Research Methods and Project Management

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Introduction to Network Analysis and Critical Path

Network analysis

- There is no clear terminology in the literature and you will see this area referred to by the phrases: network analysis, PERT, CPM, PERT/CPM, critical path analysis and project planning.
- Network analysis is a vital technique in Project Management.
- It enables us to take a *systematic quantitative structured approach* to the problem of managing a project through to successful completion.
- Moreover, it has a graphical representation which means it can be understood and used by those with a less technical background.

Various Project Management Tools/Techniques

- Gantt Chart
  - Tool that can be used to plan and track project activities.
- Critical Path Method (CPM)
  - A method used for determining the sequence of task activities that directly affect the completion of a project.
- Program Evaluation and Review Technique (PERT)
  - A technique that uses optimistic, pessimistic, and realistic time to calculate the expected time for a particular task.
- Microsoft Project
  - Most widely used project management software
  - http://office.microsoft.com/en-us/project/default.aspx

Example

- We will illustrate the concepts involved (network analysis) with reference to the following example:
  - Suppose that we are going to carry out a minor redesign of a product and its associated packaging.
  - We intend to test market this redesigned product and then revise it in the light of the test market results, finally presenting the results to the Board of the company.

Example

- After much *thought* we have identified the following list of separate activities together with their associated completion times (assumed known with certainty).
- **The key question is:**

  How long will it take to complete this project?

Activity number		Completion time (in weeks)
1	Redesign product	6
2	Redesign package	2
3	Order and receive components for redesigned product	3
4	Order and receive components for redesigned packaging	2
5	Assemble product	4
6	Make up packaging	1
7	Package redesigned product	1
8	Test market with redesigned product	6
9	Revise redesigned product	3
10	Revise redesigned packaging	1
11	Present results to the Board	1

Work Breakdown Structure (WBS) - Our Example

- Again after much thought (and aided by the fact that we listed the activities in a logical/chronological order) we come up with the following list of immediate precedence relationships.
- The key to constructing this table is, for each activity in turn, to ask the question:

"*What activities must be finished before this activity can start*"

Activity number		Activity number
1	must be finished before	3 can start
2		4
3		5
4		6
5,6		7
7		8
8		9
8		10
9,10		11

Notes on our example

- Activities 1 and 2 do not appear in the right hand column of the above table, this is because there are no activities which must finish before they can start, i.e. both activities 1 and 2 can start immediately.
- Two activities (5 and 6) must be finished before activity 7 can start .
- It is plain from this table that non-immediate precedence relationships (e.g. "activity 1 must be finished before activity 9 can start") need not be included in the list since they can be deduced from the relationships already in the list.
- Once we have completed our list of activities and our list of precedence relationships we combine them into a diagram/picture (called a *network* - which is where the name network analysis comes from).
- We asked the key question above:

How long will it take to complete this project?

