Project Scheduling

Introduction

- Involves deciding which tasks would be taken up when
- Project Manager need to do the following
  - ⍰ Identify all the tasks
  - ⍰ Break down large tasks into small activities
  - ⍰ Determine the dependency among activities
  - ⍰ Estimate the time duration to complete the activities
  - ⍰ Allocate resources to activities
  - ⍰ Plan start and end dates
  - ⍰ Determine the *Critical path*
- Task dependencies
- Milestones

“Failing to plan is planning to fail”

by J. Hinze, *Construction Planning and Scheduling*

- Planning:
  - “what” is going to be done, “how”, “where”, by “whom”, and “when”
  - for effective monitoring and control of complex projects

“Its about time”

by J. Hinze, *Construction Planning and Scheduling*

- Scheduling:
  - “what” will be done, and “who” will be working
    - relative timing of tasks & time frames
  - a concise description of the plan

“Once you plan your work, you must work your plan”

by J. Hinze, *Construction Planning and Scheduling*

- Planning and Scheduling occurs:
  - **AFTER** you have decided how to do the work
    - “The first idea is not always the best idea.”
- Requires discipline to “work the plan”
  - The act of development useful,
  - But need to monitor and track
    - only then, is a schedule an effective management tool
    - as-built schedules

Activity Network

- Activity network shows
  - Different activities
  - Estimated durations
  - Interdependencies

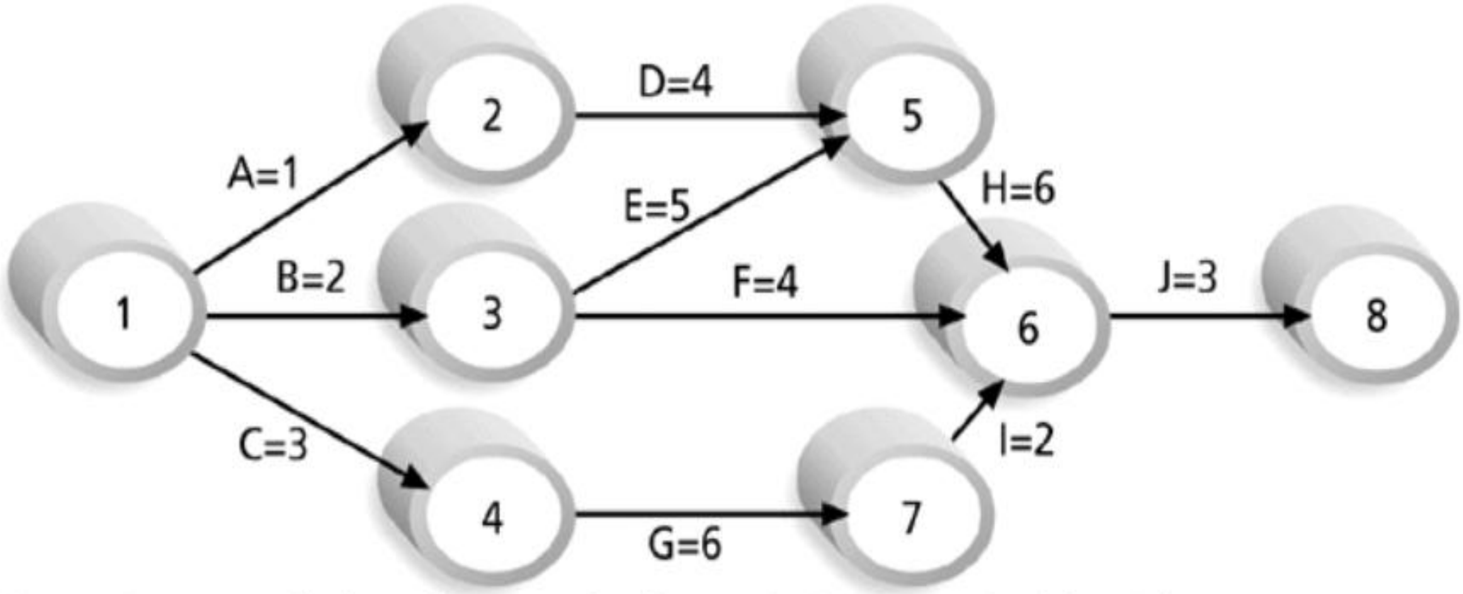
Network Diagrams

- Network diagrams are the preferred technique for showing activity sequencing.

- A **network diagram** is a schematic display of the logical relationships among, or sequencing of, project activities.

- Two main formats are the arrow and precedence diagramming methods.

Activity Network Diagram for Project X



Note: Assume all durations are in days; A=1 means Activity A has a duration of 1 day.

Techniques of Scheduling

- CPM
- PERT
- GANTT

The PERT/CPM Approach for Project Scheduling

- The PERT/CPM approach to project scheduling uses network presentation of the project to
  - Reflect activity precedence relations
  - Activity completion time
- PERT/CPM is used for scheduling activities such that the project's completion time is minimized.

Critical Path Method

- It is the chain of activities that determines the duration of the project.
- Different Parameters:
  - Earliest Start (ES) Time
  - Latest Start (LS) Time
  - Earliest Finish (EF) Time
  - Latest Finish (LF) Time
  - Slack Time (ST) = LS-ES, equivalently can be written as LF-EF
  - Critical task is one with a *zero* slack time
  - Path from start to finish containing only critical task is critical path

Identifying the Activities of a Project

- To determine optimal schedules we need to
  - Identify all the project's activities.
  - Determine the precedence relations among activities.
- Based on this information we can develop managerial tools for project control.

Identifying Activities, Example

KLONE COMPUTERS, INC.

- **KLONE Computers manufactures personal computers.**
- **It is about to design, manufacture, and market the Klonepalm 2000 palmbook computer.**

KLONE COMPUTERS, INC

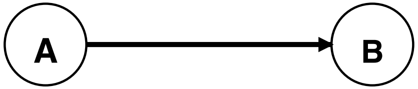
- There are three major tasks to perform:
  - Manufacture the new computer.
  - Train staff and vendor representatives.
  - Advertise the new computer.
- KLONE needs to develop a precedence relations chart.
- The chart gives a concise set of tasks and their immediate predecessors.

KLONE COMPUTERS, INC

	Activity	Description
	A	Prototype model design
	B	Purchase of materials
Manufacturing activities	C	Manufacture of prototype model
	D	Revision of design
	E	Initial production run
	F	Staff training
Training activities	G	Staff input on prototype models
	H	Sales training
Advertising activities	I	Pre-production advertising campaign
	J	Post-redesign advertising campaign

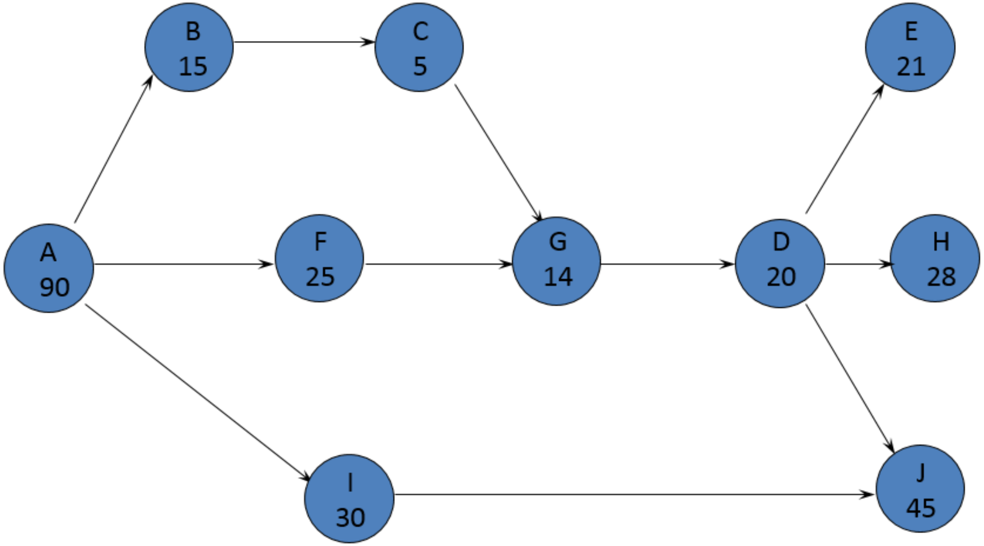
KLONE COMPUTERS, INC

From the activity description chart, we can determine immediate predecessors for each activity.



Activity A is an immediate predecessor of activity B, because it must be competed just prior to the commencement of B.

Precedence Relationships Chart



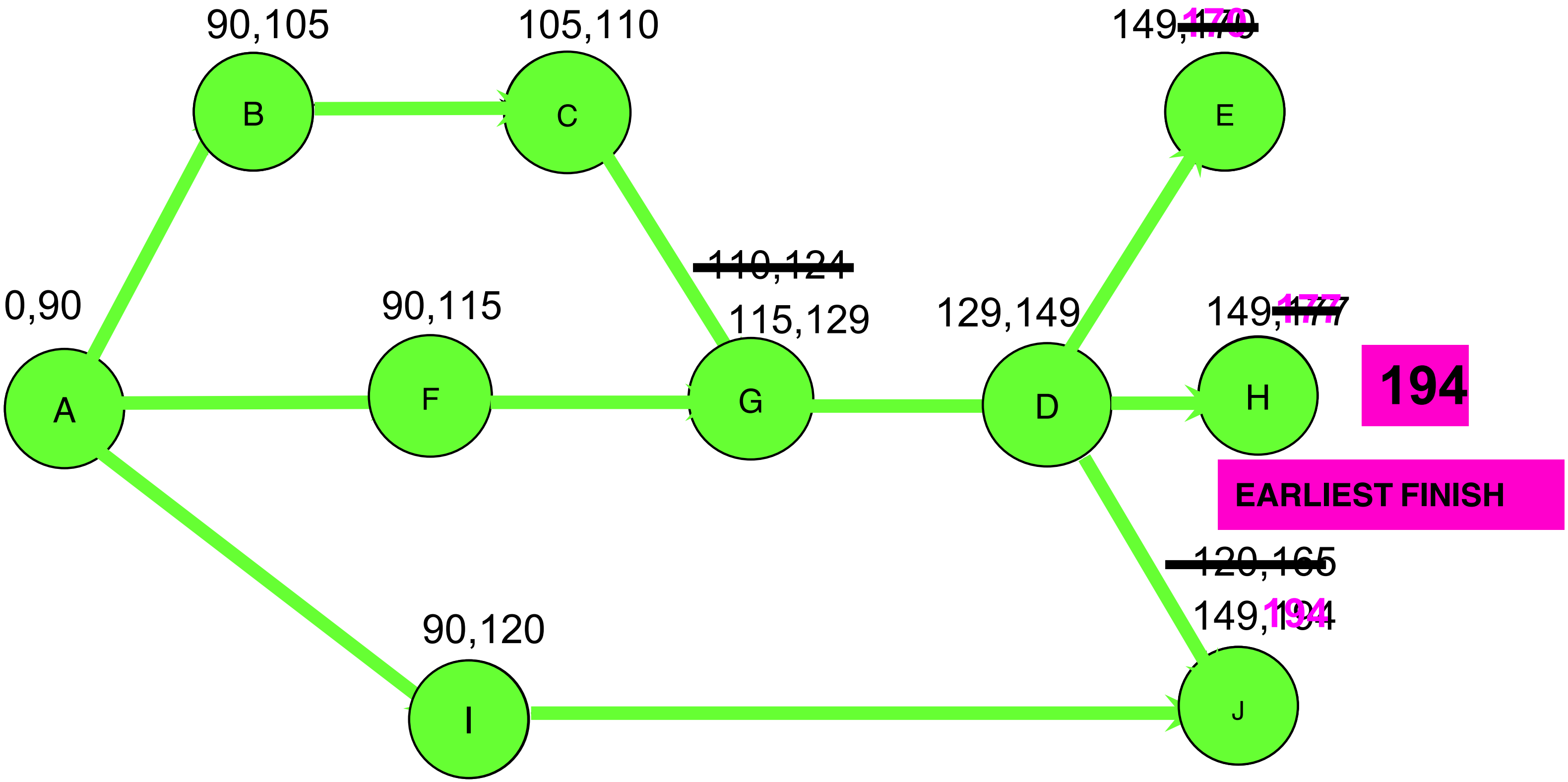
KLONE COMPUTERS, INC. - Continued

- Management at KLONE would like to schedule the activities so that the project is completed in minimal time.
- Management wishes to know:
  - The earliest and latest start times for each activity which will not alter the earliest completion time of the project.
  - The earliest finish times for each activity which will not alter this date.
  - Activities with rigid schedule and activities that have slack in their schedules.

Earliest Start Time / Earliest Finish Time

- Make a forward pass through the network as follows:
  - Evaluate all the activities which have no immediate predecessors.
    - The earliest start for such an activity is zero ES = 0.
    - The earliest finish is the activity duration EF = Activity duration.
  - Evaluate the ES of all the nodes for which EF of all the immediate predecessor has been determined.
    - ES = Max EF of all its immediate predecessors.
    - EF = ES + Activity duration.
  - Repeat this process until all nodes have been evaluated
    - EF of the finish node is the earliest finish time of the project.

