Planning Methods in Project Management

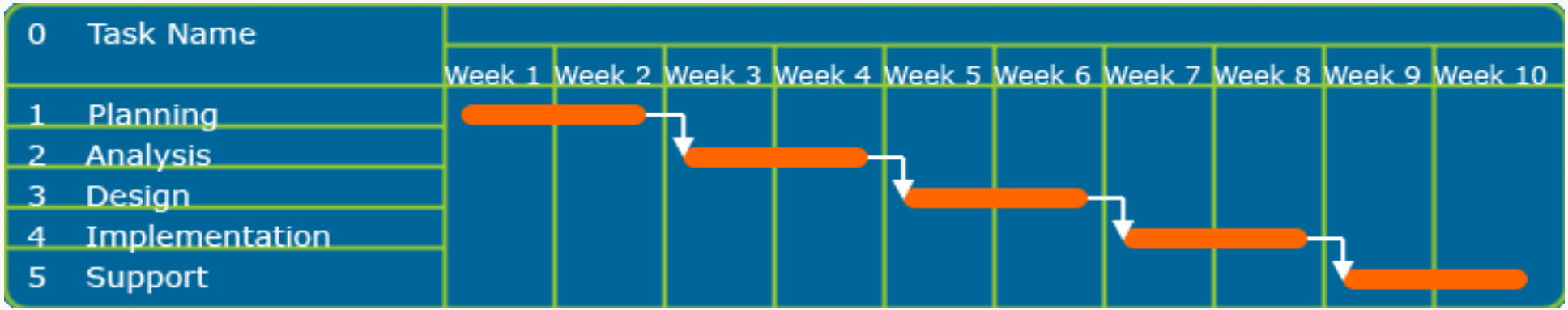
PLANNING IN PROJECT MANAGEMENT

Planning the work to be carried out in a project is important at all of its stages, but is particularly important for the project execution stage.

Planning involves deciding what staff, labour, materials etc. is needed, and when.

The project programme is the basis on which these decisions are made.

Bar Charts or Gantt Charts - give a general idea of how the various activities in a project will take place.



Gantt charts are frequently used in presentations and to communicate with stakeholders.

Advantages: can be used to record progress diagrammatically easily understood (or misunderstood)

Disadvantages: show only superficial detail, does not show the inter-relationship of activities.

The activities displayed on the chart are derived from the WBS.

A Simple Example

A project consists of 12 activities with durations and interdependencies as indicated below:

ACTIVITY	DURATION	TIMING
A	3	On Signing Contract
B	4	On Signing Contract
C	6	After Completion of A
D	7	After Completion of A
E	5	After Completion of B
F	3	After Completion of C
G	9	After Completion of C
H	5	After Completion of D & E
I	4	After Completion of F
J	7	After Completion of G, D & E
K	5	After Completion of H
L	5	After Completion of I, J & K

- How long will this project take?
- Which activities determine the minimum duration ?
- Are there any activities which can be delayed without delaying the project as a whole?
- What is the maximum acceptable delay on each of the individual activities if we want to ensure that the project is completed as quickly as possible?

Critical Path Method

Here is the list of activities for the same example project again.

ACTIVITY	DURATION	TIMING
A	3	On Signing Contract
B	4	On Signing Contract
C	6	After Completion of A
D	7	After Completion of A
E	5	After Completion of B
F	3	After Completion of C
G	9	After Completion of C
H	5	After Completion of D & E
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J	7	After Completion of G, D & E
K	5	After Completion of H
L	5	After Completion of I, J & K