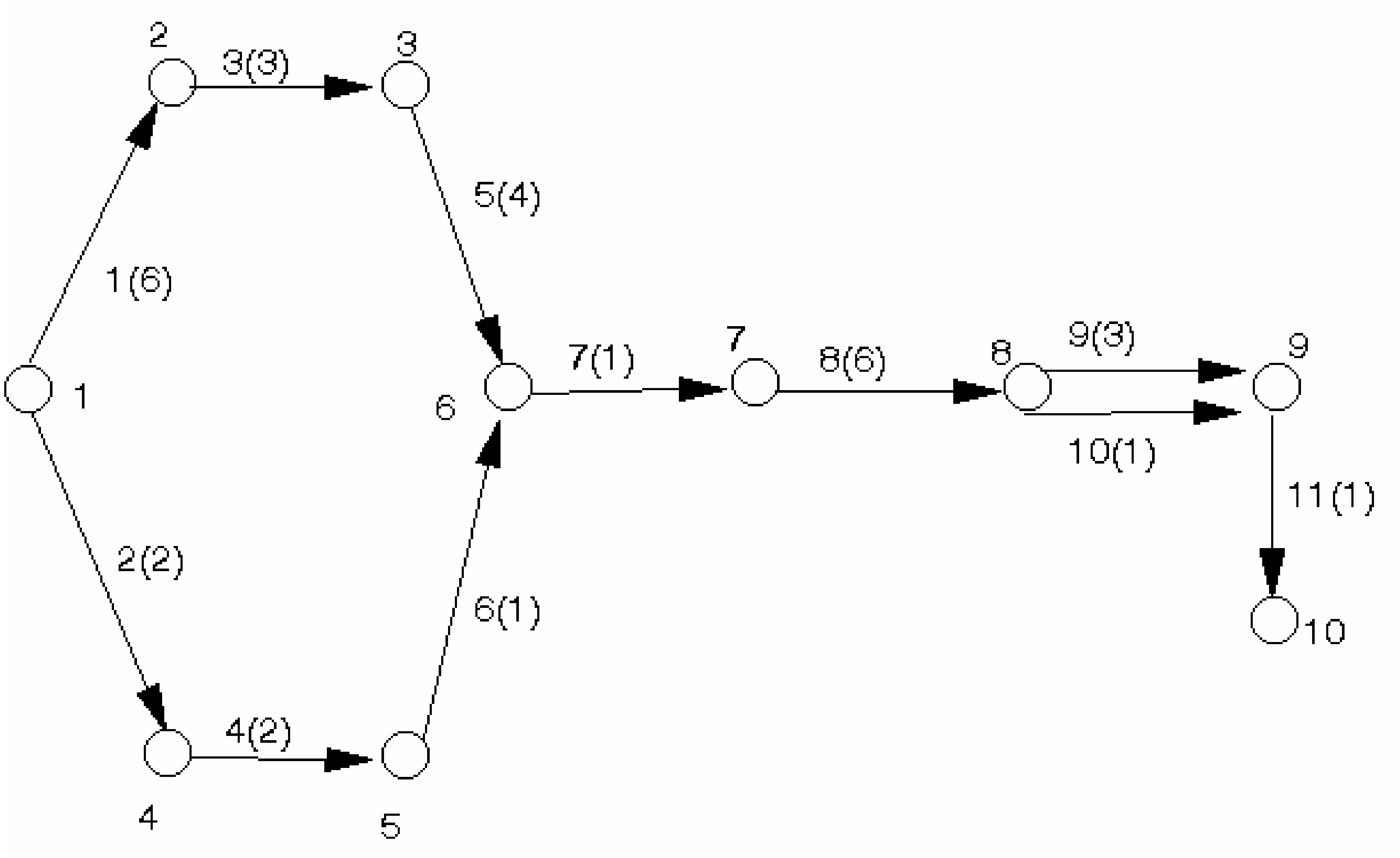
Notes on our example

- One answer could be if we first do activity 1, then activity 2, then activity 3, ..., then activity 10, then activity 11.
- This is possible here and the project would then take the sum of the completion times of all activities, i.e. 30 weeks.
- However could we complete theproject in less time? It is clear that logically we need to amend our key question to be:

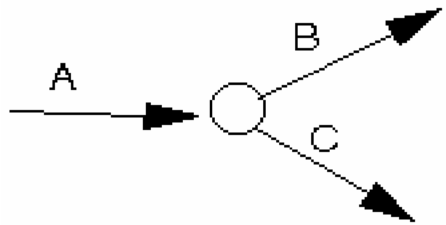
  What is the minimum possible time in which we can complete this project?

- We shall see how the network diagram we construct and its analysis helps us to answer this question.

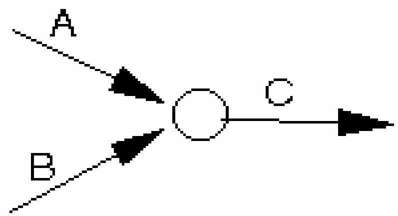
Network diagram (Activity on Arc)



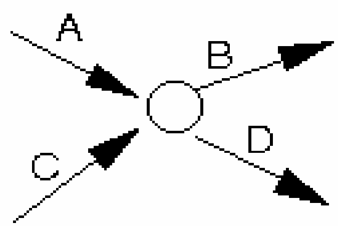
Situations represented in a Network Diagram



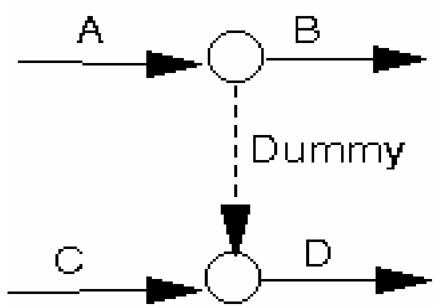
A must finish before either B or C can start