Earliest Start / Earliest Finish – Forward Pass



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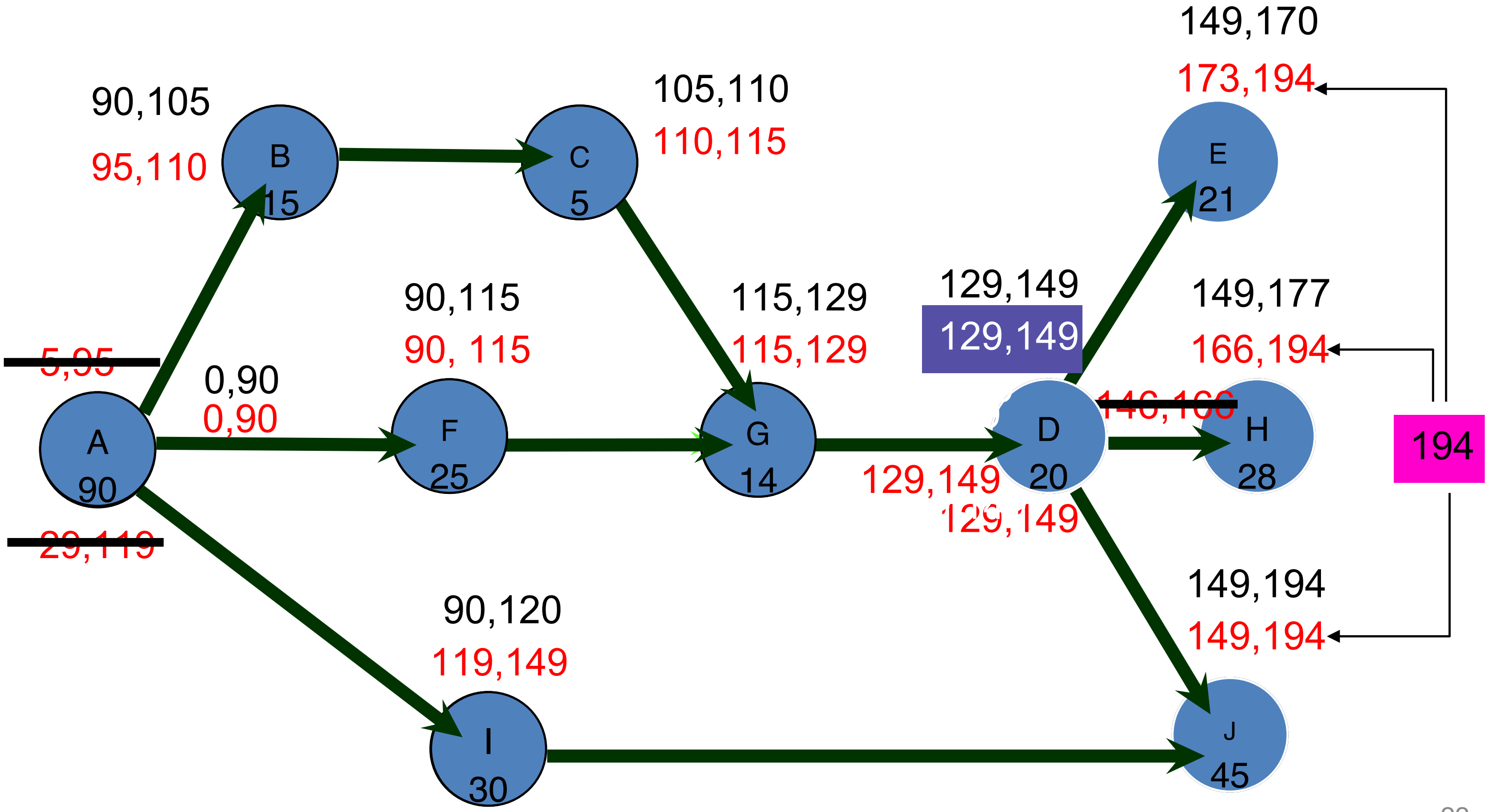
EARLIEST FINISH

Latest start time / Latest finish time

- Make a backward pass through the network as follows:
  - – Evaluate all the activities that immediately precede the finish node.
    - The latest finish for such an activity is LF = minimal project completion time.
    - The latest start for such an activity is LS = LF - activity duration.
  - – Evaluate the LF of all the nodes for which LS of all the immediate successors has been determined.
    - LF = Min LS of all its immediate successors.
    - LS = LF - Activity duration.
  - – Repeat this process backward until all nodes have been evaluated.

Latest Start / Latest Finish – Backward Pass



Slack Times

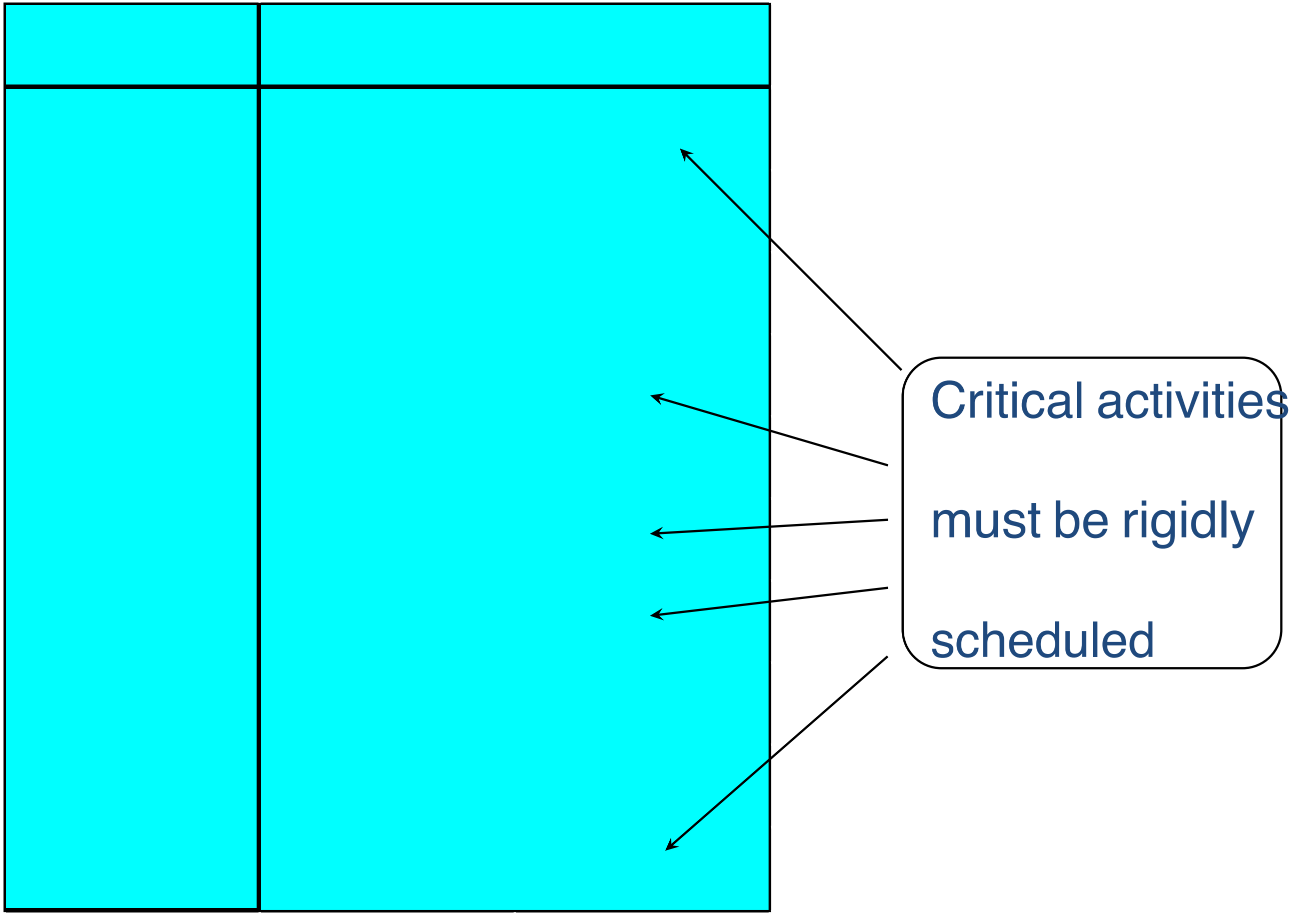
- Activity start time and completion time may be delayed by planned reasons as well as by unforeseen reasons.
- Some of these delays may affect the overall completion date.
- To learn about the effects of these delays, we calculate the **slack time**, and form the **critical path**.

Slack Times

- Slack time is the amount of time an activity can be delayed without delaying the project completion date, assuming no other delays are taking place in the project.

Slack Time = LS - ES = LF - EF

Slack time in the Klonepalm 2000 Project



Critical activities must be rigidly scheduled

The Critical Path

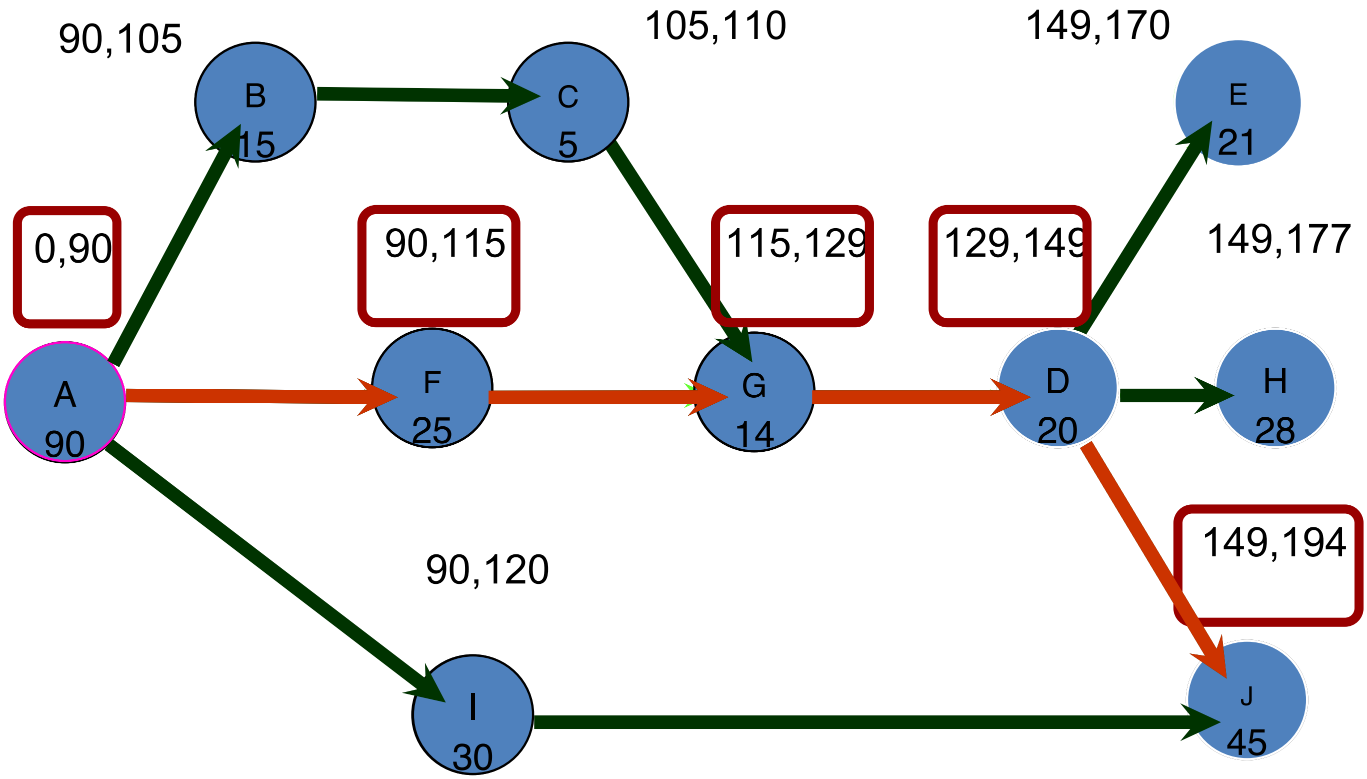
- The critical path is a set of activities that have no slack, connecting the START node with the FINISH node.

- The critical activities (activities with 0 slack) form at least one critical path in the network.

- A critical path is the longest path in the network.

- The sum of the completion times for the activities on the critical path is the minimal completion time of the project.

The Critical Path

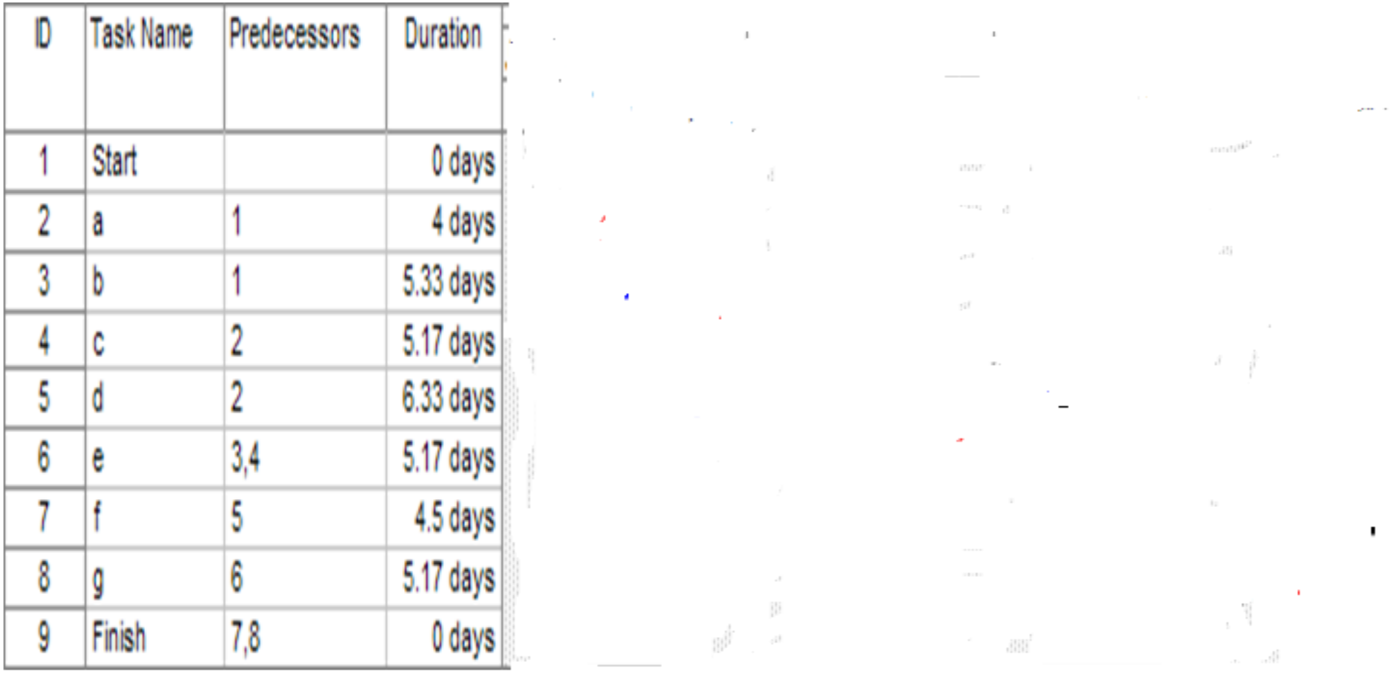


Gantt Chart

- Gantt charts illustrate the start and finish dates of the terminal elements and summary elements of a project

