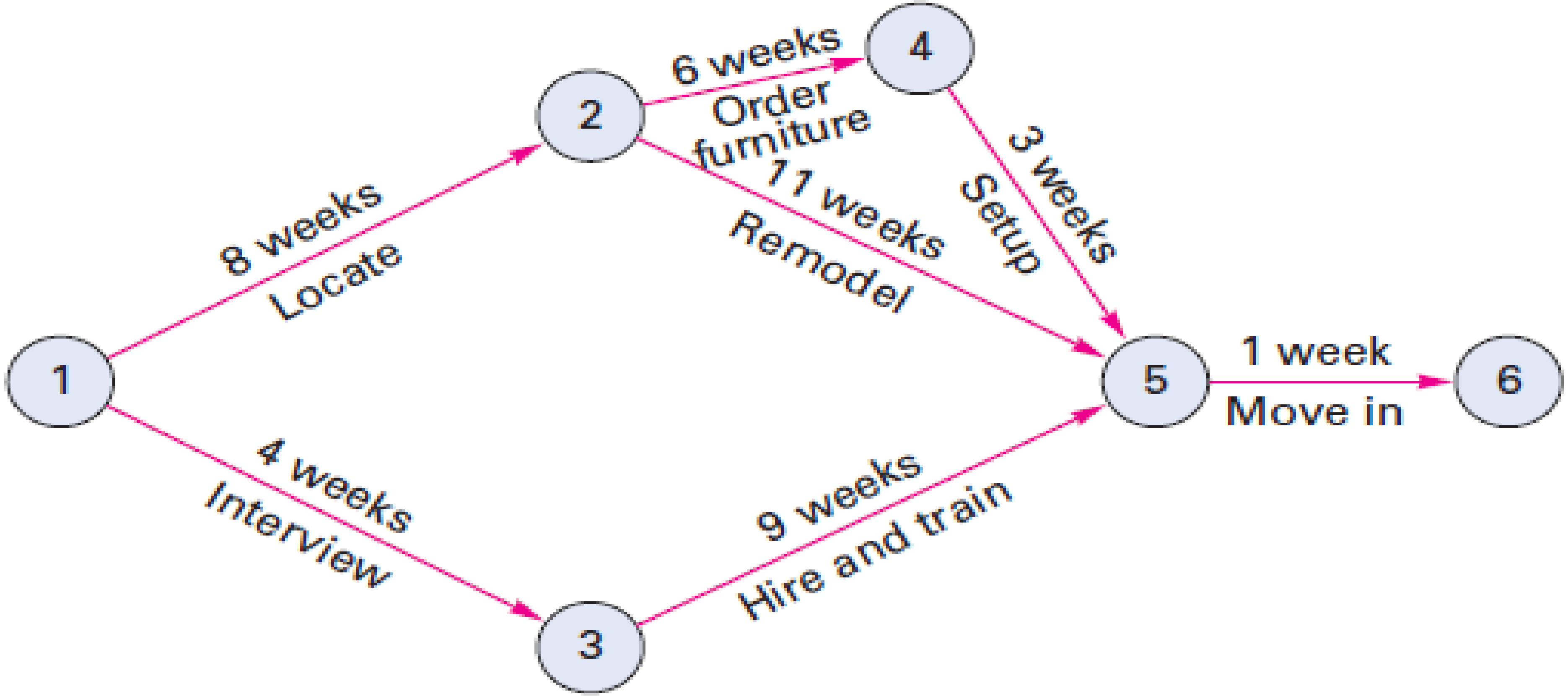
Determine

a. The length of each path.

b. The critical path.

c. The expected length of the project.

d. The amount of slack time for each path.



Solution **Cont….**

a. The path lengths are 18 weeks, 20 weeks, and 14 weeks.

b. Path 1-2-5-6 is the longest path (20 weeks), so it is the critical path.

c. The expected length of the project is equal to the length of the critical path (i.e., 20 weeks).

d. The slack for each path by subtracting its length from the length of the critical path.

Path	Length (weeks)	Slack
1-2-4-5-6	8 + 6 + 3 +1 = 18	20 – 18 = 2
1-2-5-6	8 + 11 + 1 = 20*	20 – 20 = 0
1-3-5-6	4 + 9 +1 = 14	20 – 14 = 6

Hence, the critical path will be 1-2-5-6 with project duration of 20 weeks.

Computing forward & backward passes (ES, EF, LS & LF)

- Managers use an algorithm to develop four pieces of information about the network activities:
    - Earlier start (ES), the earliest time activity can start.
    - Earlier finish (EF), the earliest time the activity can finish.
    - Latest start (LS), the latest time the activity can start and not delay the project.
    - Latest finish (LF), the latest time the activity can finish and not delay the project.
- These values used to find

    1. Expected project duration.

    2. Slack time.

    3. The critical path.

Cont.…

Computation of earliest starting and finish times is added by two simple rules:

1. The earliest finish time for any activity is equal to its earliest start time plus its expected duration (t).

$$EF = ES + t$$

2. ES for activities at nodes with one entering arrow is equal to EF of the entering arrow is equal to the largest EF of the entering arrow.

Cont.…

Computation of latest starting and finish times is aided by the use of two simple rules:

1. The latest starting time for each activity is equal to its latest finishing time minus its expected duration (t).

   $$LS = LF - t$$

2. For nodes with one leaving arrow, LF for arrows entering that node equals the LS of the leaving arrow. For nodes with multiple leaving arrows, LF for arrows entering that node equals the smallest LS of leaving arrows.

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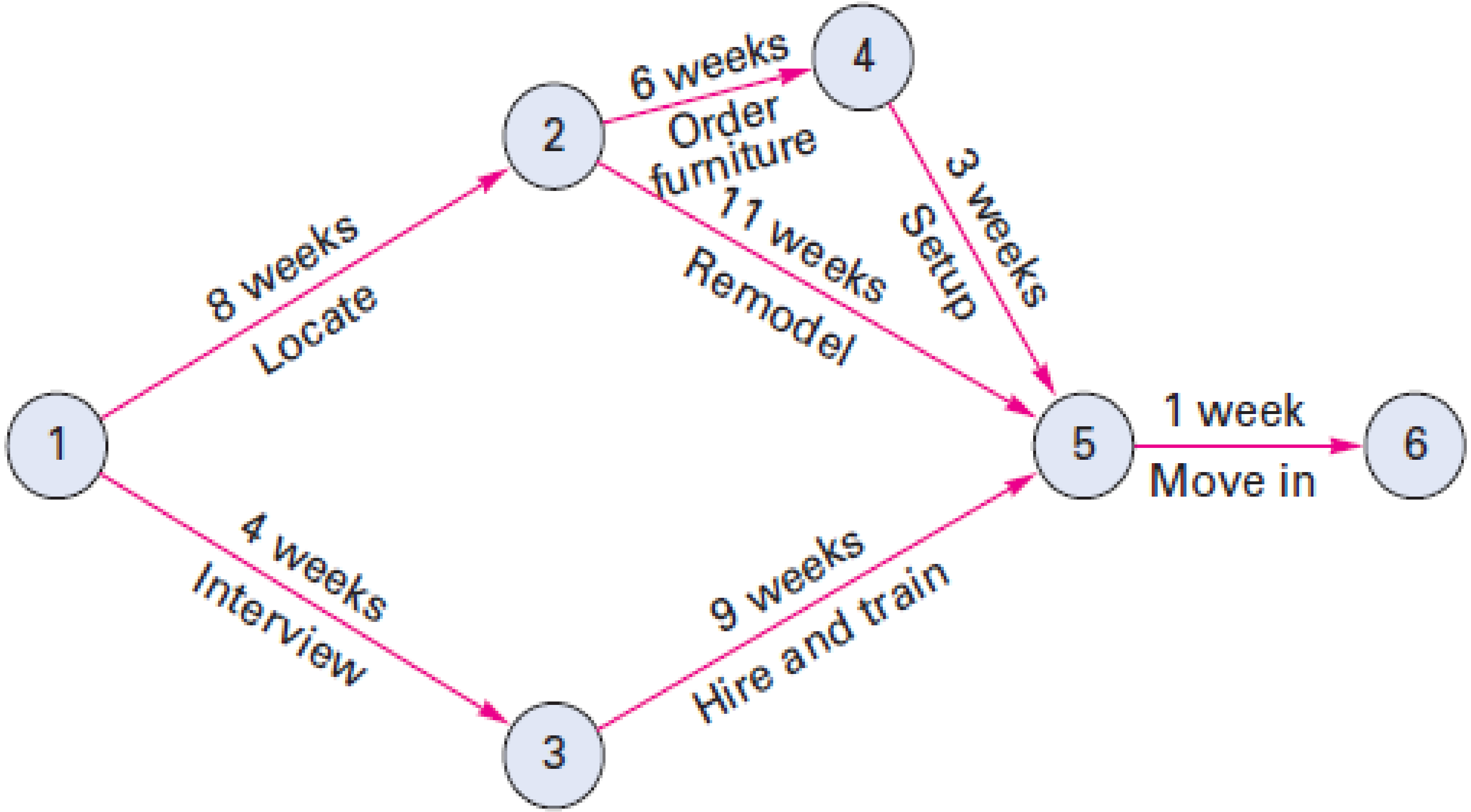
Forward passes - ES and EF