both A and B must finish before C can start



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



A must finish before B can start

both A and C must finish before D can start

Building a house

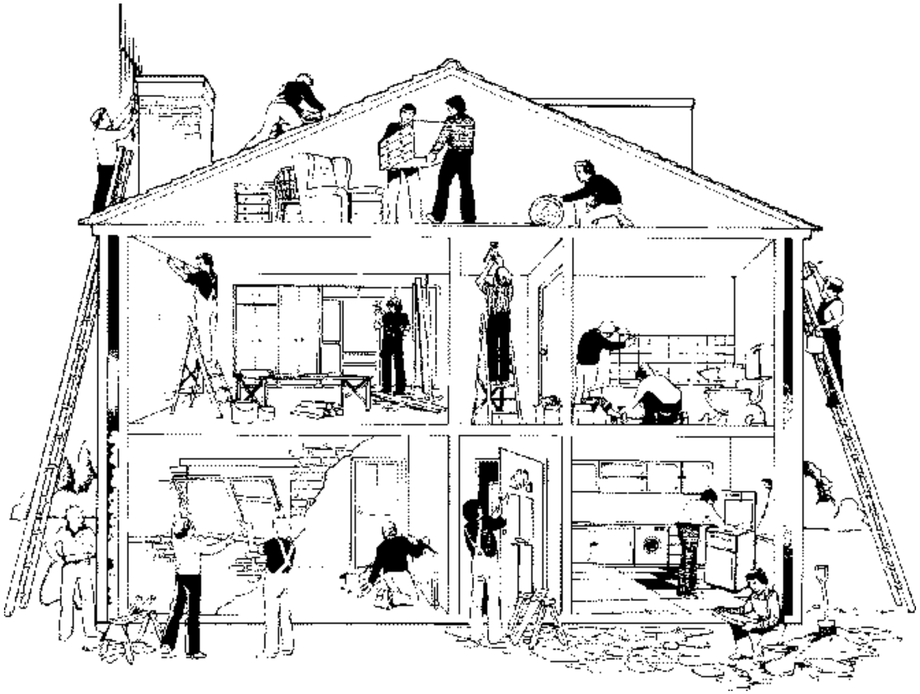
THE NETWORK DIAGRAM IS ABOUT CREATING RELATIONSHIPS BETWEEN ACTIVITIES

Building a house

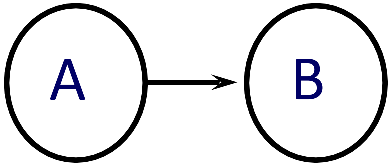
RELATIONSHIPS ARE ALSO REFERRED TO AS DEPENDENCIES – THE MOST BASIC IS "FINISH TO START"

THUS THE BASIC QUESTION IS …
"WHICH ACTIVITIES MUST BE FINISHED BEFORE WHICH ACTIVITIES CAN START"

Building a house

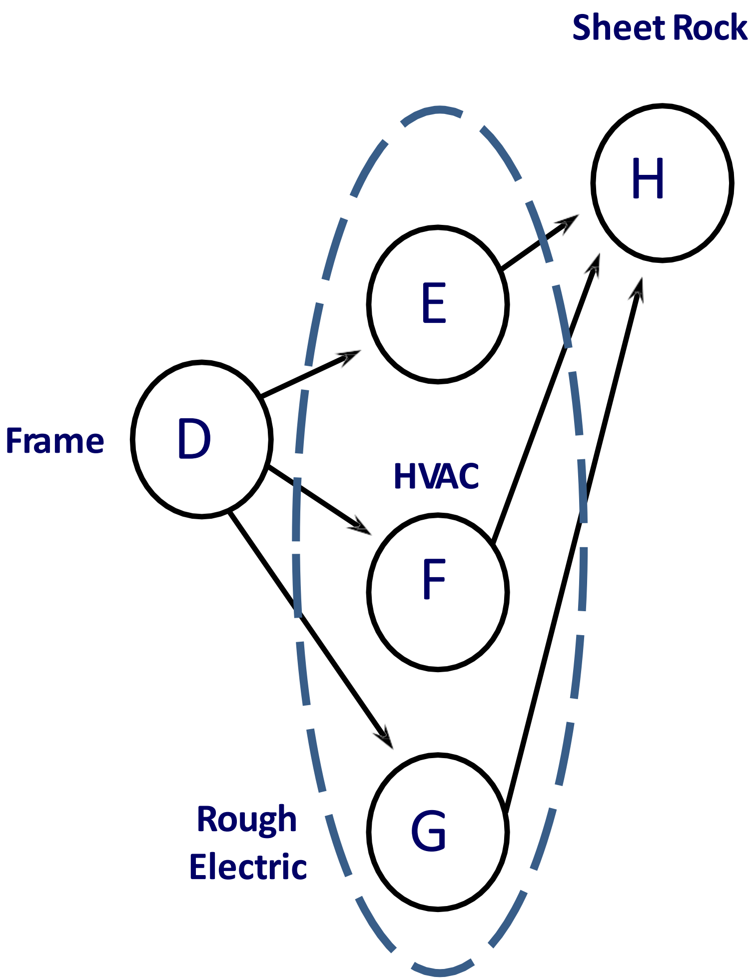


THE USE OF AN ARROW (SPECIFICALLY IN THE NOTATION USED IN THIS EXAMPLE) SHOWS THIS RELATIONSHIP



Activity A must be finished before B can start

Building a house



- But activity E, F and G don't have to wait for each other.
- Note that E, F and G don't have to start and finish at the same time.
- They however need to be finished before H can start.

1st Task is to create these Dependencies by indicating the Predecessors for each Activity