A Graphical Representation of the Activities in a Project

ACTIVITY	DURATION	TIMING
A	3	On Signing Contract
B	4	On Signing Contract
C	6	After Completion of A
D	7	After Completion of A
E	5	After Completion of B
F	3	After Completion of C
G	9	After Completion of C
H	5	After Completion of D & E
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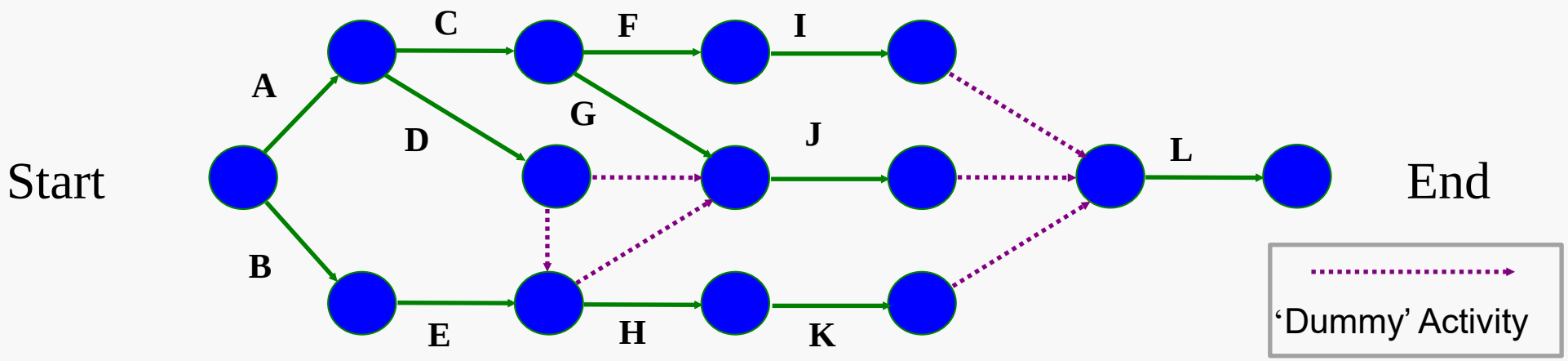
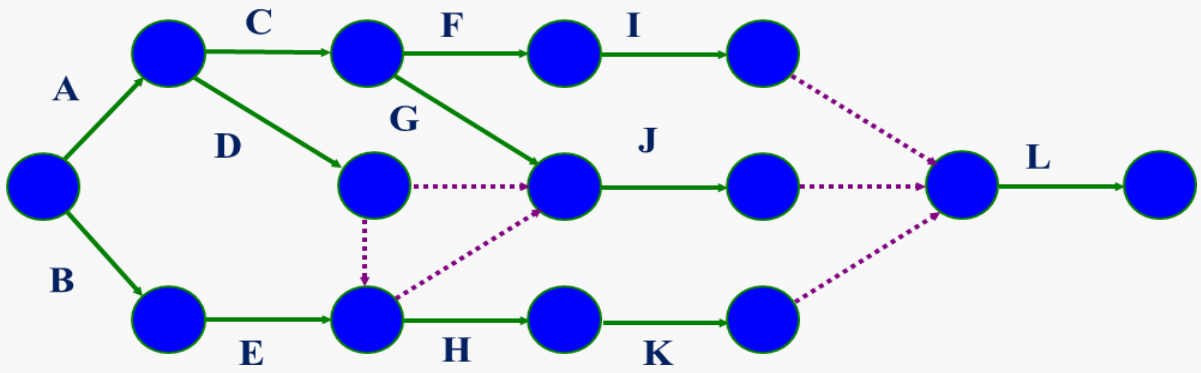


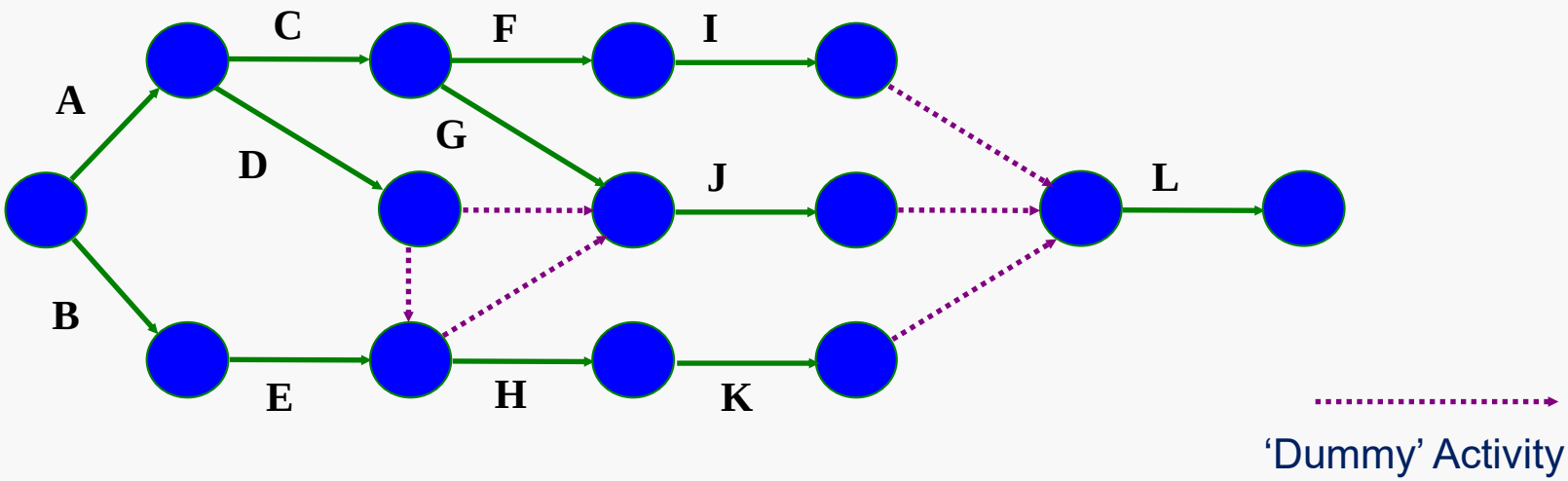
This type of diagrammatic representation of a project is usually referred to as an **'Arrow Diagram'** (or, more specifically, as an 'Activity-on-Arrow Diagram').