Example: Compute the ES and EF time for each activity in the diagram



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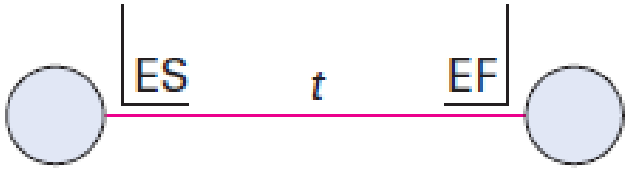
- Begin by placing brackets at the two ends of each starting activity:

- Determine and place in the brackets for each activity the ES and EF for every activity, and put them in brackets, as follows:



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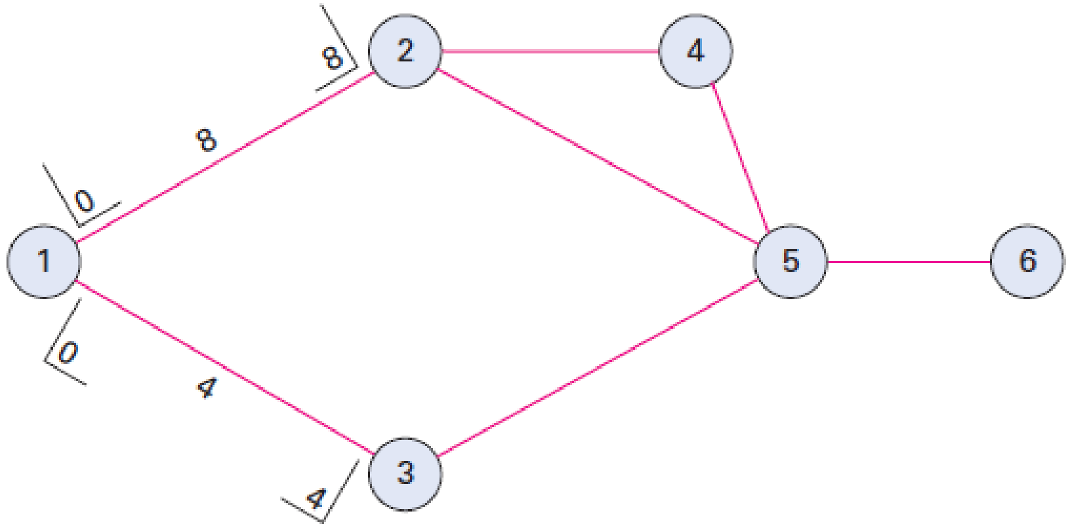
- Once ES is determined for each activity, EF can be found by adding the activity time, t, to ES:

$$EF = ES + t$$

- Use an ES of 0 for all starting activities. Thus, activities 1-2 and 1-3 are assigned ES values of 0. This permits computation of the EF for each of these activities:

$$EF_{1\text{-}2} = 0 + 8 = 8 \quad \text{and} \quad EF_{1\text{-}3} = 0 + 4 = 4$$



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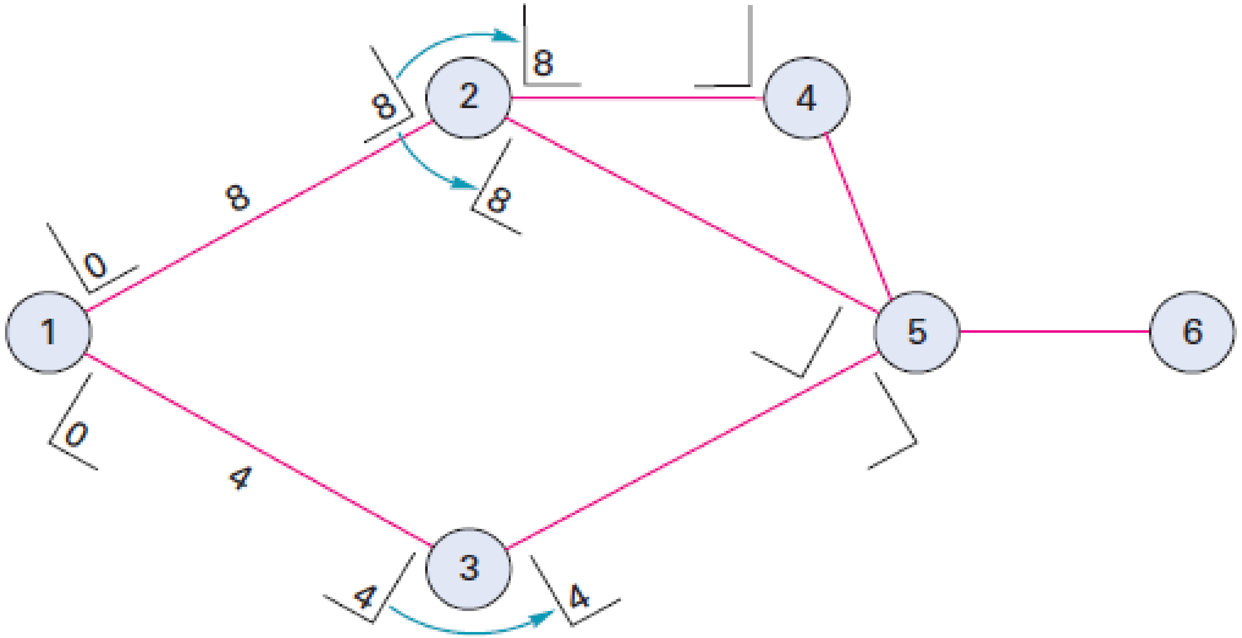
- The EF time for an activity becomes the ES time for the next activity to follow it in the diagram.
- Hence, because activity 1-2 has an EF time of 8, both activities 2-4 and 2-5 have ES times of 8. Similarly, activity 3-5 has an ES time of 4.