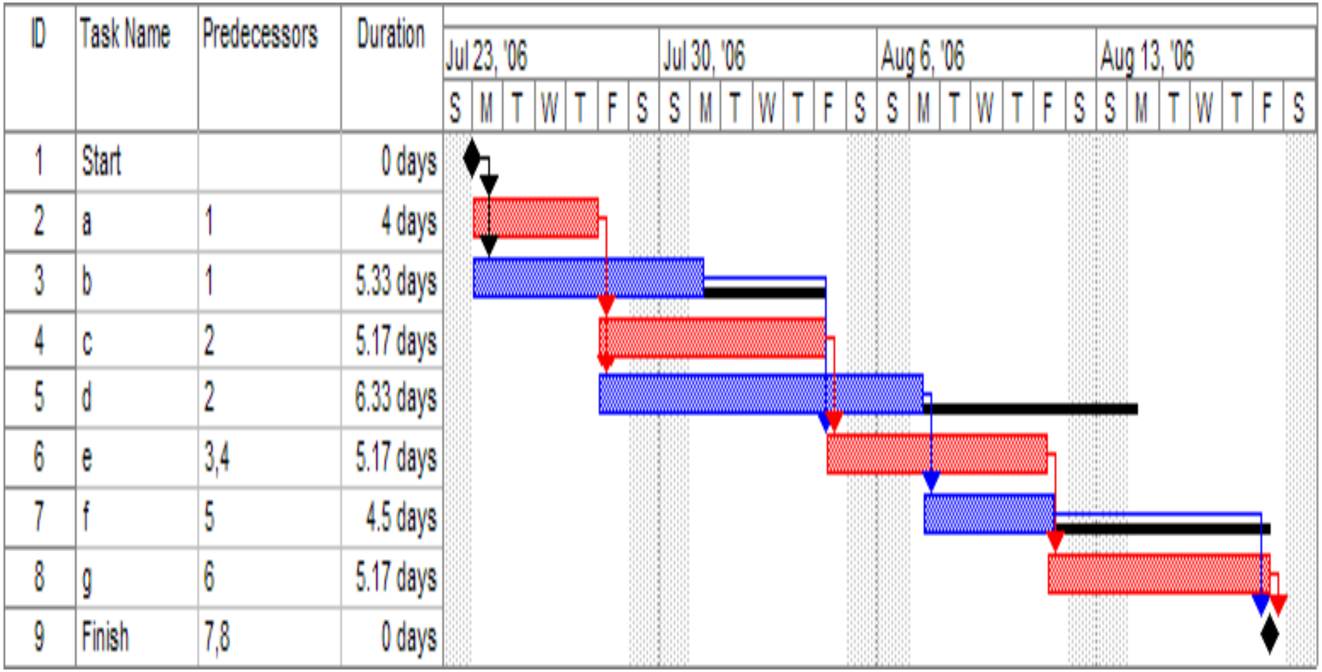
- Gantt charts also show the dependency relationships between activities.

Example - 1 on Gantt Chart



ID	Task Name	Predecessors	Duration
1	Start		0 days
2	a	1	4 days
3	b	1	5.33 days
4	c	2	5.17 days
5	d	2	6.33 days
6	e	3,4	5.17 days
7	f	5	4.5 days
8	g	6	5.17 days
9	Finish	7,8	0 days

Example - 1 on Gantt Chart with Critical Path



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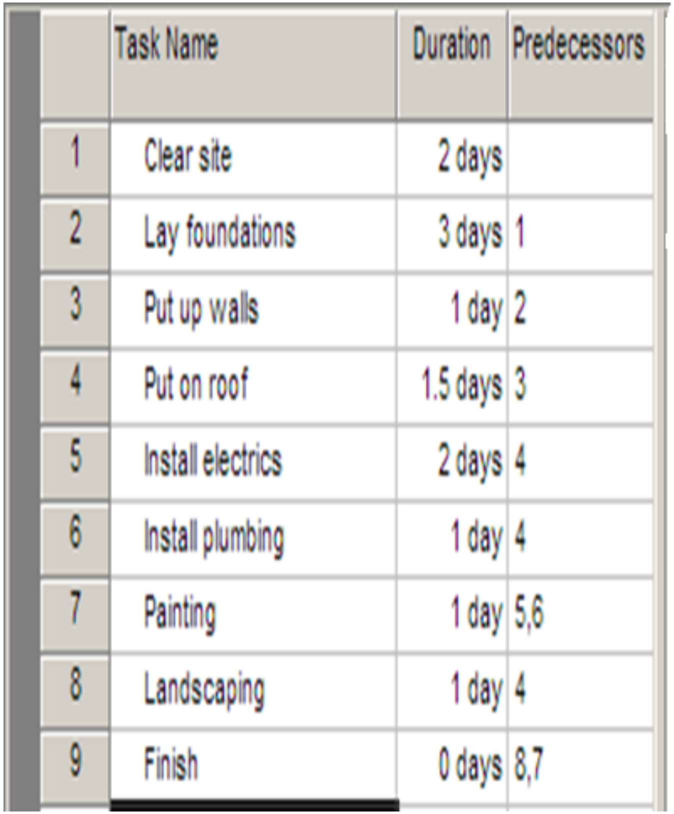
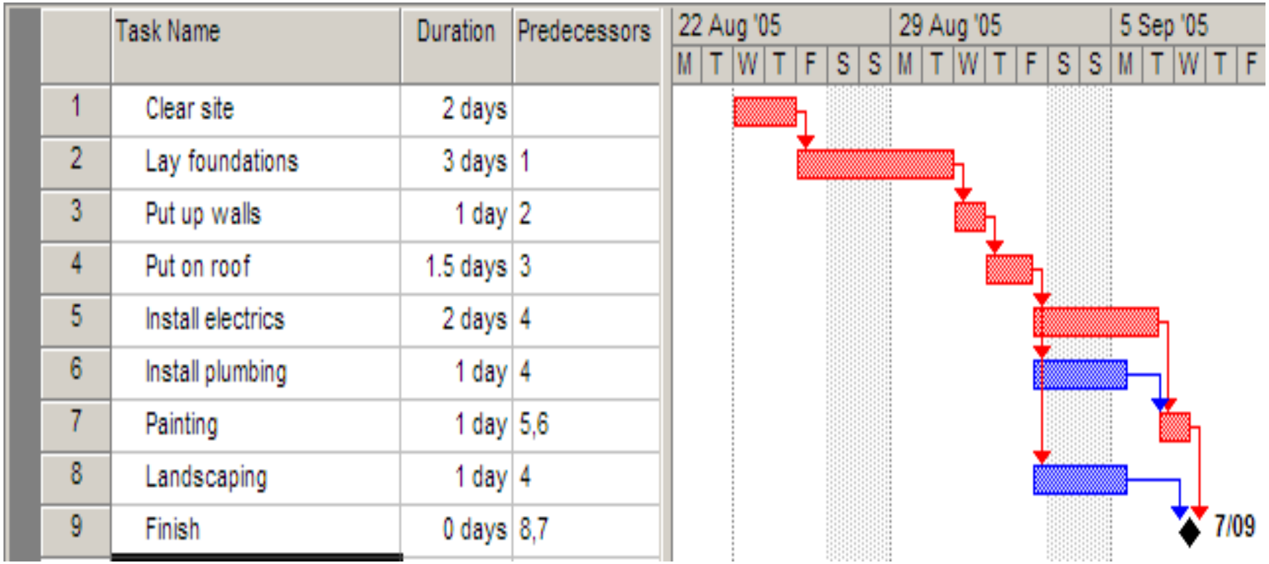


	Task Name	Duration	Predecessors
1	Clear site	2 days	
2	Lay foundations	3 days	1
3	Put up walls	1 day	2
4	Put on roof	1.5 days	3
5	Install electrics	2 days	4
6	Install plumbing	1 day	4
7	Painting	1 day	5,6
8	Landscaping	1 day	4
9	Finish	0 days	8,7

Example - 1 on Gantt Chart with Critical Path

- The length of the critical path is the sum of the lengths of all critical tasks (the red tasks 1,2,3,4,5,7) which is 2+3+1+1.5+2+1 = 10.5 days.



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6	Install plumbing	1 day	4
7	Painting	1 day	5,6
8	Landscaping	1 day	4
9	Finish	0 days	8,7

PERT Chart

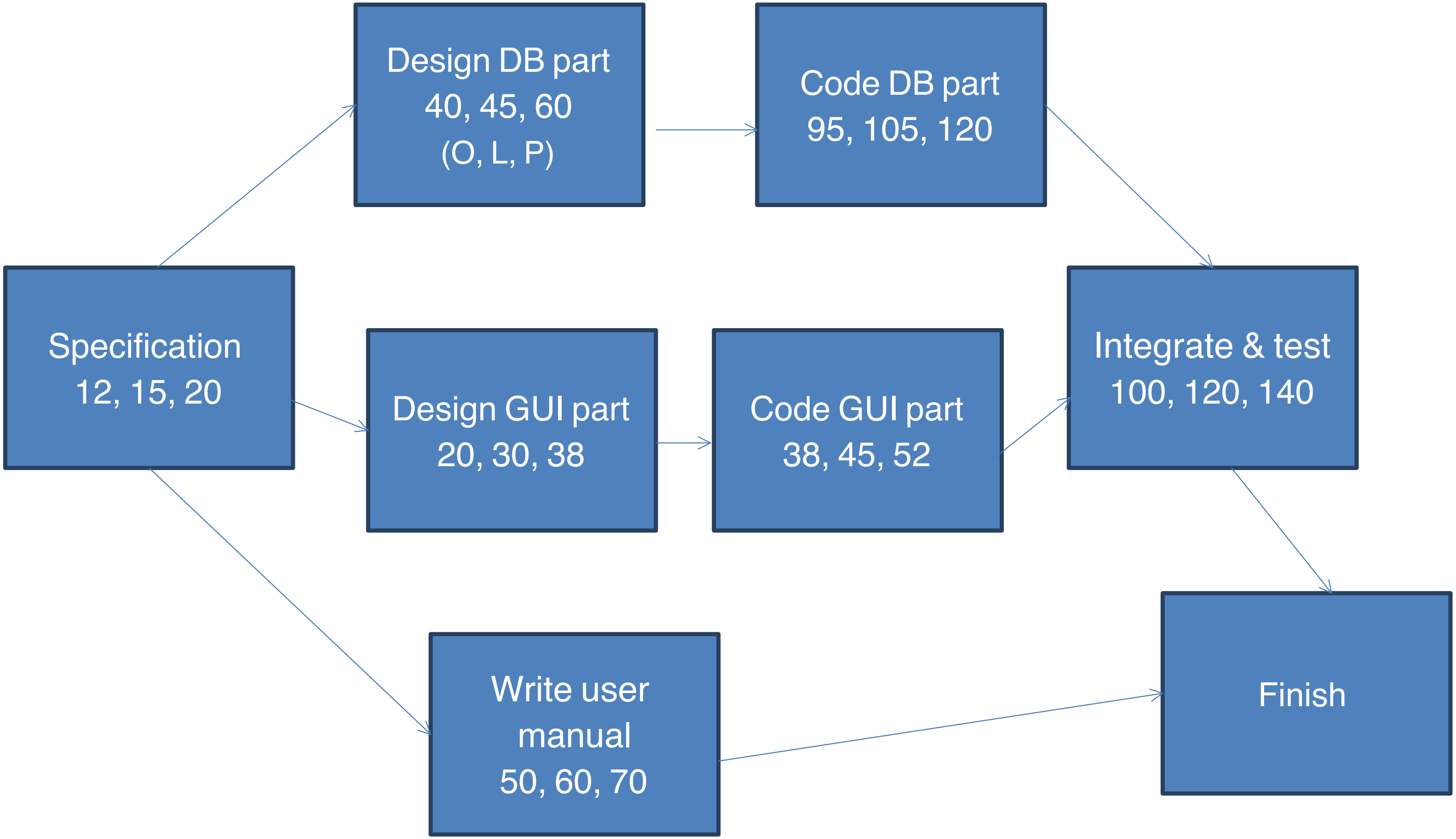
- Program Evaluation and Review Technique (PERT)

- Consists of a network of boxes (activities) and arrows (task dependencies)

- Helps to identify parallel activities

- PERT estimation
    - ⍰Optimistic
    - ⍰Likely
    - ⍰Pessimistic

Example on PERT estimation



Gantt v/s PERT

- Gantt chart is represented as a bar graph, while PERT chart is represented as a flow chart.

- Gantt charts are limited to small projects and are not effective for projects with more than 30 activities.

- Generally Gantt is useful for resource planning, while PERT is used for monitoring the timely progress of activities

- Gantt chart do not efficiently represent the dependency of one task to another, while PERT charts can manage large projects that have numerous complex tasks a very high inter-task dependency

Additional Theory and Examples

CPM

- Finding the critical path is a major part of controlling a project.
- The activities on the critical path represent tasks that will delay the entire project if they are delayed.
- Manager gain flexibility by identifying noncritical activities and replanning, rescheduling, and reallocating resources such as personnel and finances

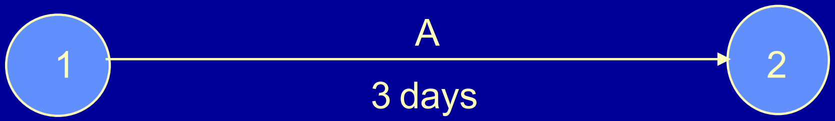
Project Network

- A project network can be constructed to model the precedence of the activities.
- The arcs of the network represent the activities.
- The nodes of the network represent the start and the end of the activities.
- A critical path for the network is a path consisting of activities with zero slack. And it is always the longest path in the project network.

Drawing the project network (AOA)

n An activity carries the arrow symbol, → . This represent a task or subproject that uses time or resources

n A node (an event), denoted by a circle , marks the start and completion of an activity, which conta● a number that helps to identify its location. For example activity A can be drawn as:



This means activity A starts at node 1 and finishes at node 2 and it will takes three days

Determining the Critical Path

- Step 1: Make a forward pass through the network as follows: For each activity *i* beginning at the Start node , compute:
  - Earliest Start Time (ES) = the maximum of the earliest finish times of all activities immediately preceding activity *i*. (This is 0 for an activity with no predecessors.). This is the earliest time an activity can begin without violation of immediate predecessor requirements.
  - Earliest Finish Time (EF) = (Earliest Start Time) + (Time to complete activity *i*. This represent the earliest time at which an activity can end.

The project completion time is the maximum of the Earliest Finish Times at the Finish node.

Determining the Critical Path

- Step 2: Make a backwards pass through the network as follows: Move sequentially backwards from the Finish node to the Start node. At a given node, *j*, consider all activities ending at node *j*. For each of these activities, (*i*,*j*), compute:
  - Latest Finish Time (LF) = the minimum of the latest start times beginning at node *j*. (For node *N*, this is the project completion time.). This is the latest time an activity can end without delaying the entire project.
  - Latest Start Time (LS) = (Latest Finish Time) - (Time to complete activity (*i*,*j*)). This is the latest time an activity can begin without delaying the entire project.