Summary of activities

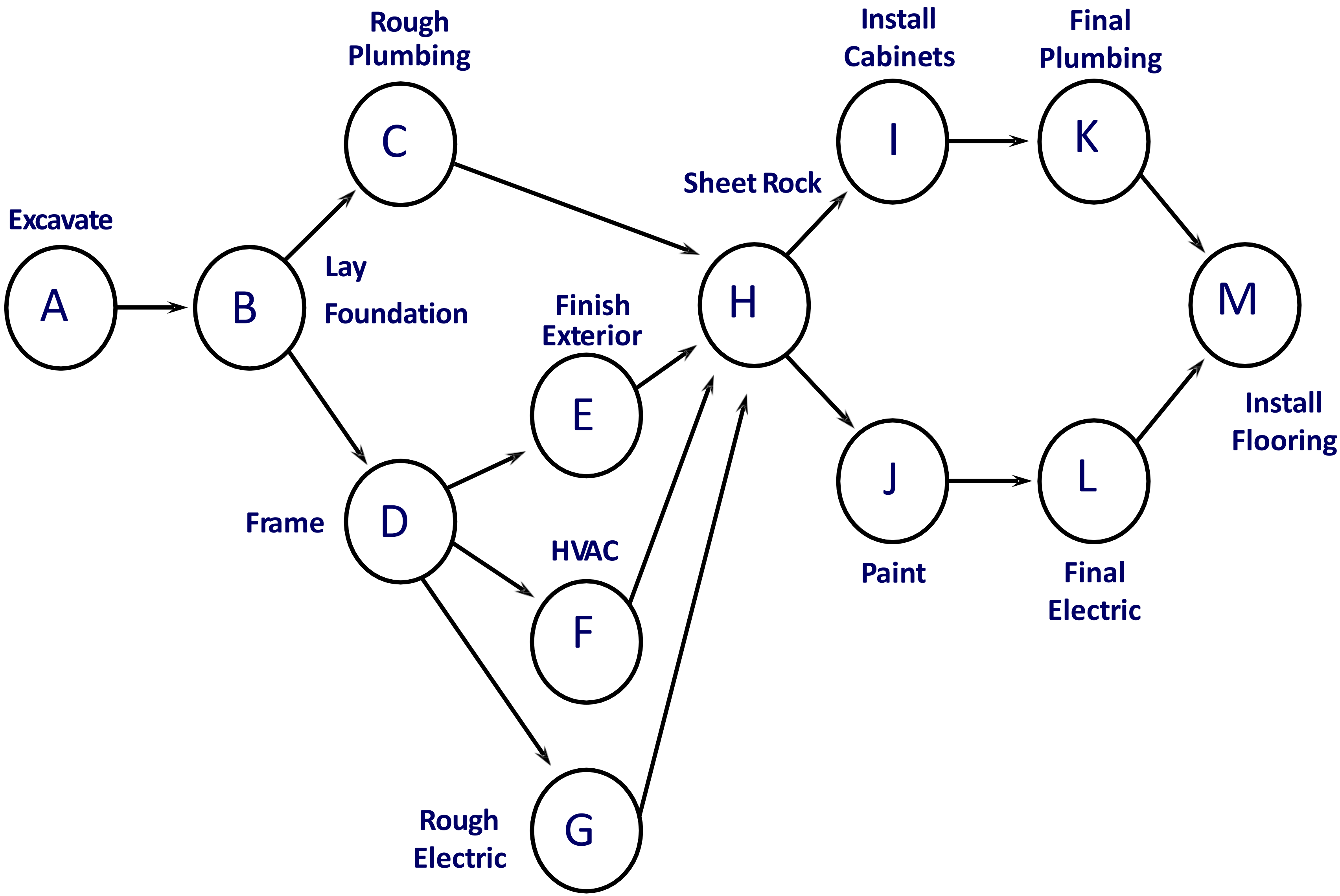
Activity	Description	Time Required (in days)	Immediate Predecessor Activities
A	Excavate		
B	Lay foundation		
C	Rough plumbing		
D	Frame		
E	Finish exterior		
F	Install HVAC (Heating, Ventilation and Air Conditioning)		
G	Rough electric		
H	Sheet rock		
I	Install cabinets		
J	Paint		
K	Final plumbing		
L	Final electric		

Summary of activities

Activity	Description	Time Required (in days)	Immediate Predecessor Activities
A	Excavate		--
B	Lay foundation		A
C	Rough plumbing		B
D	Frame		B
E	Finish exterior		D
F	Install HVAC		D
G	Rough electric		D
H	Sheet rock		C, E, F, G
I	Install cabinets		H
J	Paint		H
K	Final plumbing		I
L	Final electric		J
M	Install flooring		K, L

Task 2
Test the logic by constructing the Network Diagram

An Activity-On-Node (AON) Network



Basic Rules for Constructing the Network Diagram

- Networks typically flow from left to right;
- An activity cannot begin until all of its preceding activities are complete;
- Arrows indicate precedence and flow and can cross over each other;
- Identify each activity with a unique number; this number must be greater than its predecessors;
- Looping is not allowed;
- Conditional statements are not allowed;
- Use unique start and stop nodes.