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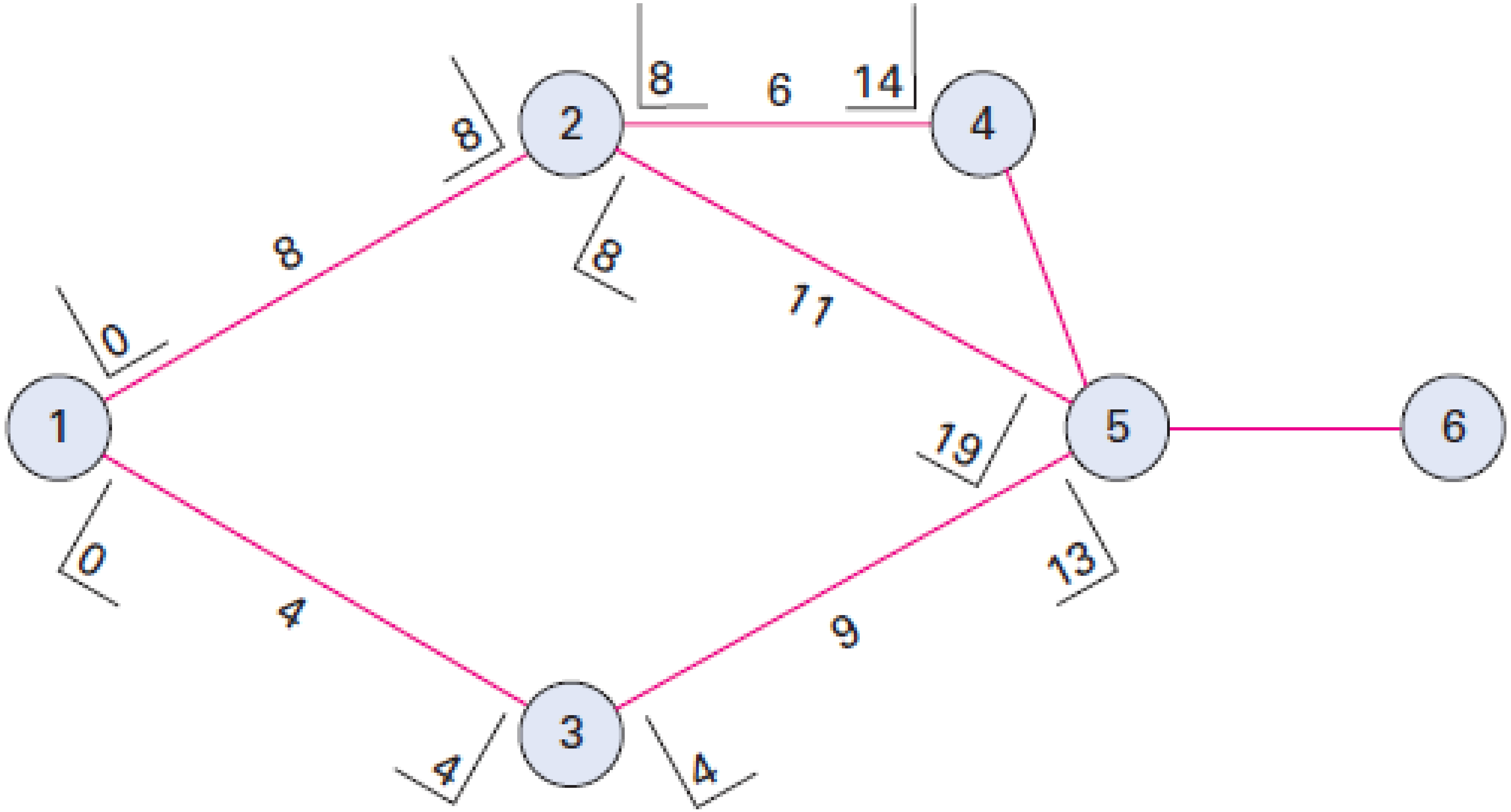
This permits calculation of the EF times for these activities: $EF_{2\text{-}4} = 8 + 6 = 14$; $EF_{2\text{-}5} = 8 + 11 = 19$; and $EF_{3\text{-}5} = 4 + 9 = 13$.



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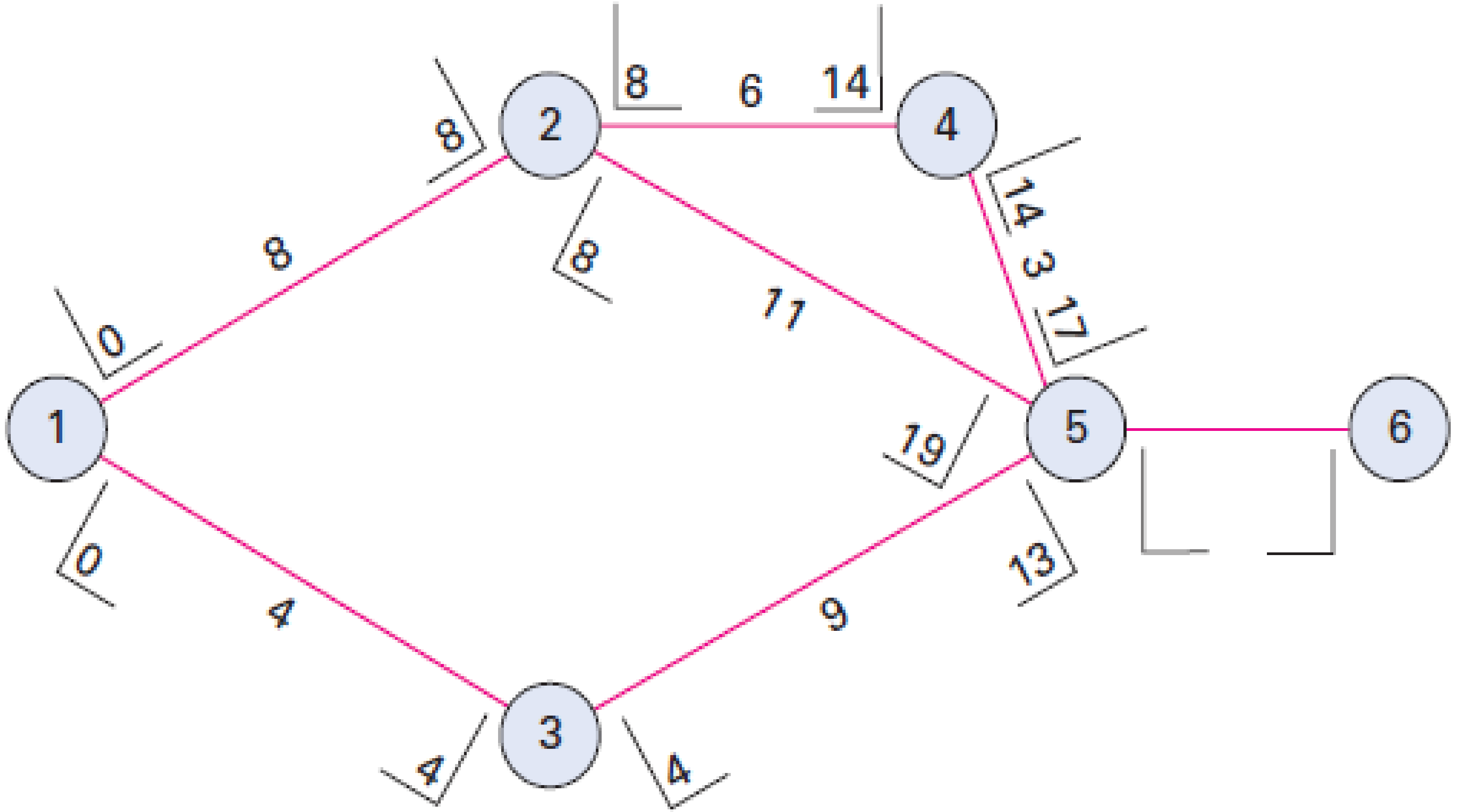
The ES for activity 4-5 is the EF time of activity 2-4, which is 14. Using this value, we find the EF for activity 4-5 is 17; $EF_{4\text{-}5} = 14 + 3 = 17$.