Determining the Critical Path

- Step 3: Calculate the slack time for each activity by:

  Slack = (Latest Start) - (Earliest Start), or

  = (Latest Finish) - (Earliest Finish).

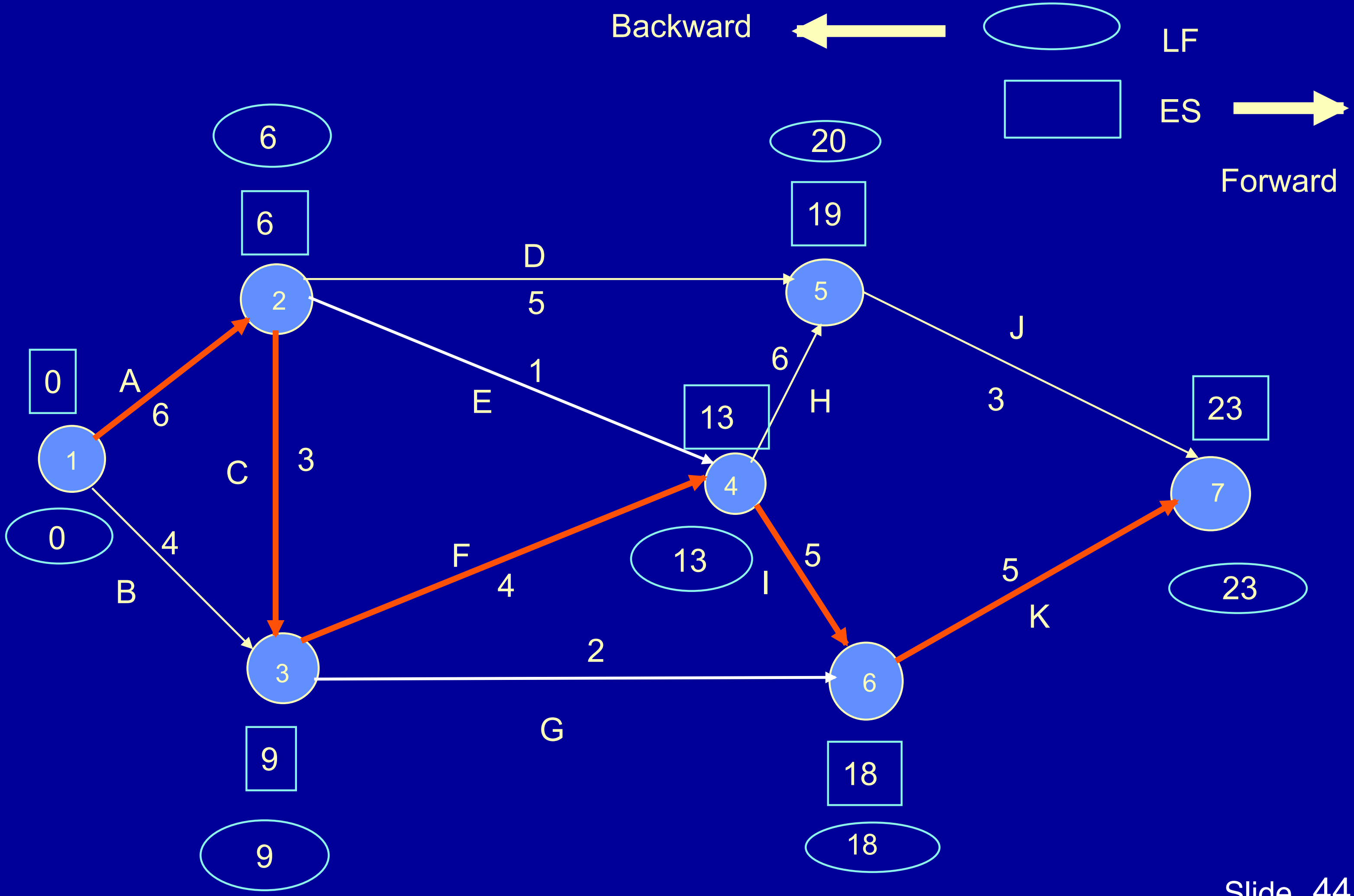
  A critical path is a path of activities, from the Start node to the Finish node, with 0 slack times.

Example: ABC Associates

- Consider the following project:

Activity	Immediate Predecessor	time (days)
A	--	6
B	--	4
C	A	3
D	A	5
E	A	1
F	B,C	4
G	B,C	2
H	E,F	6
I	E,F	5
J	D,H	3
K	G,I	5

Example: network



Example: ABC Associates

- Earliest/Latest Times

*critical

EF = ES + t

LS = LF – t

Where t is the Activity time

Slack = LF – EF
= LS - ES

Activity	time	ES	EF	LS	LF	Slack
A	6	0	6	0	6	0 *
B	4	0	4	5	9	5
C	3	6	9	6	9	0 *
D	5	6	11	15	20	9
E	1	6	7	12	13	6
F	4	9	13	9	13	0 *
G	2	9	11	16	18	7
H	6	13	19	14	20	1
I	5	13	18	13	18	0 *
J	3	19	22	20	23	1
K	5	18	23	18	23	0 *

- The estimated project completion time is the Max EF at node 7 = 23.

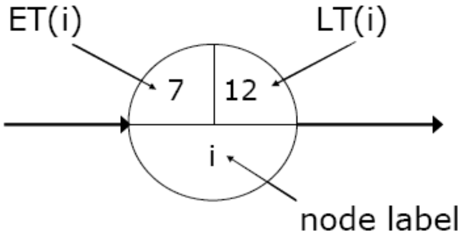
Additional Example

CPM – Critical Path Method

- It is determined by adding the times for the activities in each sequence.
- CPM determines the total calendar time required for the project.
- If activities outside the critical path speed up or slow down (within limits), the total project time does not change.
- The amount of time that a non-critical activity can be delayed without delaying the project is called slack-time.

CPM – Critical Path Method

- ET – Earliest node time for given activity duration and precedence relationships
- LT – Latest node time assuming no delays



- ES – Activity earliest start time
- LS – Activity latest start time
- EF – Activity earliest finishing time
- LF – Activity latest finishing time
- Slack Time – Maximum activity delay time

CPM – Critical Path Method

Step 1. Calculate ET for each node.

For each node i for which predecessors j are labelled with ET(j), ET(i) is given
by:

$$ET(i) = maxj\,[ET(j) + t(j,i)]$$

where t(j,i) is the duration of task between nodes (j,i).

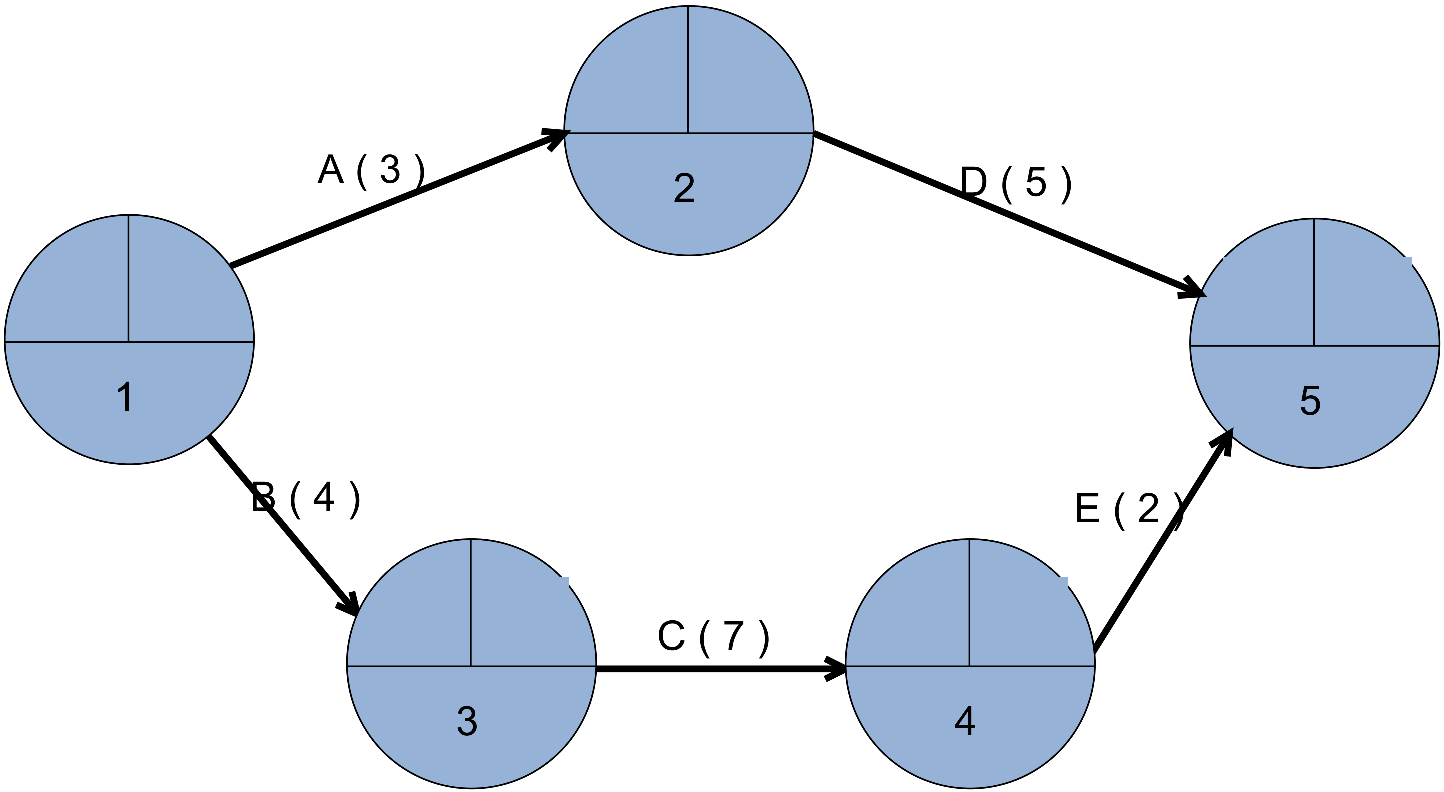
Step 2. Calculate LT for each node.

For each node i for which successors j are labelled with LT(j), LT(i) is given
by:

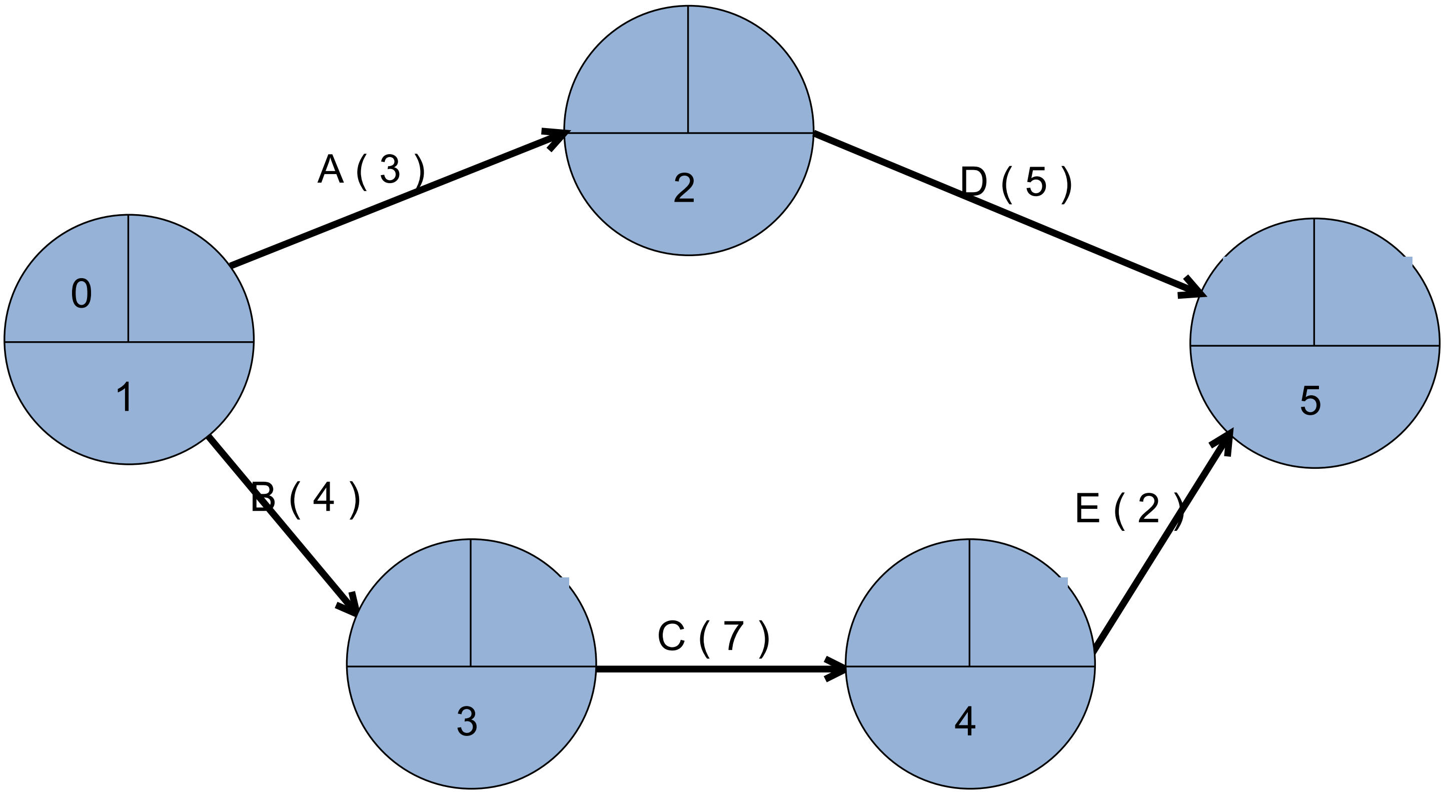
$$\mathrm{LT(i) = minj\,[LT(j) - t(i,j)]}$$

where t(j,i) is the duration of task between nodes (i,j).