Task 3
Determine durations for each activity

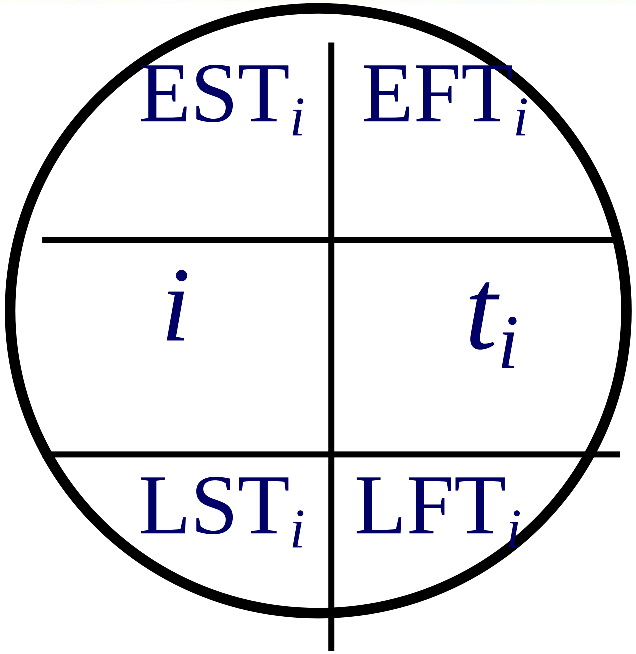
Summary of activities

Activity	Description	Time Required (in days)	Immediate Predecessor Activities
A	Excavate	3	--
B	Lay foundation	4	A
C	Rough plumbing	3	B
D	Frame	10	B
E	Finish exterior	8	D
F	Install HVAC	4	D
G	Rough electric	6	D
H	Sheet rock	8	C, E, F, G
I	Install cabinets	5	H
J	Paint	5	H
K	Final plumbing	4	I
L	Final electric	2	J
M	Install flooring	4	K, L

Task 4

Fill each node as follows ….

Information Recorded for each Node



t_i = DURATION required to perform activity i

EST_i = earliest possible start for activity i

EFT_i = earliest possible finish for activity i

LST_i = latest possible start for activity i

LFT_i = latest possible finish for activity i

Task 5
Calculate the forward and backward pass

Forword and Backward pass

- A Forward Pass through the network determines:
  - the earliest times each activity can start and finish and also
  - determines the total duration of the project.
- A Backward Pass through the network determines
  - the latest times each activity can start and finish without delaying completion of the project
  - with this information we can determine where we can delay activities (have slack) and where we cannot.

The Forward pass

- The earliest start(EST) for the initial activity in a project is "time zero";
- The EST of an activity is equal to the latest (or maximum) finish of the activities directly preceding it;
- The EFT of an activity is equal to its EST plus the duration required to perform the activity.

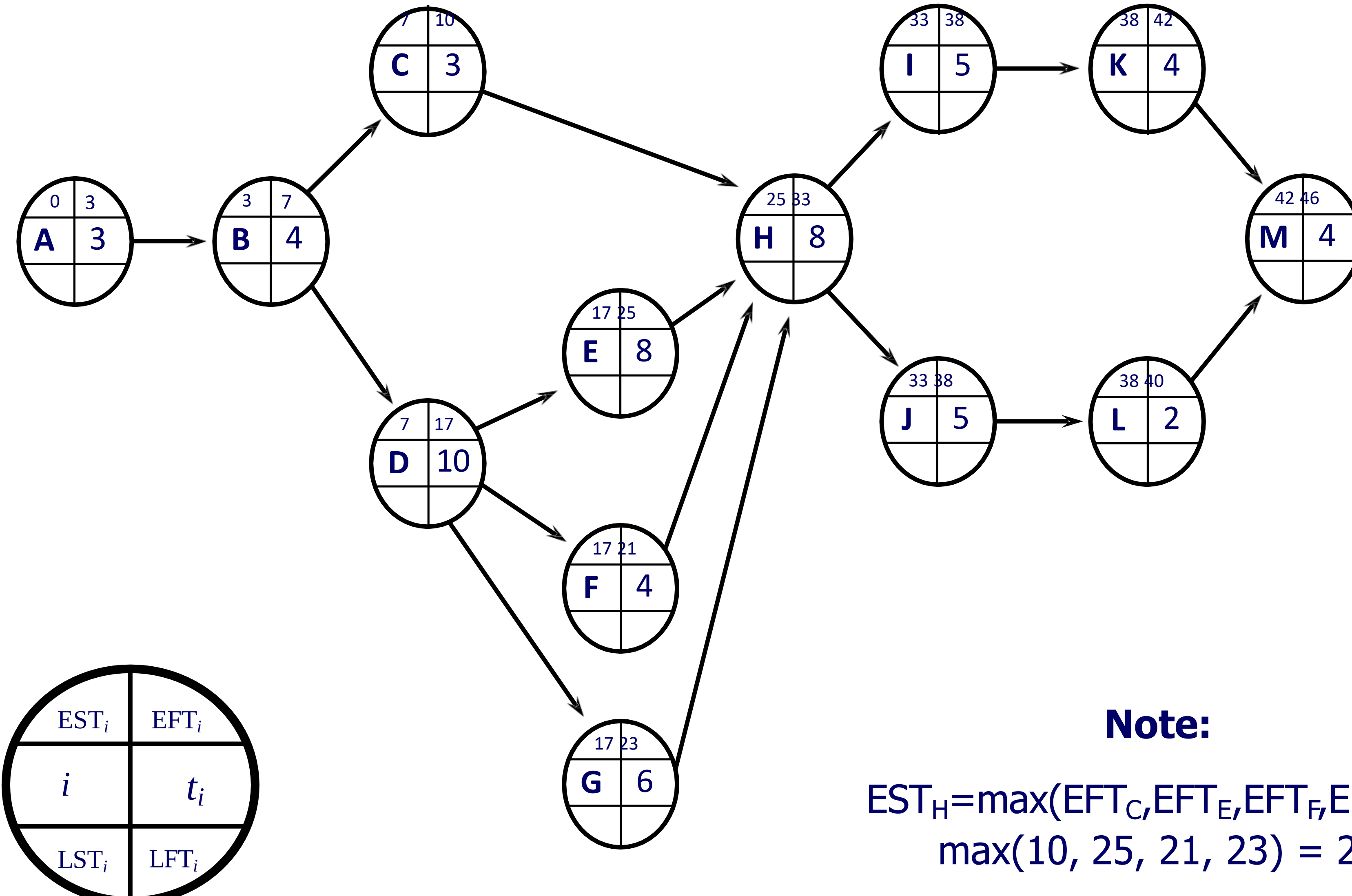
Earliest time

- Note here that the formal definition of the earliest times is given by:

  $EST_j = \max[EST_i + T_{ij}$ | i one of the nodes linked to j by an arc from i to j]

- This equation for calculating E_j is actually a formal statement of the dynamic programming algorithm for the problem.

Results of the Forward pass

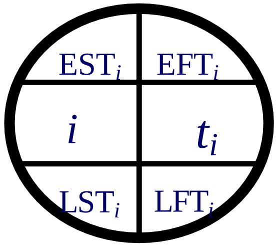


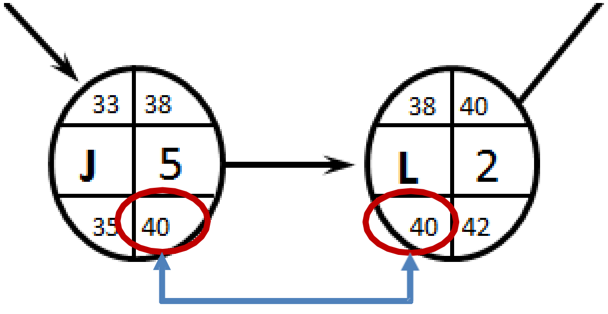
Note:

$EST_H = max(EFT_C, EFT_E, EFT_F, EFT_G) =$
$max(10, 25, 21, 23) = 25$

The Backward pass

- The latest finish(LFT) for the final activity in a project is equal to its EFT as determined by the forward pass;
- The LFT for any other activity is equal to the earliest (or minimum) LST of the activities directly following (or succeeding) it;
- The LST of an activity is equal to its LFT minus the time required to perform the activity.