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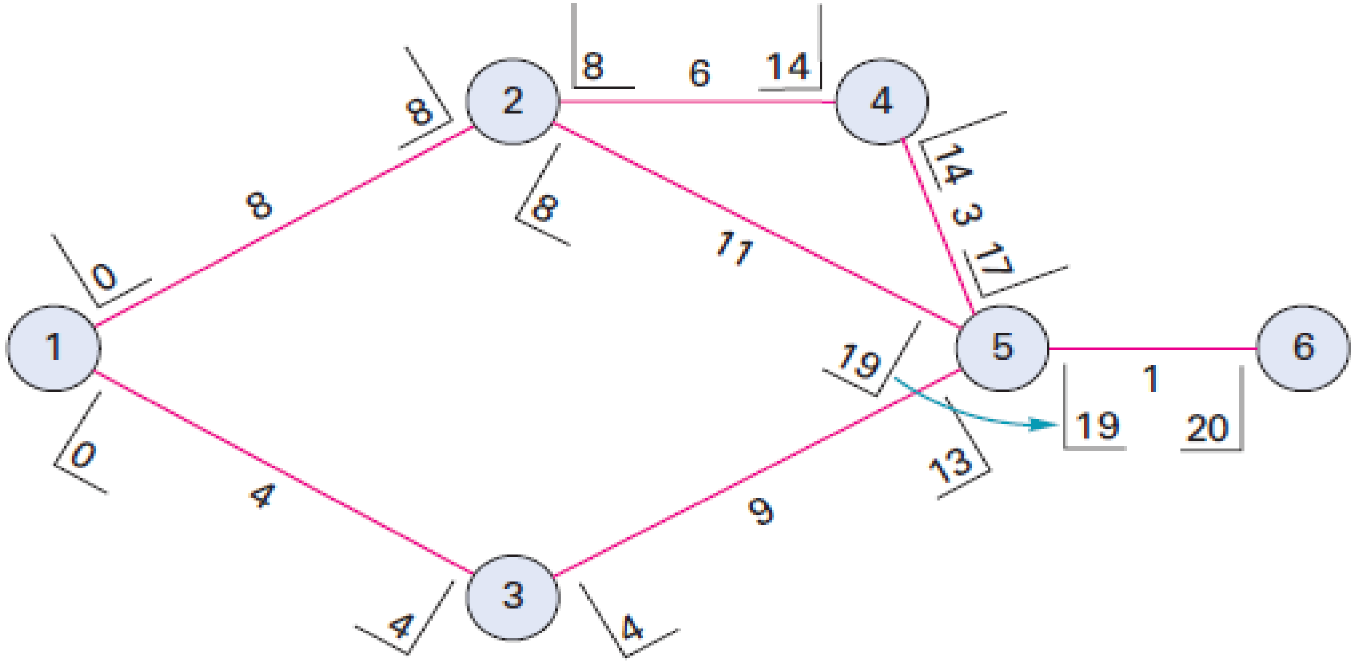
- In order to determine the ES for activity 5-6, we must realize that activity 5-6 cannot start until every activity that precedes it is finished.
- Therefore, the largest of the EF times for the three activities that precede activity 5-6 determines ES for 5-6 . Hence, the ES for activity 5-6 is 19.



Then the EF for the last activity, 5-6, is 20; $EF_{5\text{-}6} = 19 + 1 = 20$. Note that the latest EF is the project duration. Thus, the expected length of the project is 20 weeks.

Backward passes - LS and LF

- Finding ES and EF times involves a forward pass through the network; but finding LS and LF times involves a backward pass through the network.

The LS for the last activity is obtained by subtracting its expected duration from its LF. i.e. $LS = LF - t$

- Compute the LF and LS times for the precedence diagram developed in the above Example.

- We must add the LS and LF times to the brackets on the diagram.

Cont.…

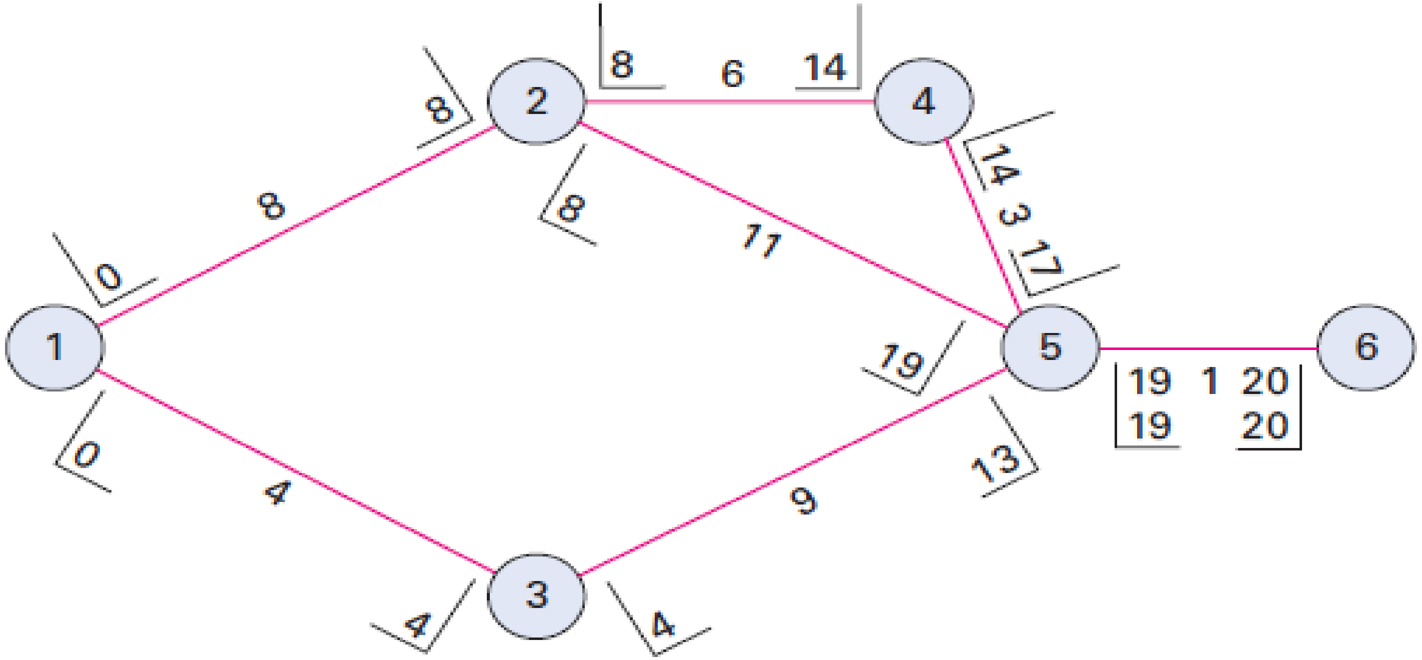
- Begin by setting the LF time of the last activity equal to the EF of that activity. Thus,

$$LF_{5\text{-}6} = EF_{5\text{-}6} = 20 \text{ weeks}$$

- Obtain the LS time for activity 5-6 by subtracting the activity time, *t*, from the LF time:

$$LS_{5\text{-}6} = LF_{5\text{-}6} - t = 20 - 1 = 19$$

- Mark these values on the diagram:



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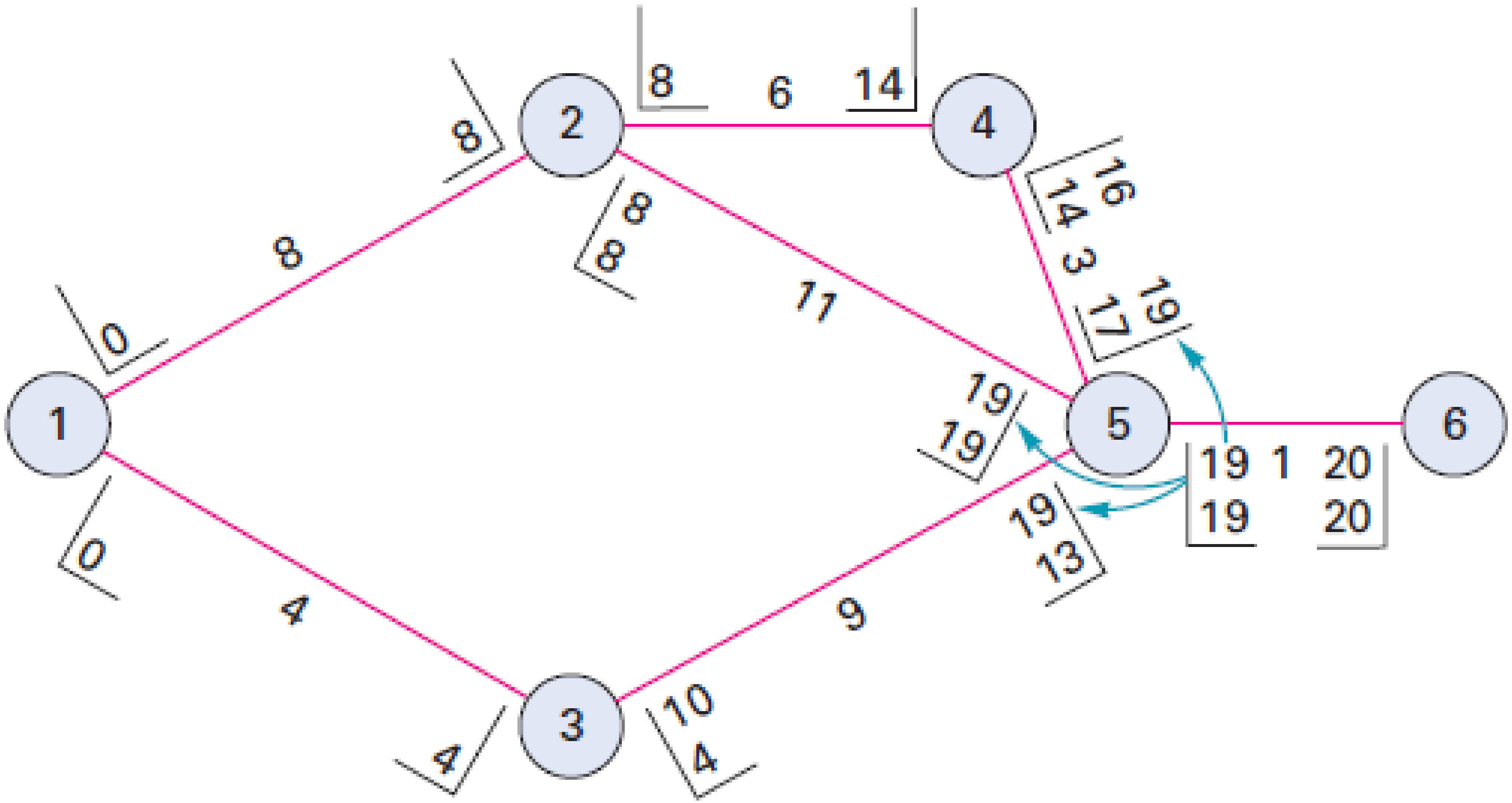

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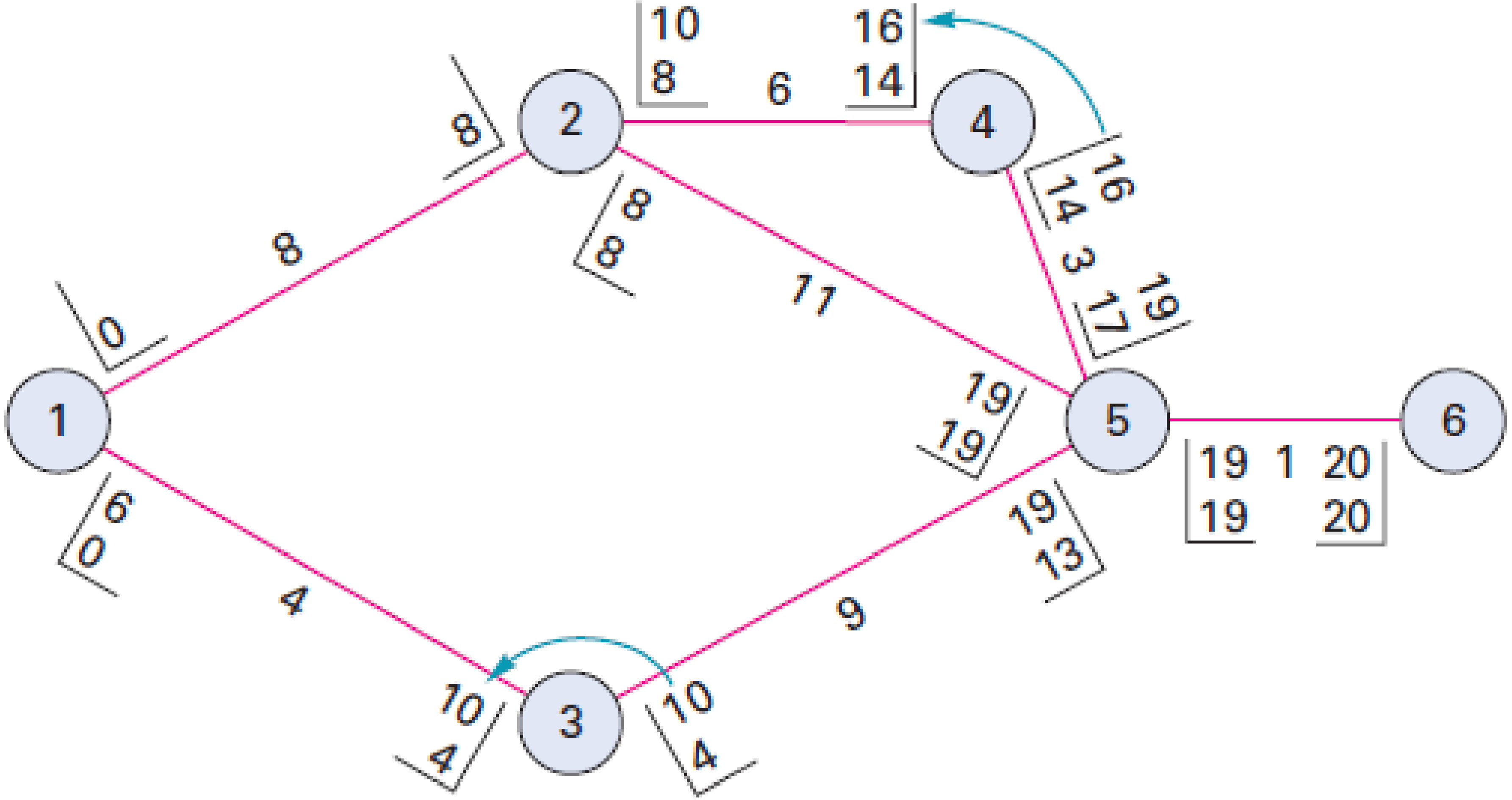