CPM – Critical Path Method



CPM – Critical Path Method



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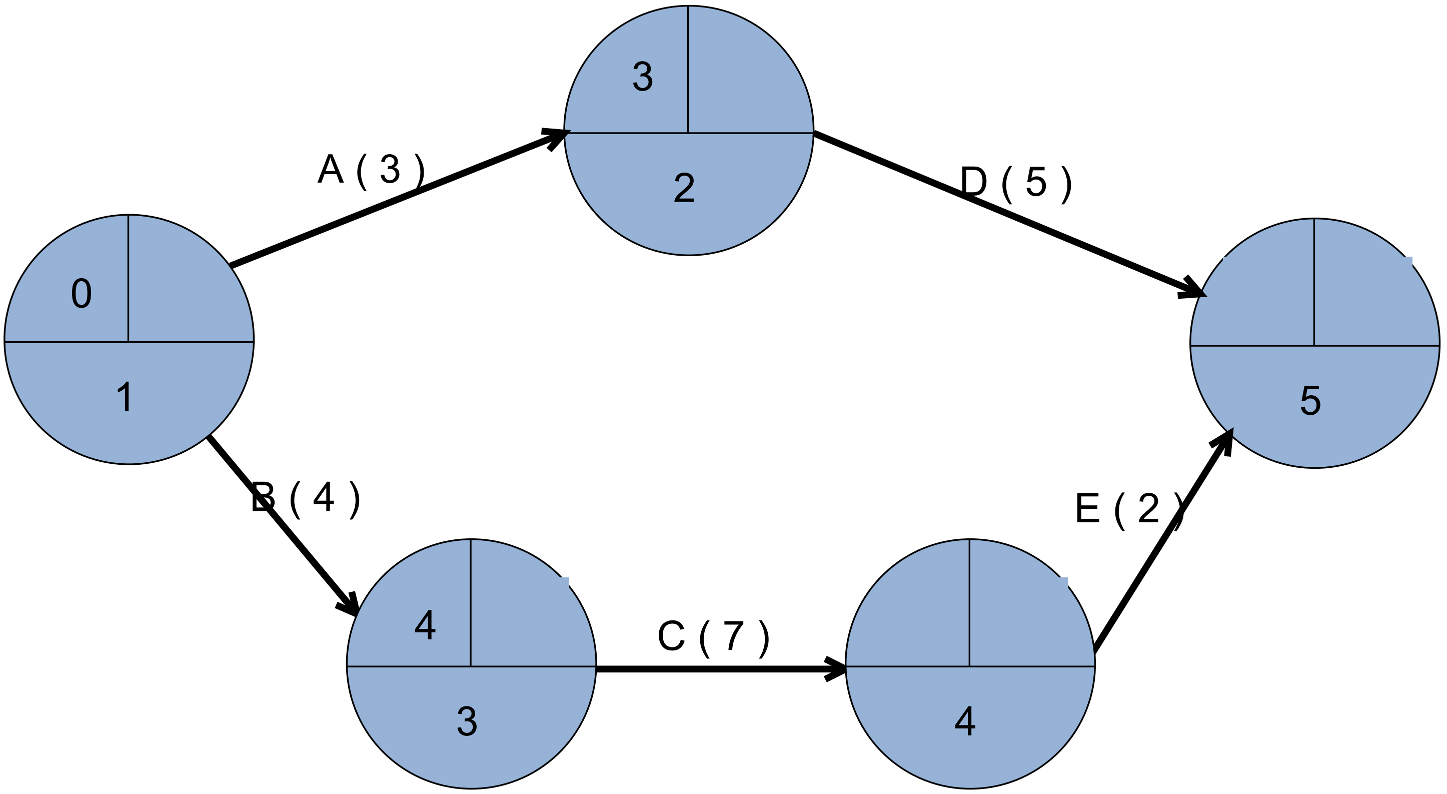

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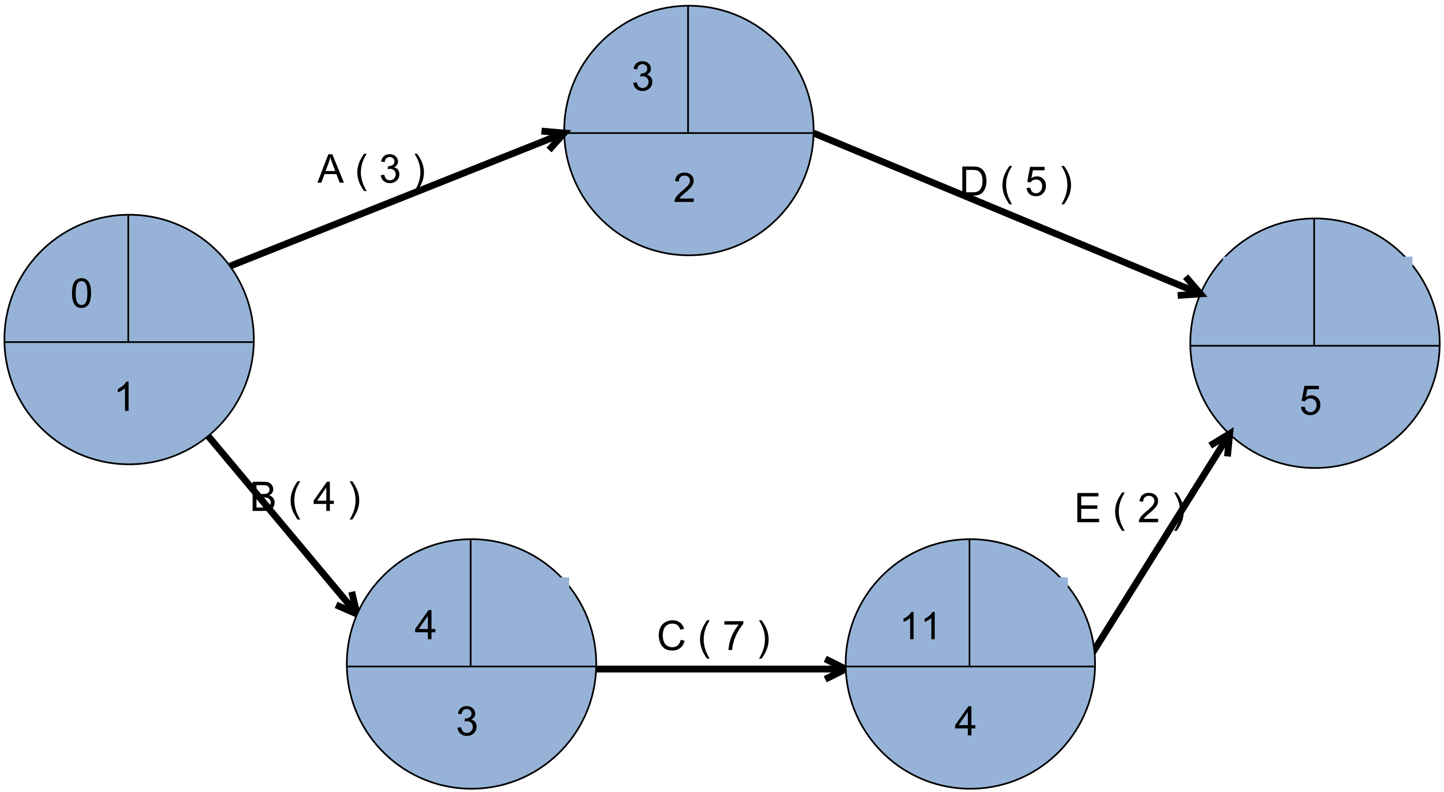

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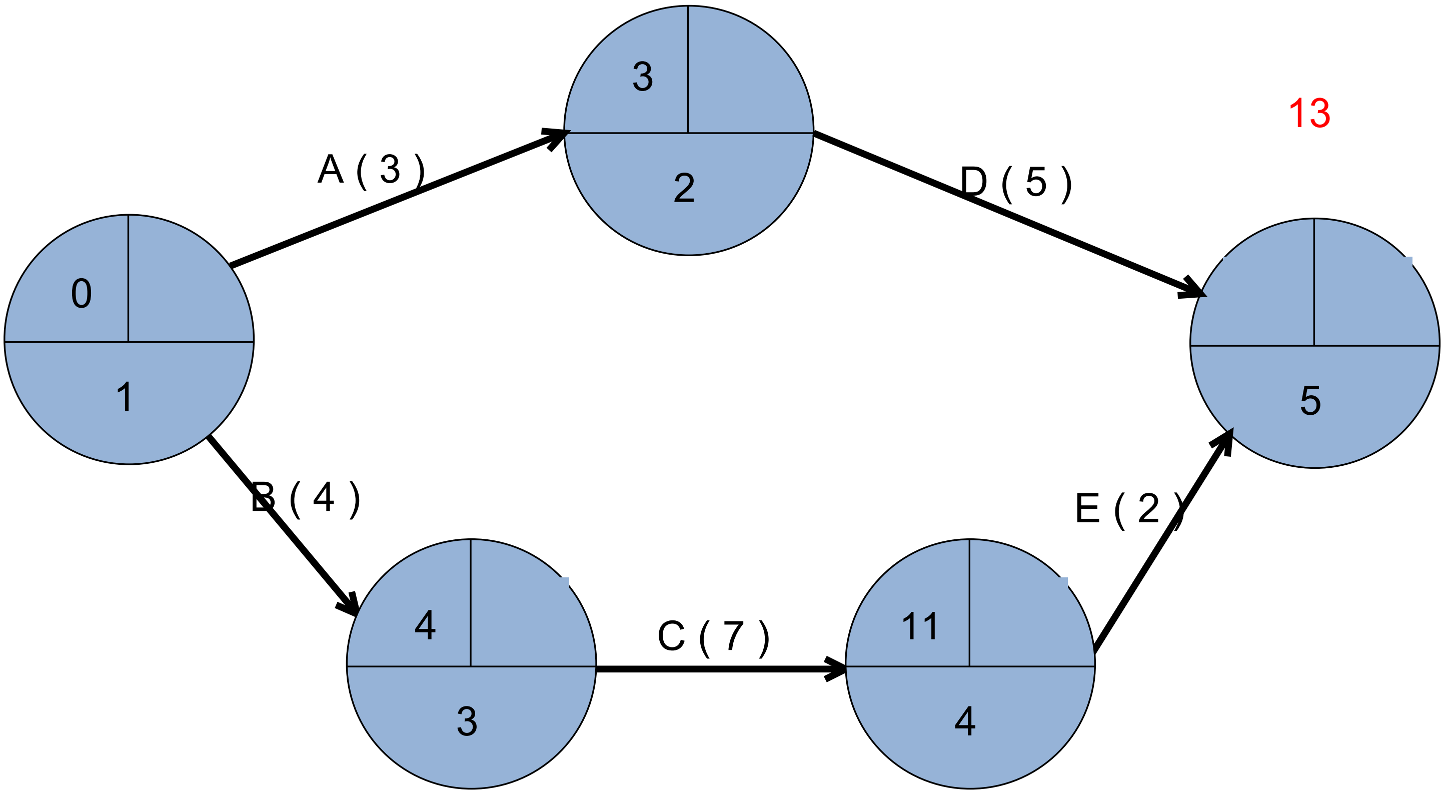

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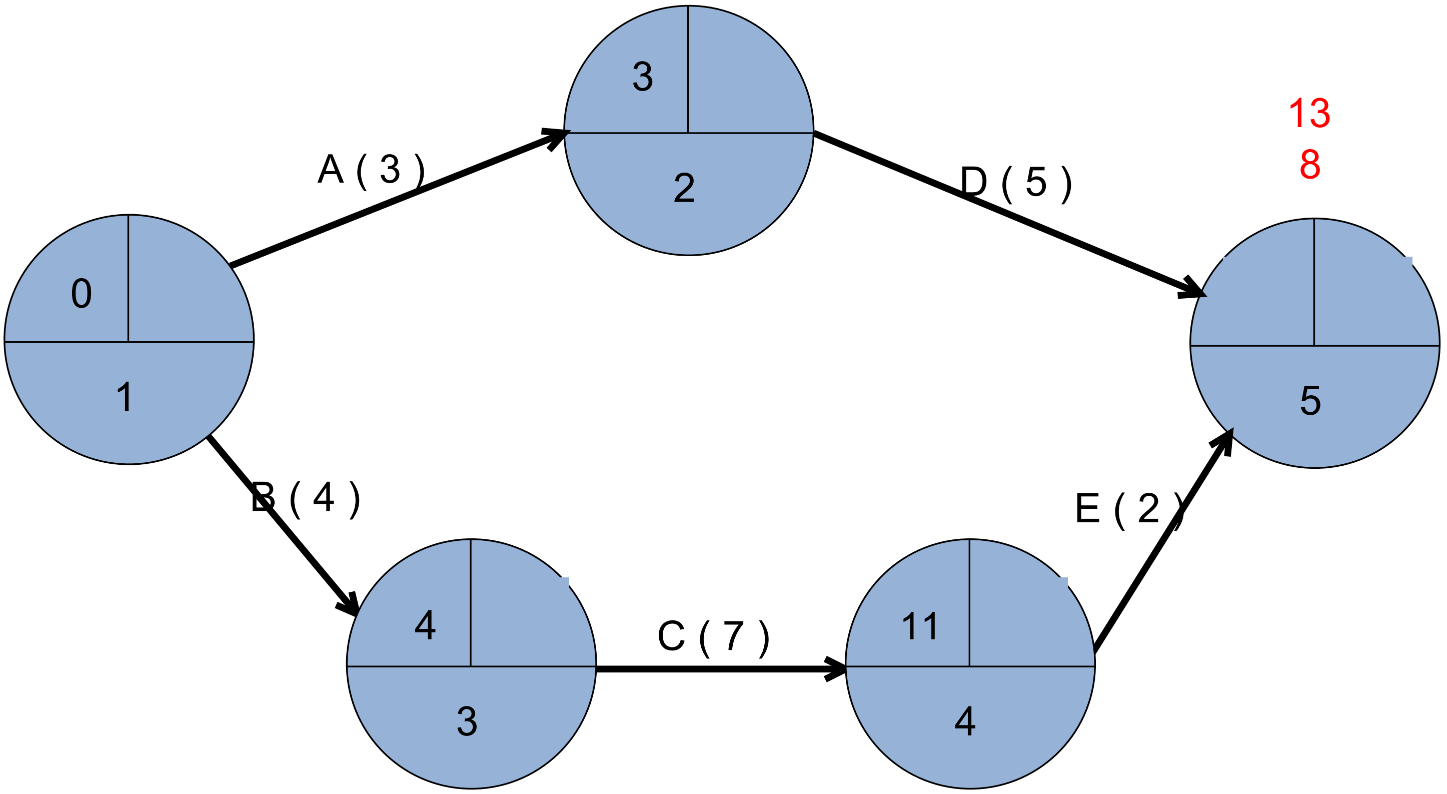