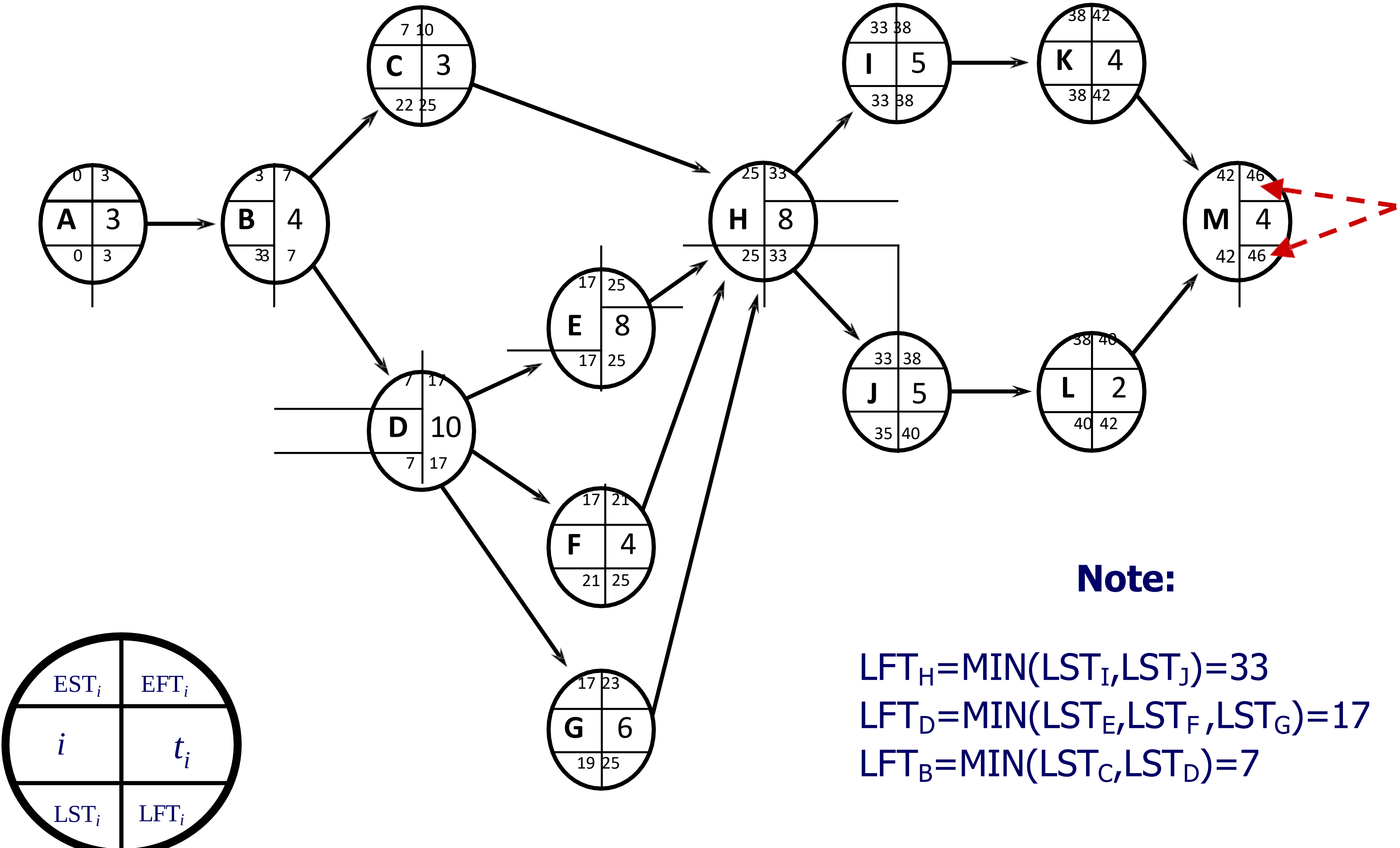
Latest time

- The formal definition of the latest times is given by:

  $LST_i = \min[L_j - T_{ij} \mid j$ one of the nodes linked to i by an arc from i to j]

- As a check, that we have done both the earliest start times and latest start times calculations correctly, we must have:
  - all latest start times must be >= 0
  - at least one node must have a latest start time of zero.

Results of the Backward pass



Note:

$LFT_H = MIN(LST_I, LST_J) = 33$
$LFT_D = MIN(LST_E, LST_F, LST_G) = 17$
$LFT_B = MIN(LST_C, LST_D) = 7$

Task 6
Determine the critical path

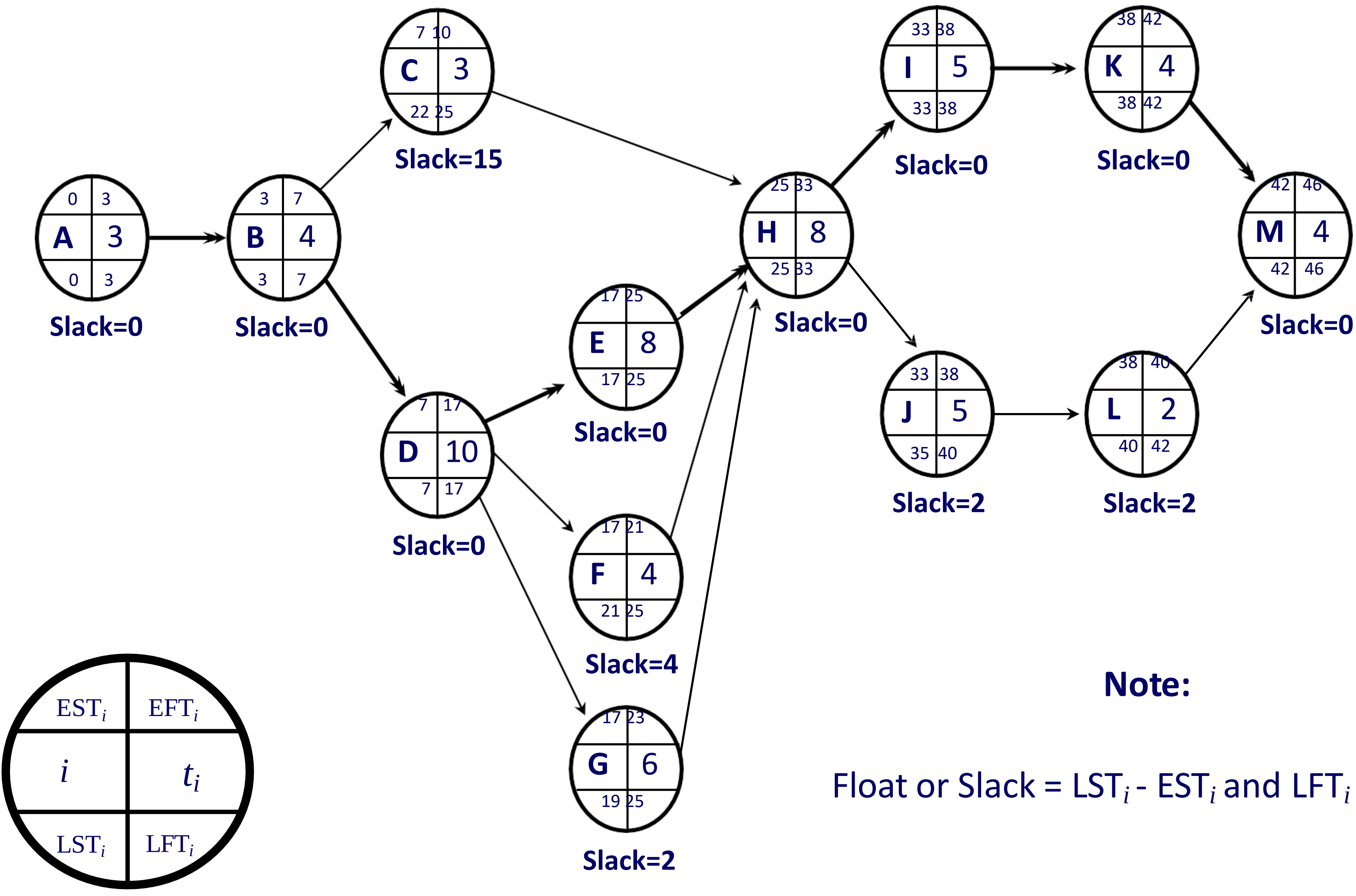
Float or Slack

- The amount of slack or *float* time F_i available is given by

$$F_i = LST_i - EST_i$$

which is the amount by which we can increase the time taken to complete activity i without changing (increasing) the overall project completion time.