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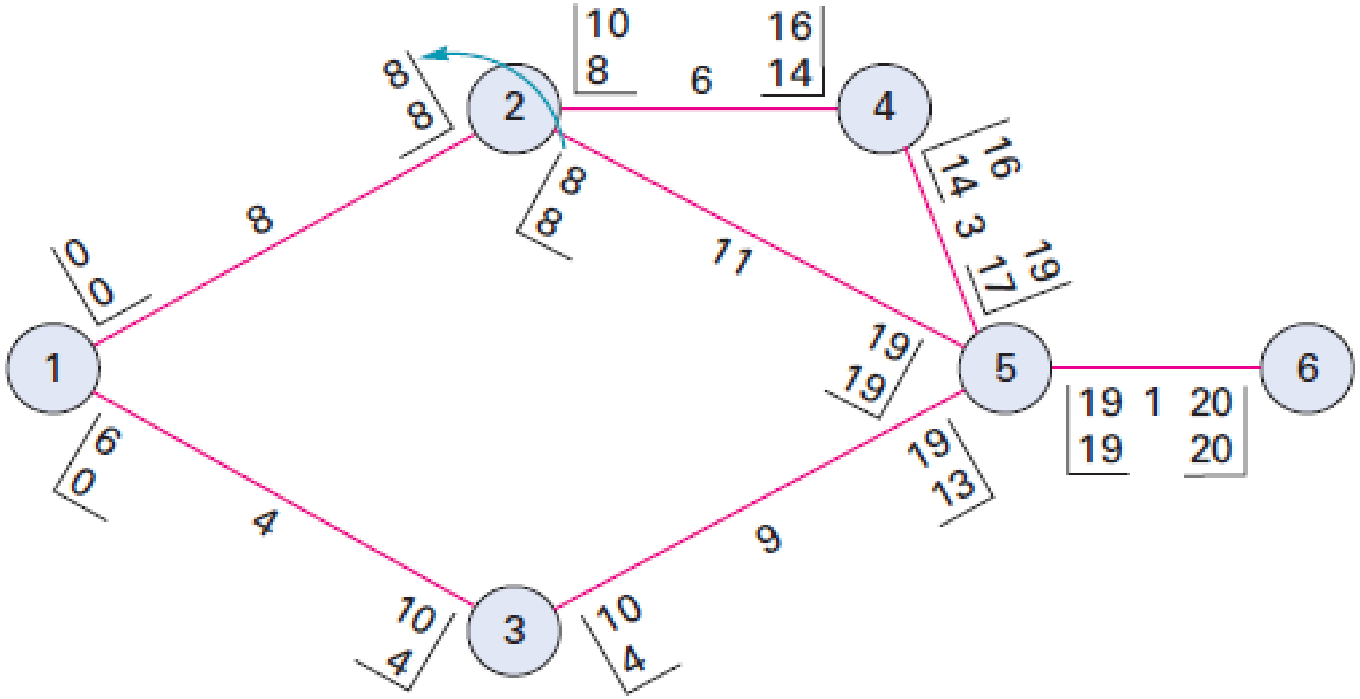
Cont.…

- The LF for activity 1-2 is the smaller of the two LS times of the activities that 1-2 precedes. Hence, the LF time for activity 1-2 is 8. The reason you use the smaller time is that activity 1-2 must finish at a time that permits all following activities to start no later than their LS times.



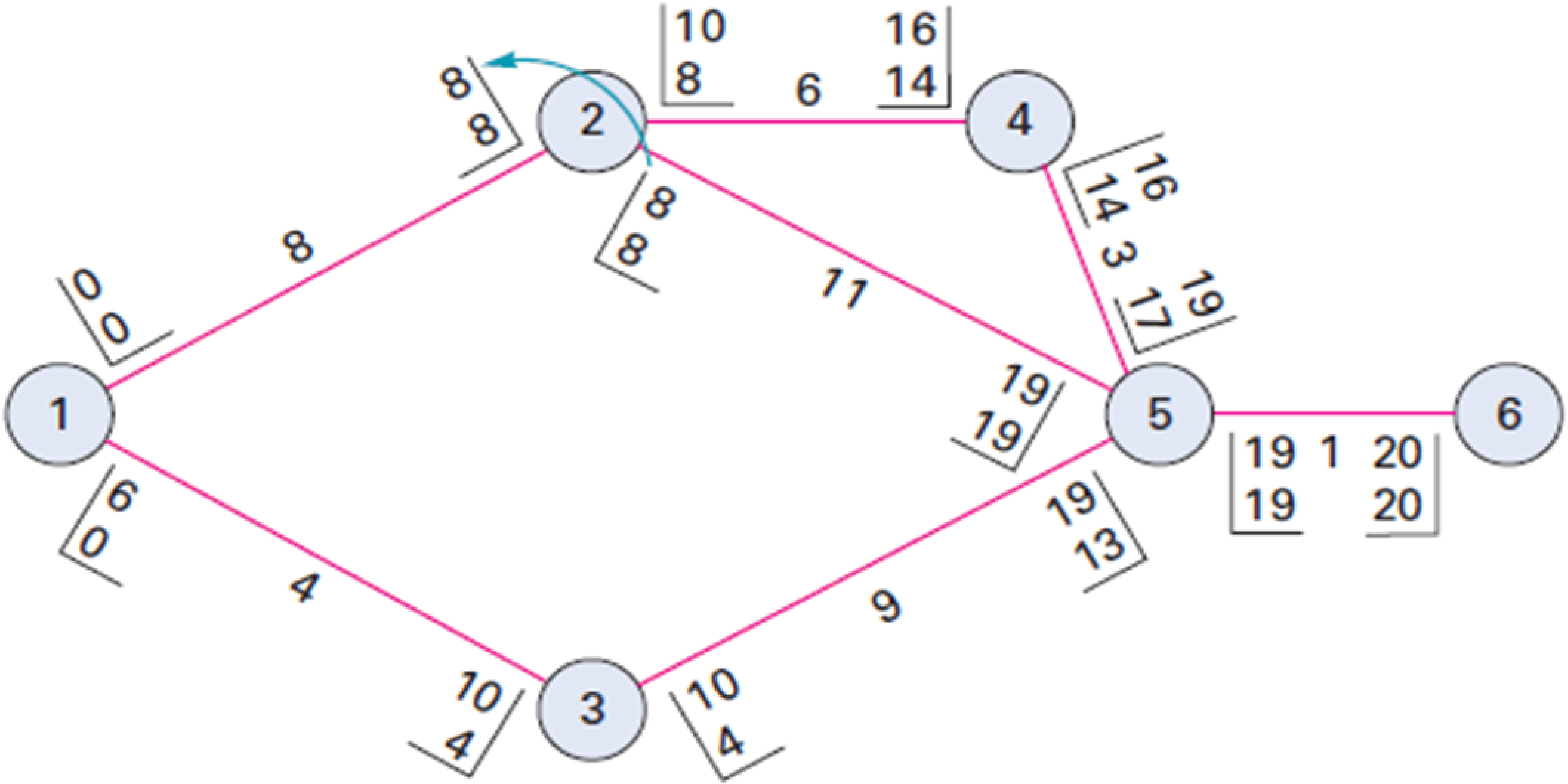
Computing Slack Times

- The slack time can be computed in either of two ways:

  Slack time = LS – ES or Slack time = LF - EF

- Activity slack is a measure of flexibility in the assignment of activity start times.
- Compute slack times for the preceding example.
- Either the starting times or the finishing times can be used. Suppose we choose the starting times.