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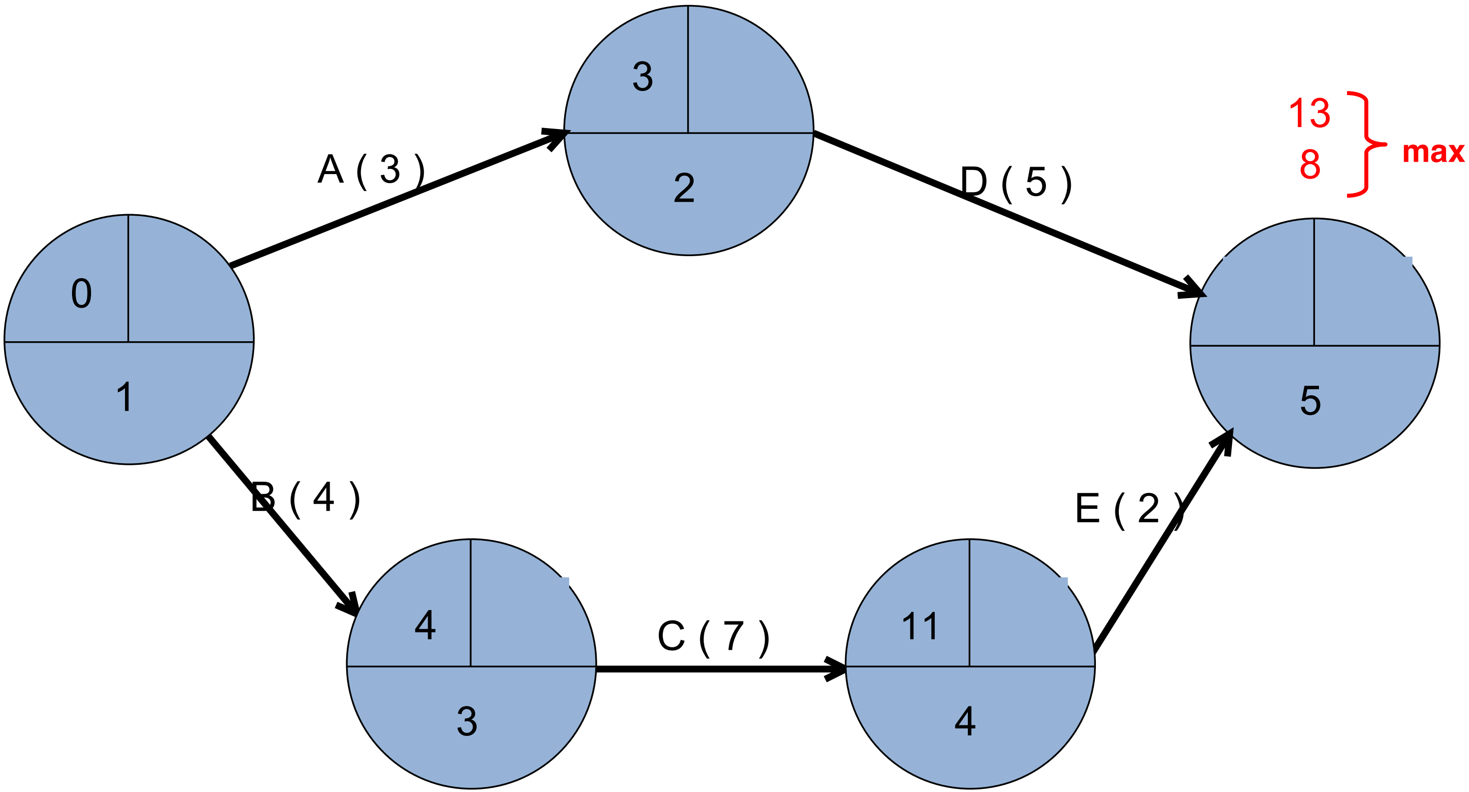

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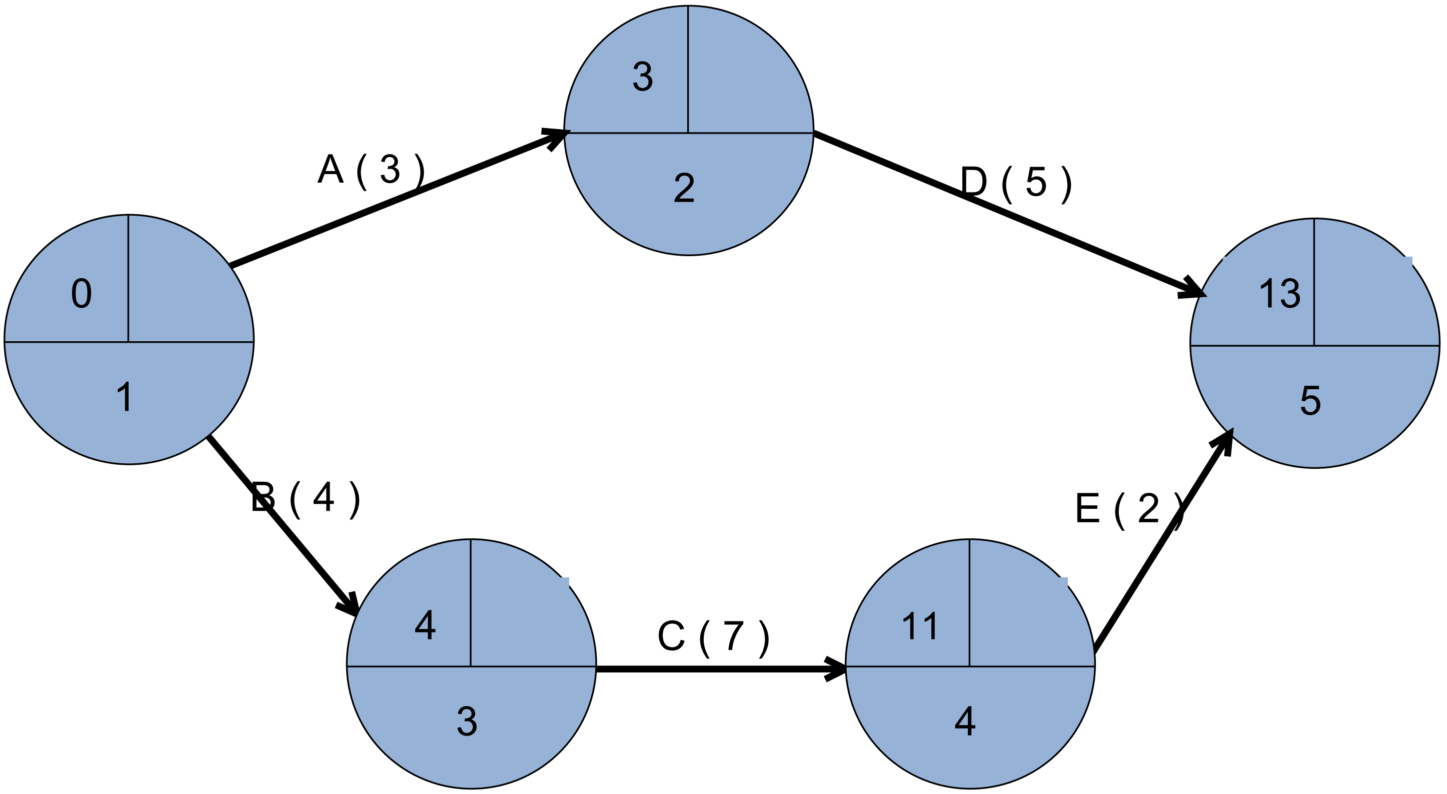

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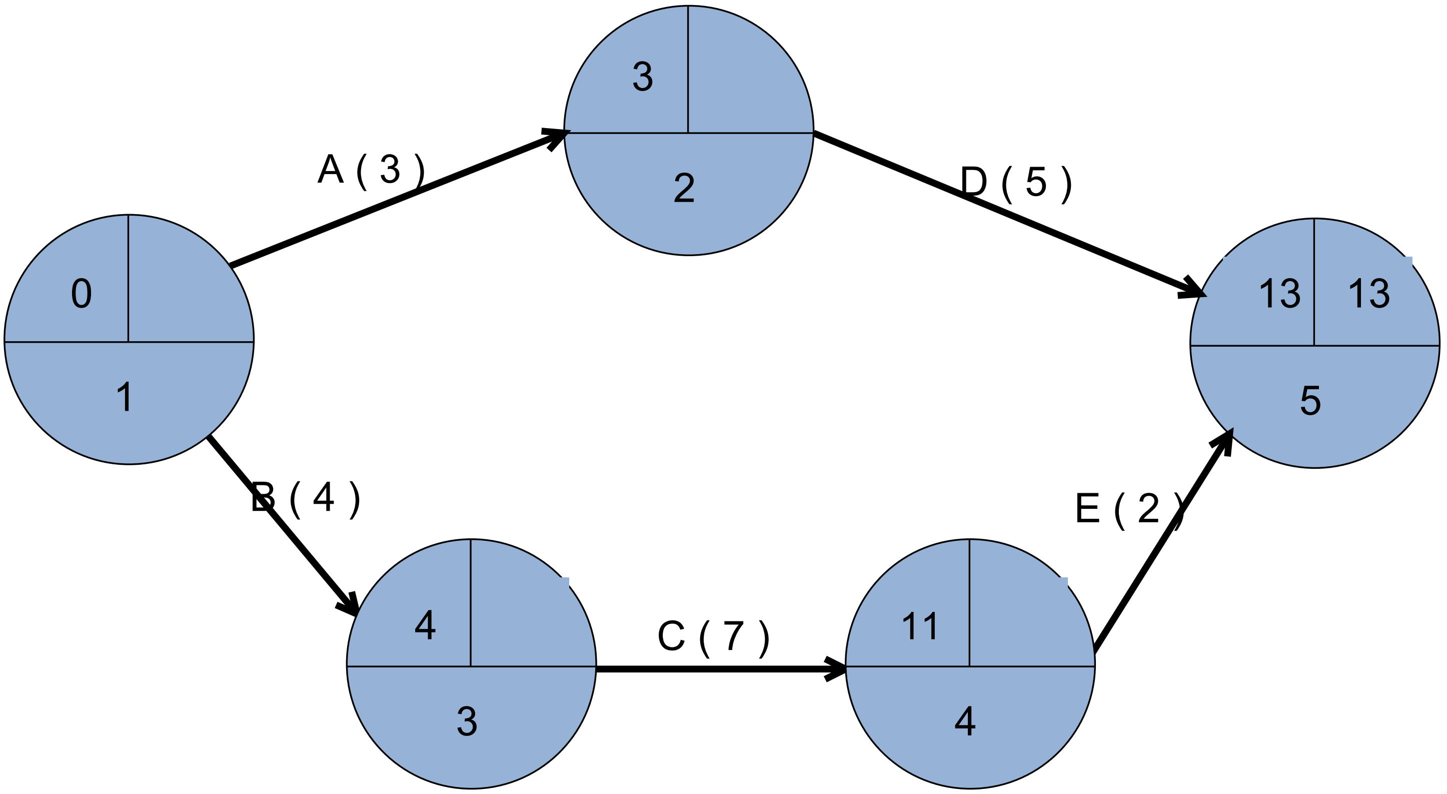

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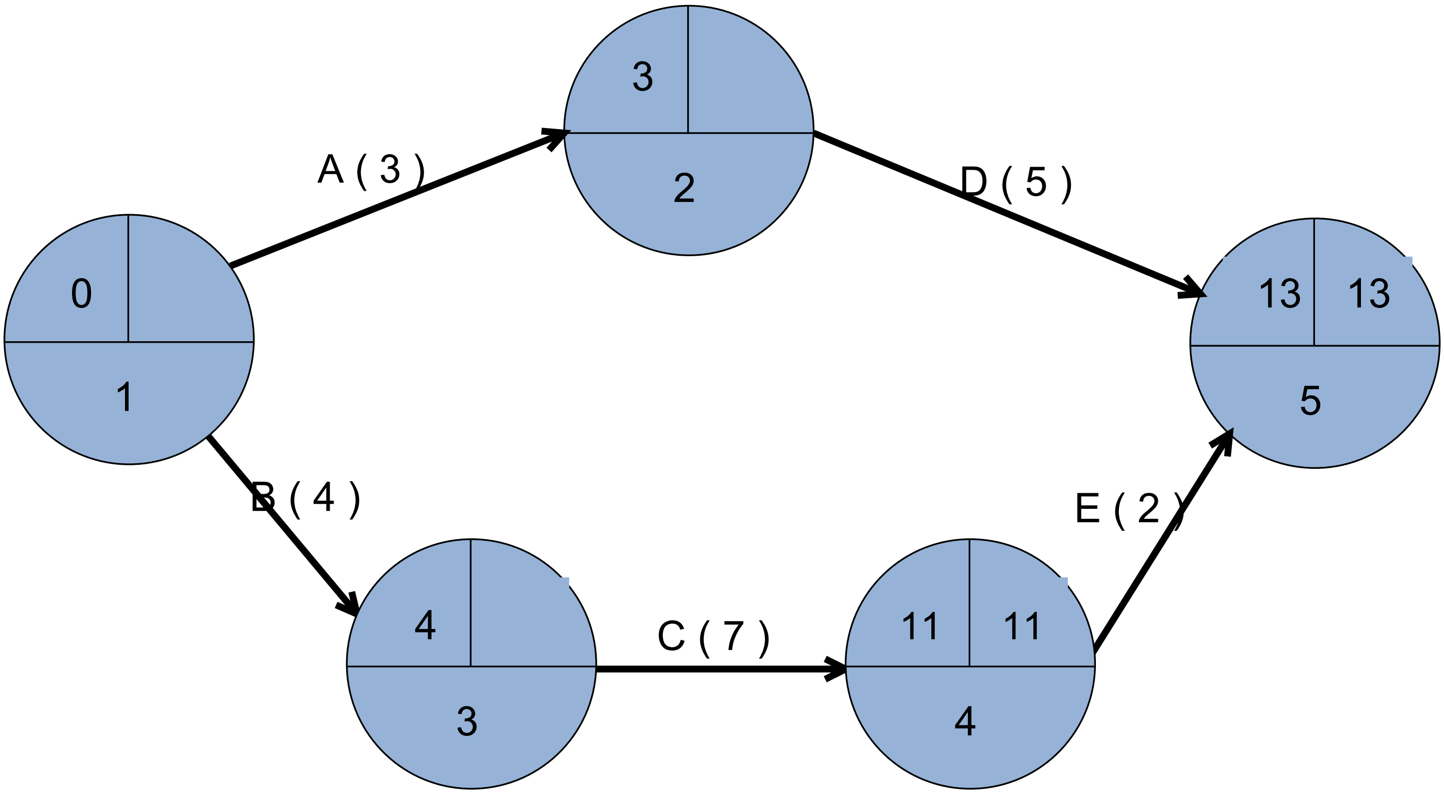