Determing slack



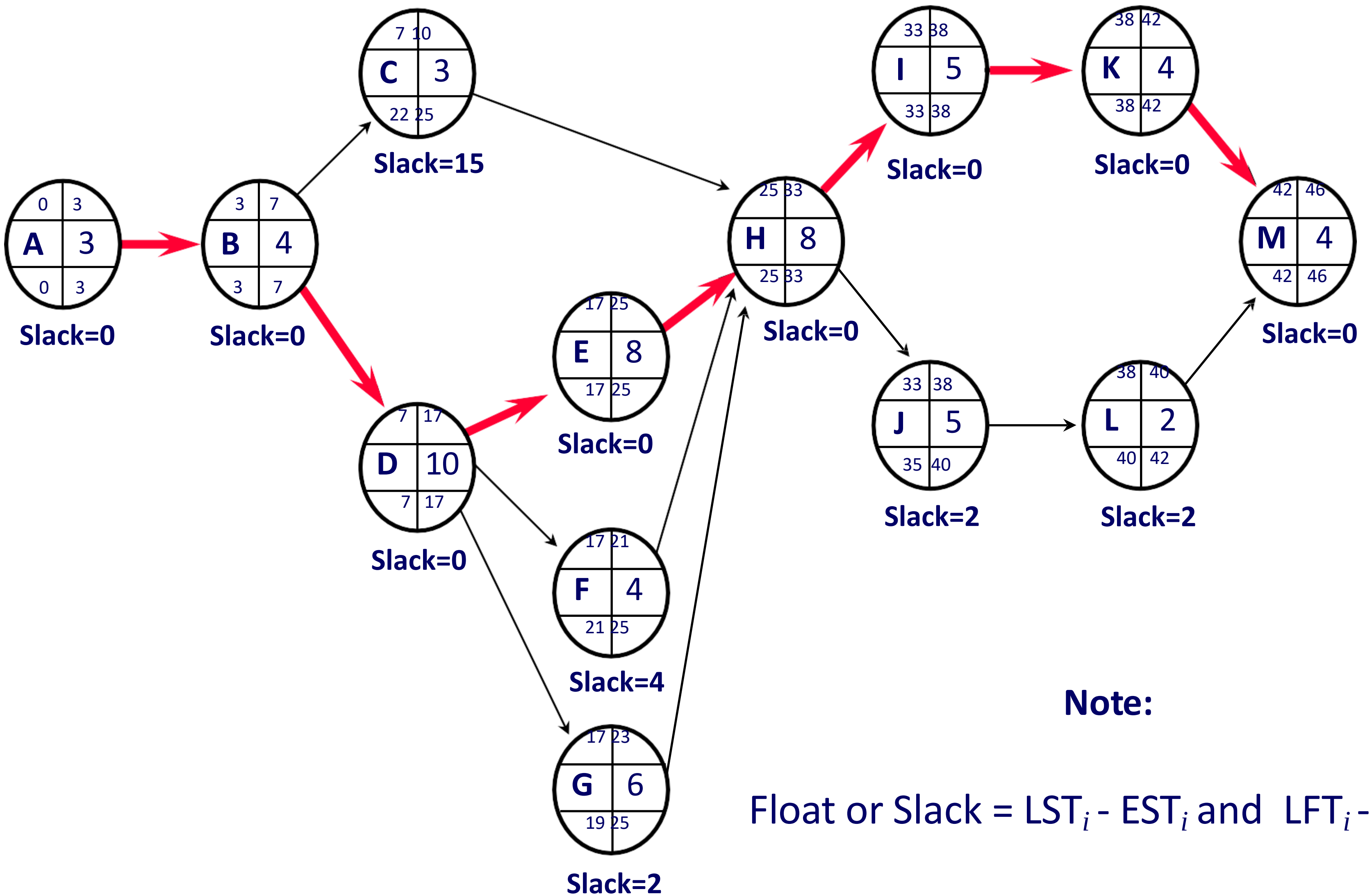
Note:

Float or Slack = LST_i - EST_i and LFT_i - EFT_i

Determining The Critical Path

- Critical activities have zero slack and cannot be delayed without delaying the completion of the project;
- The slack for non-critical activities represents the amount of time by which the start of these activities can be delayed without delaying the completion of the entire project (assuming that all predecessor activities start at their earliest start times);
- The longest path on the network;
- Could also be those activities with the least slack.

The Critical Path



Note:

Float or Slack = LST_i - EST_i and LFT_i - EFT_i

Q & A