All calculations finished network diagram



Cont.…

Activity	LS	ES	Slack = LS - ES
1 - 2	0	0	0
1 - 3	6	0	6
2 – 4	10	8	2
2 - 5	8	8	0
3 - 5	10	4	6
4 - 5	16	14	2
5 - 6	19	19	0

Activity	LF	EF	Slack = LF - EF
1 - 2	8	8	0
1 - 3	10	4	6
2 – 4	16	14	2
2 - 5	19	19	0
3 - 5	19	13	6
4 - 5	19	17	2
5 - 6	20	20	0

Activities that have a slack of zero are on the critical path. Hence, the critical path is 1-2-5-6.

II. PERT- Project evaluation and review technique

- **Probabilistic model**
- **Three time estimates**
- **Consideration of success/failure probability**

- In **PERT** activities are shown as a network of precedence relationships.
  - Multiple time estimates
  - Probabilistic activity times

USED IN: Project management - for non-repetitive jobs, where the time and cost estimates tend to be quite uncertain. This technique uses probabilistic time estimates.

Probabilistic Time Estimates

- ✓The preceding discussion assumed that activity times were known and not subject to variation.
- ✓PERT is based on the assumption that an activity's duration follows a probability distribution instead of being a single value.
- ✓The probabilistic approach involves three time estimates instead of one:

  I. **<u>Pessimistic time</u> (t_p) -** The length of time required under the worst conditions, if things did not go well.

  II. **<u>Most likely time</u> (t_m) -** The most probable amount of time required.

  III. **<u>Optimistic time</u> (t_o) -** The length of time required under optimum conditions or if things did go well.

Cont.….

The expected time of an activity, $\mathbf{t_e}$, is a weighted average of the three time estimates:

- **Mean (expected time):** $\mathbf{t_e = \dfrac{t_p + 4\,t_m + t_o}{6}}$

$$\sigma = \frac{t_p - t_o}{6}$$

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

EXAMPLE: **Cont….**

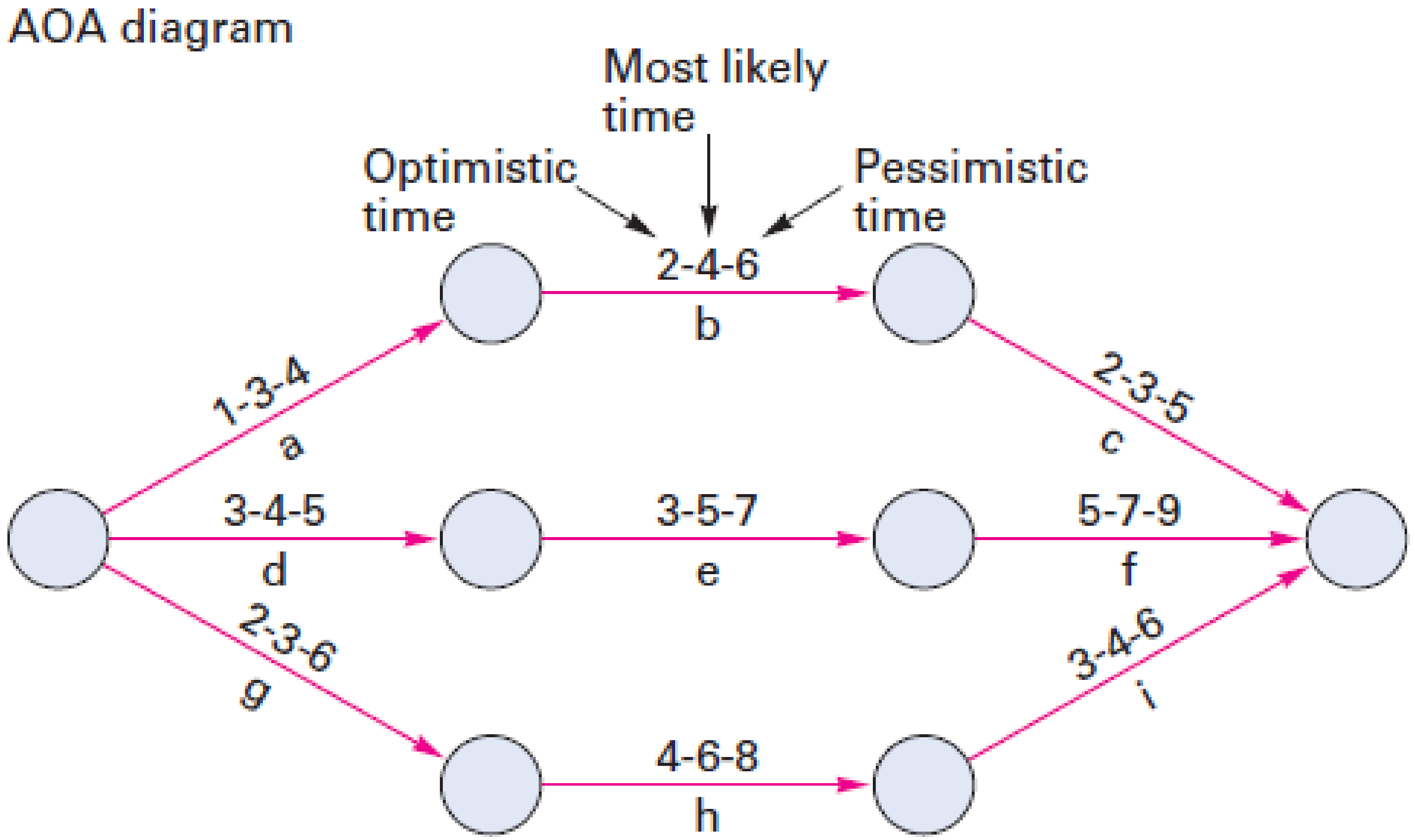
- The network diagram for a project is shown in the accompanying figure, with three time estimates for each activity. Activity times are in weeks. Do the following:

a. Compute the expected time for each activity and the expected duration for each path.

b. Identify the critical path.

c. Determine standard deviation

& variance.



Cont….

a.

Path	Activity	TIMES t_o	t_m	t_p	$t_e = \frac{t_o + 4t_m + t_p}{6}$	Path Total
a-b-c	a	1	3	4	2.83	
	b	2	4	6	4.00	10.00
	c	2	3	5	3.17	
d-e-f	d	3	4	5	4.00	
	e	3	5	7	5.00	16.00
	f	5	7	9	7.00	
g-h-i	g	2	3	6	3.33	
	h	4	6	8	6.00	13.50
	i	3	4	6	4.17	

b. The path that has the longest expected duration is the critical path. Because path **d-e-f** has the largest path total i.e. 16 , this is the critical path.

c. To determine standard deviation & variance know critical path and remember the formulas:-

Cont……

$$\sigma = \frac{t_p - t_o}{6}$$

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

Activity's name	**Time estimates (in days)**			$\boldsymbol{\sigma = \frac{t_p - t_o}{6}}$	**Variance** $= \boldsymbol{\sigma^2 = \left(\frac{t_p - t_o}{6}\right)^2}$
	$\boldsymbol{t_o}$	$\boldsymbol{t_m}$	$\boldsymbol{t_p}$		
d	**3**	**4**	**5**	**0.33**	**0.11**
e	**3**	**5**	**7**	**0.67**	**0.44**
f	**5**	**7**	**9**	**0.67**	**0.44**
				Sum=1.67	Sum=1.00

Resource allocation

- It is usually wise to maintain relatively stable employment levels and to utilize resources at a more constant rate.
- In such situations, resource leveling programs are most appropriate.
- We know that activity slack is a measure of flexibility in the assignment of activity start times.
- The scheduler may use activity slack as a means of smoothing peak resource requirements.