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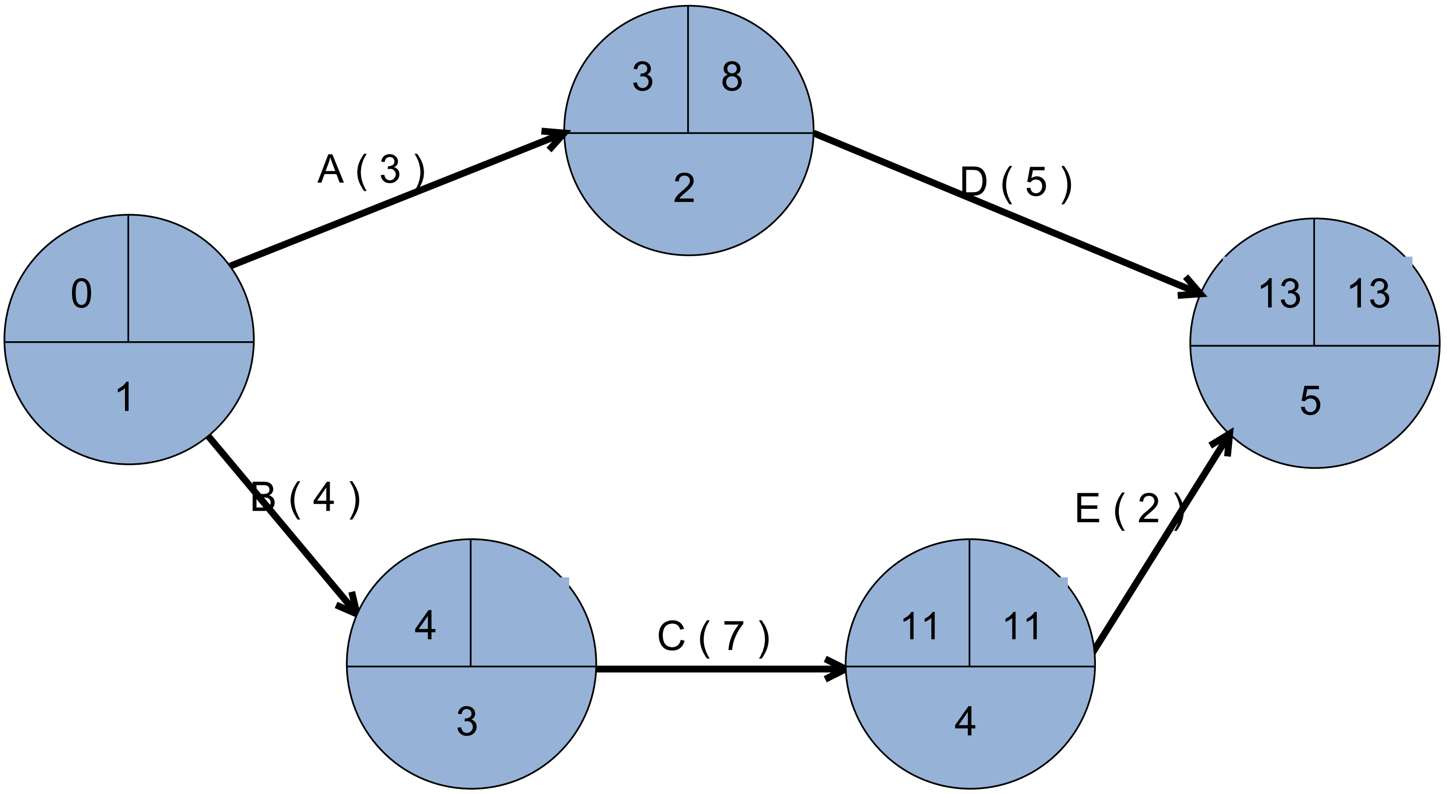

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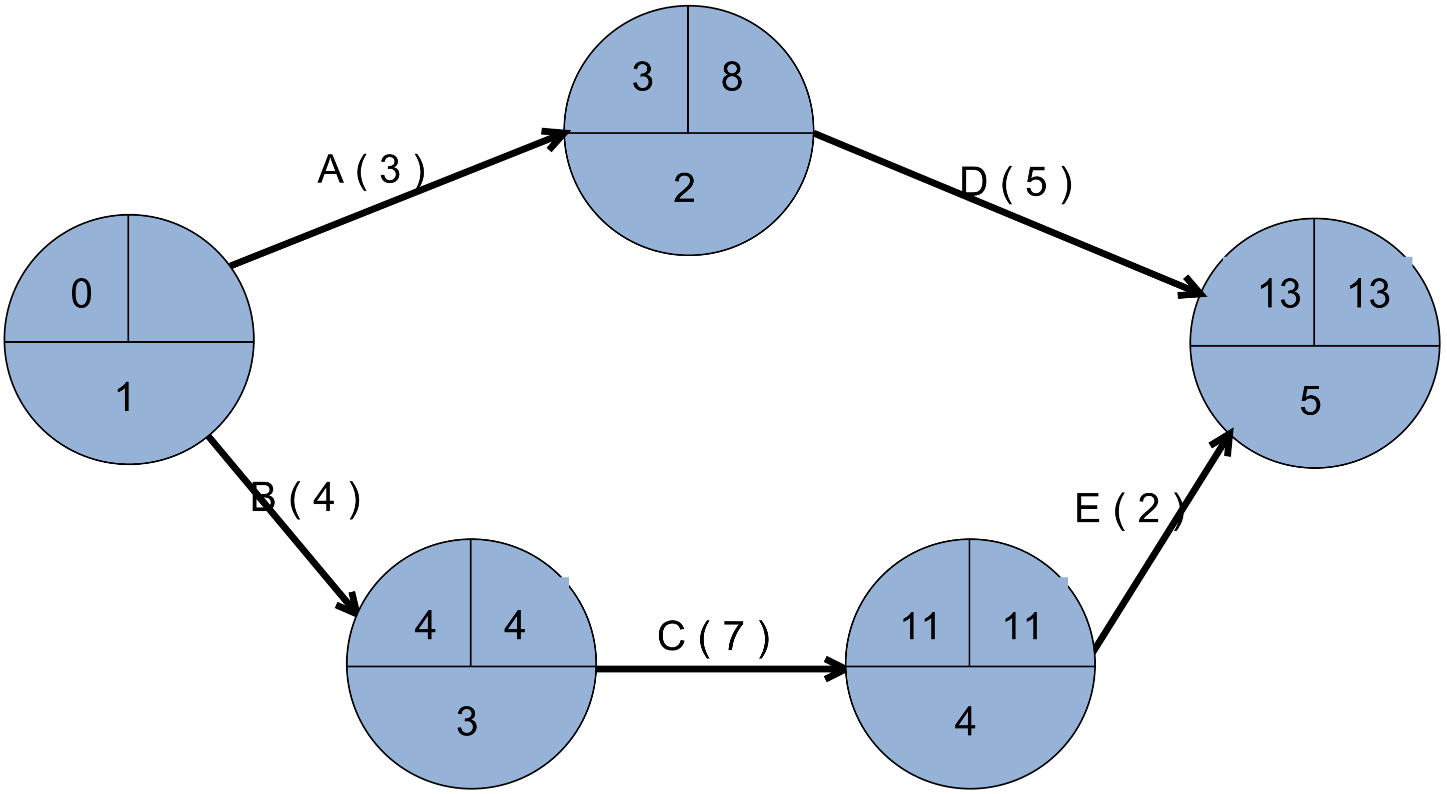

CPM – Critical Path Method

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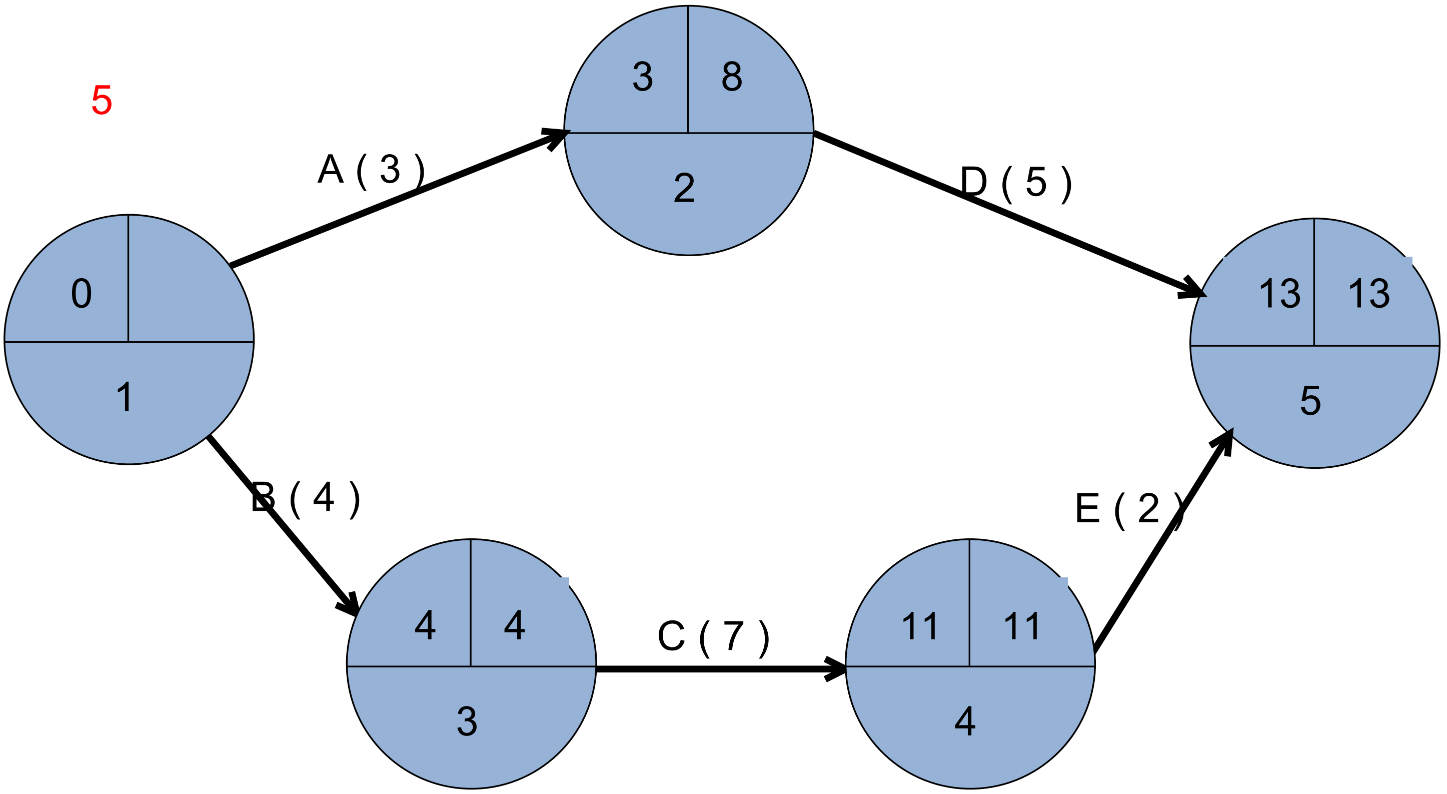
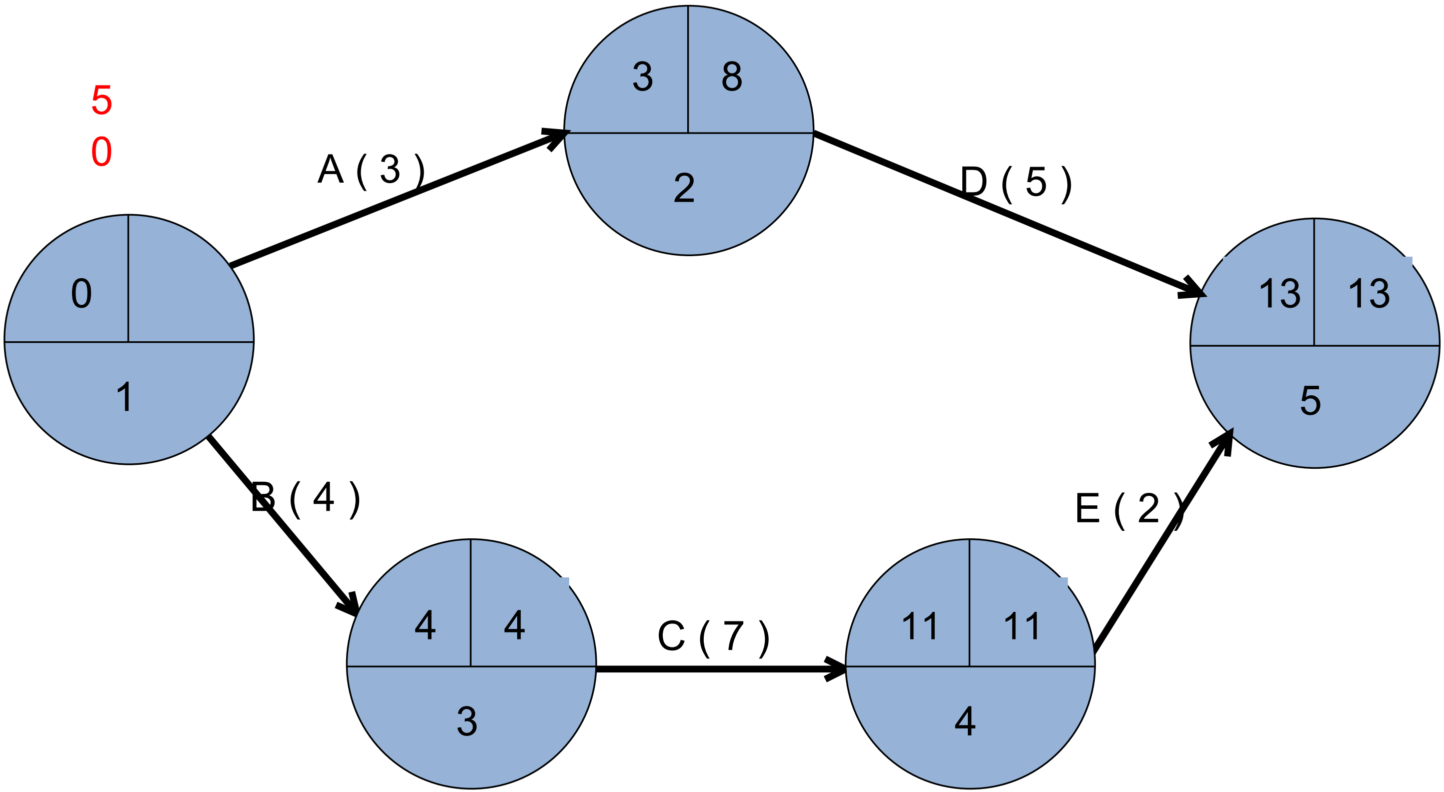