Steps in resource allocation

i. Allocate resources serially in time. It means, start on the first day and schedule all jobs that are possible, then do the same for the second day, and so on.

ii. When several jobs compete for the same resources, give preference to the jobs with the least slack.

iii. • Schedule non-critical jobs, if possible, to free resources for scheduling critical or non-slack jobs.

Project Risks

- A risk may be defined as any event that prevents you achieving the project's goals and objectives.
- Risks bring undesirable consequences, such as delays, increased costs, an inability to meet technical specifications, and may cause a project to be terminated.
- Careful planning can reduce risks, but no amount of planning can eliminate chance events due to unforeseen, or uncontrollable, circumstances.
- The probability of occurrence of risk events is highest near the beginning of a project and lowest near the end. However, the cost associated with risk events tends to be lowest near the beginning of a project and highest near the end.

Cont.…

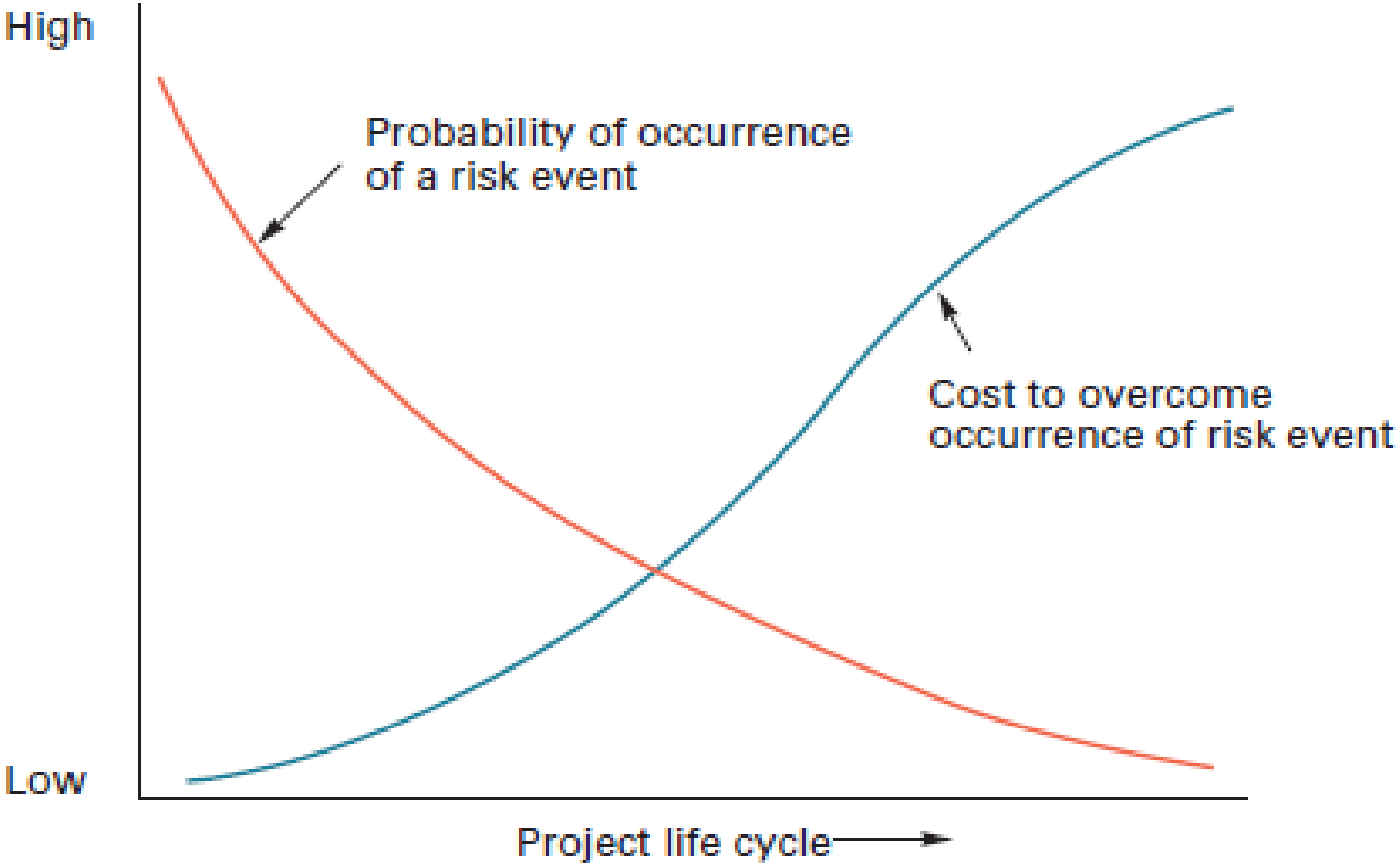


Figure: Risk event probability and cost

Cont….

- Good risk management entails identifying as many potential risks as possible, analyzing and assessing those risks, working to minimize the probability of their occurrence.
- With increasing market competition, increasing technology and an increasing rate of change, risk management is gaining significance and importance.
- The risk continuum indicates the boundaries of risk management between certainty and uncertainty.
- **Project Risk Management is defined**: the processes concerned with identifying, analyzing and responding to uncertainty. It includes maximizing the results of positive events and minimizing the consequences of adverse events.

Cont….

- The generally accepted risk management model sub-divides the risk management process into the following headings:

  i. **Define Objectives**: define the context of your work and your plan for success. This defines what you have to achieve to be successful and establishes a basis for dealing with risk and future decisions.

  ii. **Identify Risk**: identify areas of risk and uncertainty which may limit or prevent you achieving your objectives.

  iii. **Quantify Risk**: evaluate and prioritize the level of risk and uncertainty and quantify frequency of occurrence and impact.

Cont.…

iv. Develop Response: define how you are going to respond to the identified risks; eliminate, mitigate, deflect or accept.

v. Document: the risk management plan documents how you propose to tackle risk on your project.

vi. Risk Control: the risk control function implements the risk management plan. And as the risks and the work environment are continually changing, it is essential to continually monitor and review the level of risk and the ability to effectively respond..

Risk Identification

Risk identification should be a systematic process to ensure nothing significant is over looked.

The risks may be based on operational, technical, financial, legal, social and humanitarian requirements.

Techniques for identifying risk include:

- ✓Analyzing historical records (closeout reports)
- ✓Structured questionnaires and interviews

Cont.…

- ✓ Brainstorming
- ✓ Structured checklists
- ✓ Flow charts
- ✓ Judgment based on knowledge and experience
- ✓ System analysis
- ✓ Scenario analysis (what-if)..

Common reasons for project failure:

- ✓Misinterpreting the scope of work
- ✓Mixing and confusing tasks, specifications, approvals, and special instructions
- ✓Using imprecise or vague language, for example; nearly, optimum, about or approximately can lead to confusion, ambiguity or misinterpretation.
- ✓Failing to get third-party review or verification from the client, sub-contractors and suppliers.
- ✓Insufficient reviews and control.
- ✓Caused by not using CPM to limit project duration and the WBS to sub-divide all the work packages to a common level of detail.

THANK YOU !!