CPM – Critical Path Method



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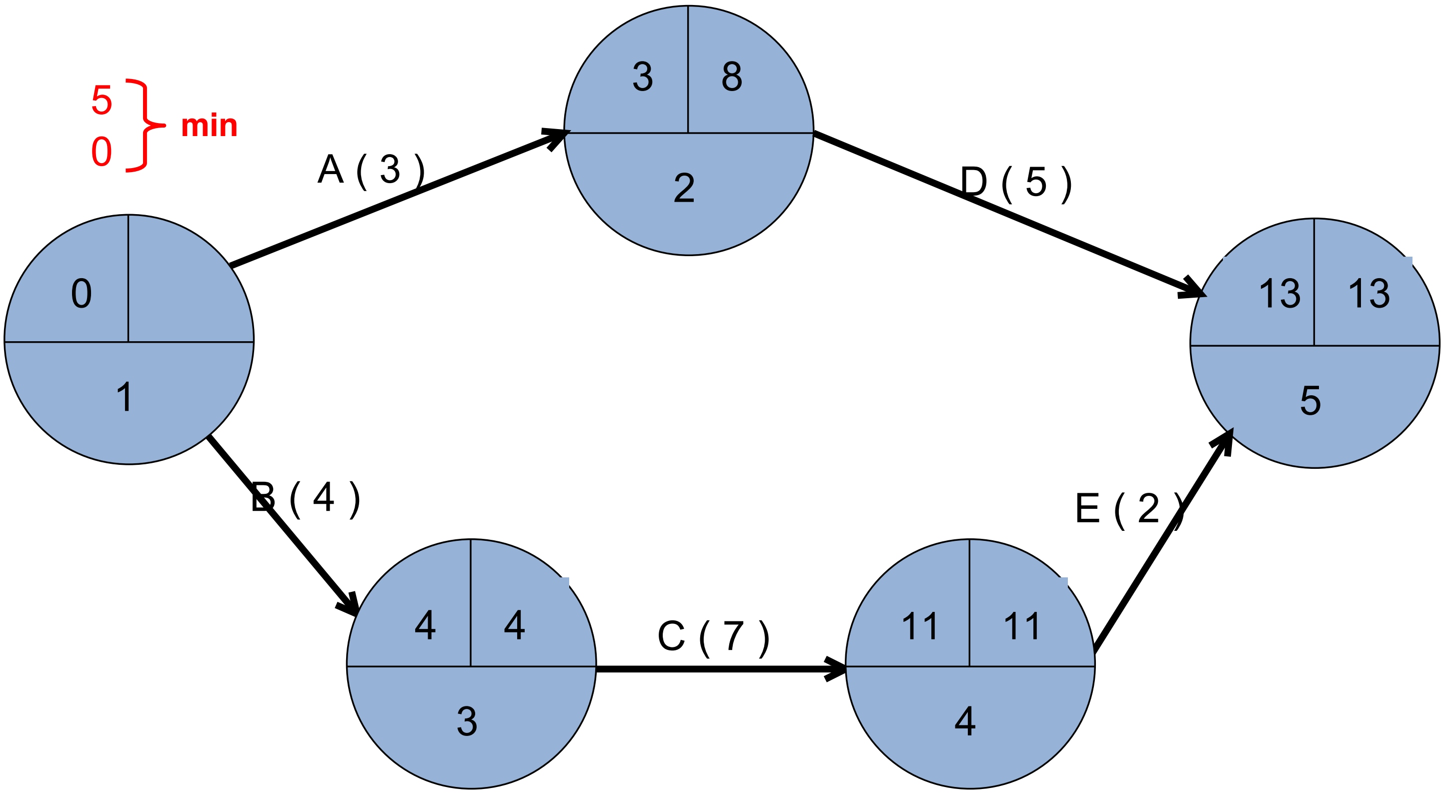

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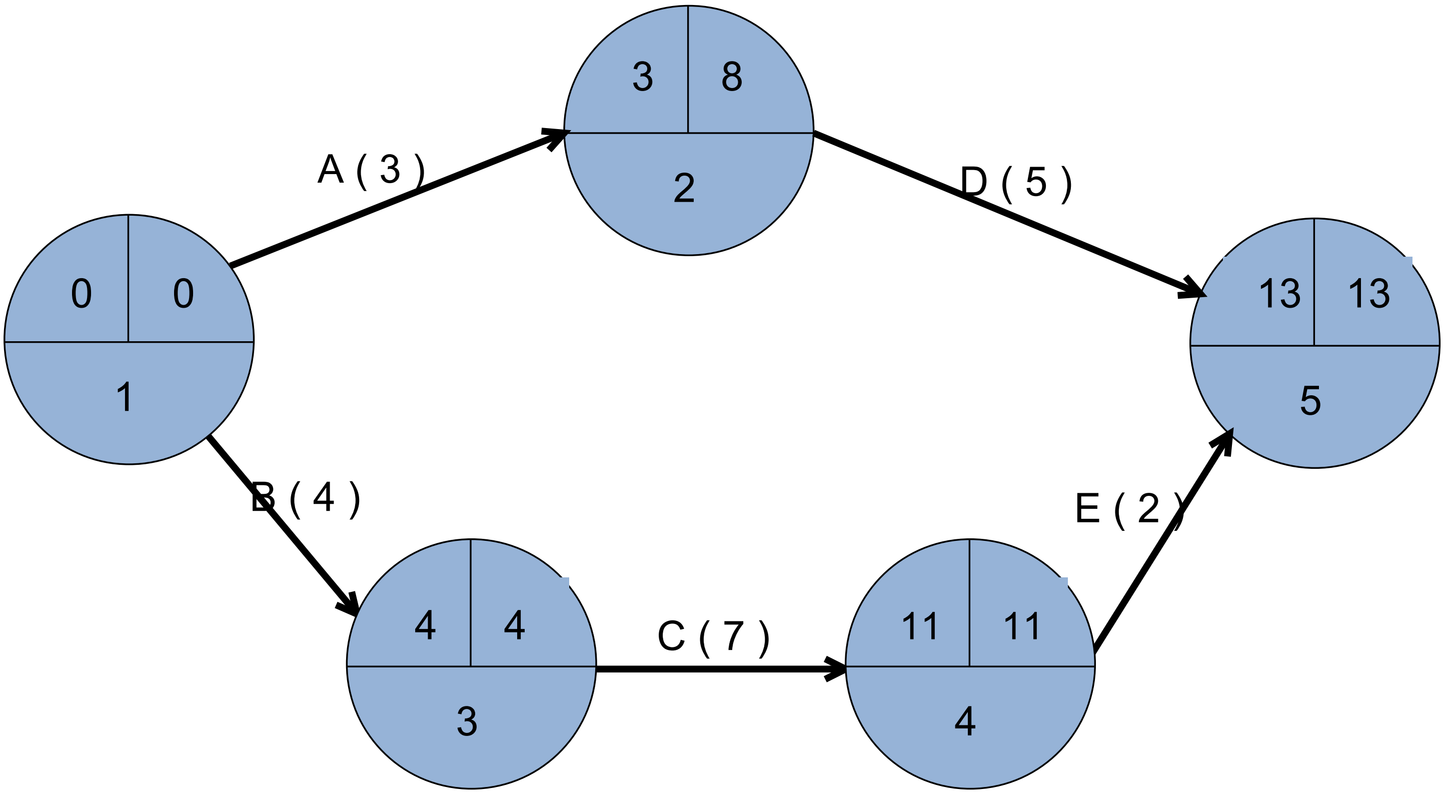
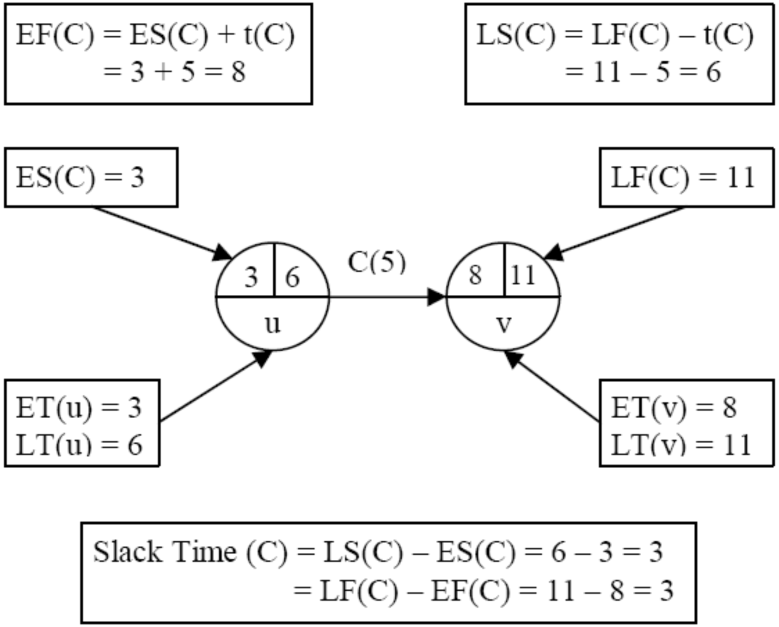


CPM – Critical Path Method

- An activity with zero slack time is a critical activity and *cannot be delayed* without causing a delay in the whole project.



$EF(C) = ES(C) + t(C)$
$= 3 + 5 = 8$

$LS(C) = LF(C) – t(C)$
$= 11 – 5 = 6$

$ES(C) = 3$

$LF(C) = 11$

$ET(u) = 3$
$LT(u) = 6$

$ET(v) = 8$
$LT(v) = 11$

$\text{Slack Time } (C) = LS(C) – ES(C) = 6 – 3 = 3$
$= LF(C) – EF(C) = 11 – 8 = 3$

CPM – Critical Path Method

Step 3. Calculate processing times for each activity.

For each activity X with start node i and end node j:

$$ES(X) = ET(i)$$

$$EF(X) = ES(X) + t(X)$$

$$LF(X) = LT(j)$$

$$LS(X) = LF(X) - t(X)$$

$$\text{Slack Time }(X) = LS(X) - ES(X) = LF(X) - EF(X)$$

Where t(X) is the duration of activity X.

An activity with zero slack time is a critical activity and cannot be delayed without causing a delay in the whole project.

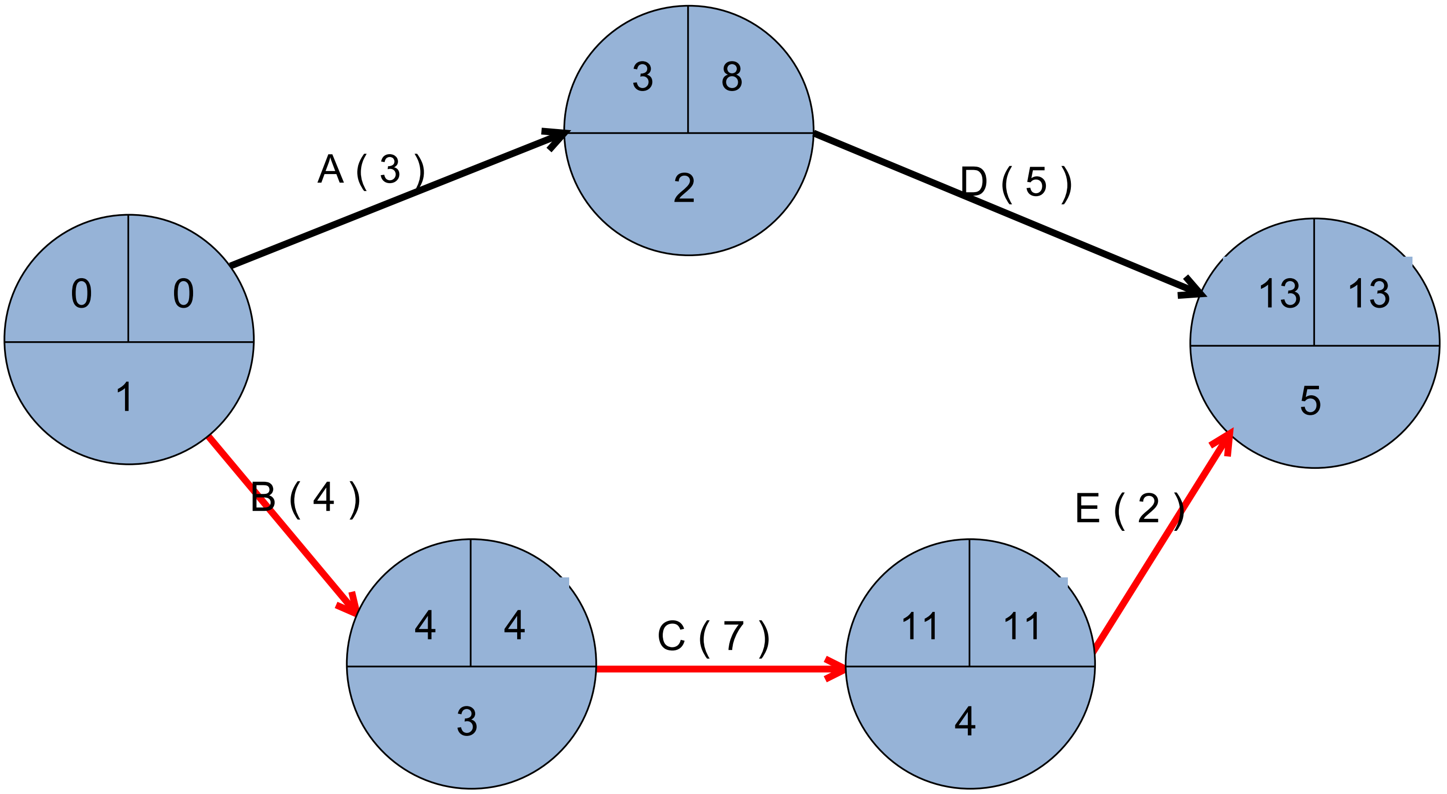
CPM – Critical Path Method

Step 3. Calculate processing times for each activity.

Task	Duration	ES	EF	LS	LF	Slack	Critical Task
A	3	0	3	5	8	5	No
B	4	0	4	0	4	0	Yes
C	7	4	11	4	11	0	Yes
D	5	3	8	8	13	5	No

Reading: (Kendall&Kendall, chapter 3), (Dennis &Wixom, chapter 3)

CPM – Critical Path Method


3
8
2
A (3)
D (5)
0
0
1
13
13
5
B (4)
E (2)
4
4
3
C (7)
11
11
4