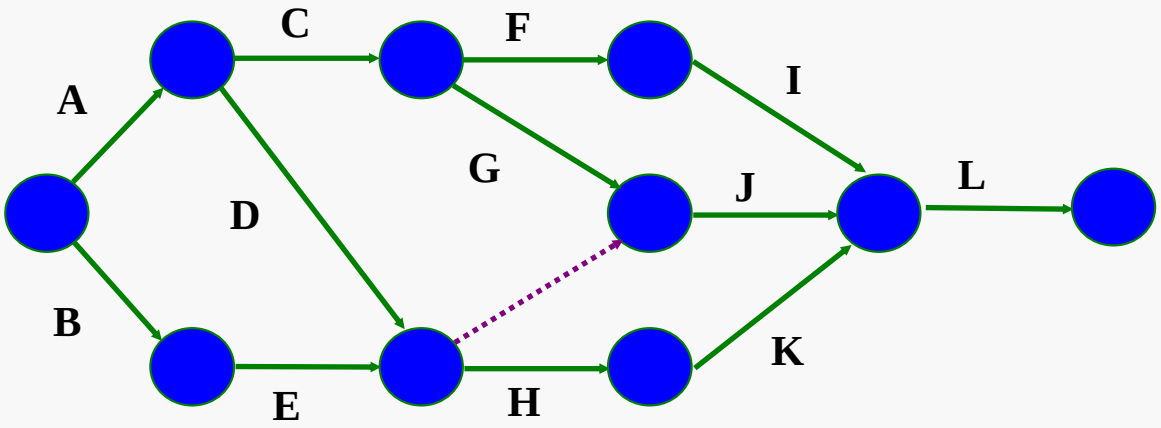
We can now answer the first question posed by simply calculating the length of each possible path from left to right:

A-C-F-I-L	21 days	
A-C-G-J-L	30 days	← Longest Path
A-D-J-L	22 days	
A-D-H-K-L	25 days	
B-E-H-K-L	24 days	
B-E-J-L	21 days	

Note that this method is not acceptable as it is impossible to use for large networks and even for smaller ones can lead to error if a path is not recognised.



Simplified Diagram:



An illustration of the use, and need for a "Dummy" activity.

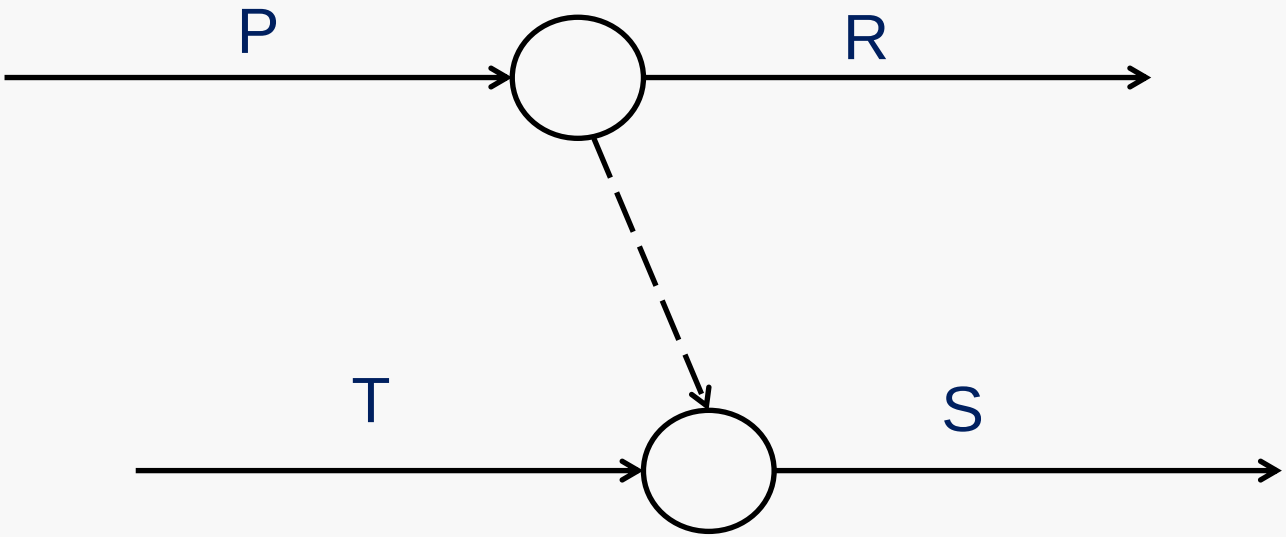
Suppose there are activities whose logic is as follows;

R follows P

S follows T and P

This is represented as;

R follows P
S follows both T and P

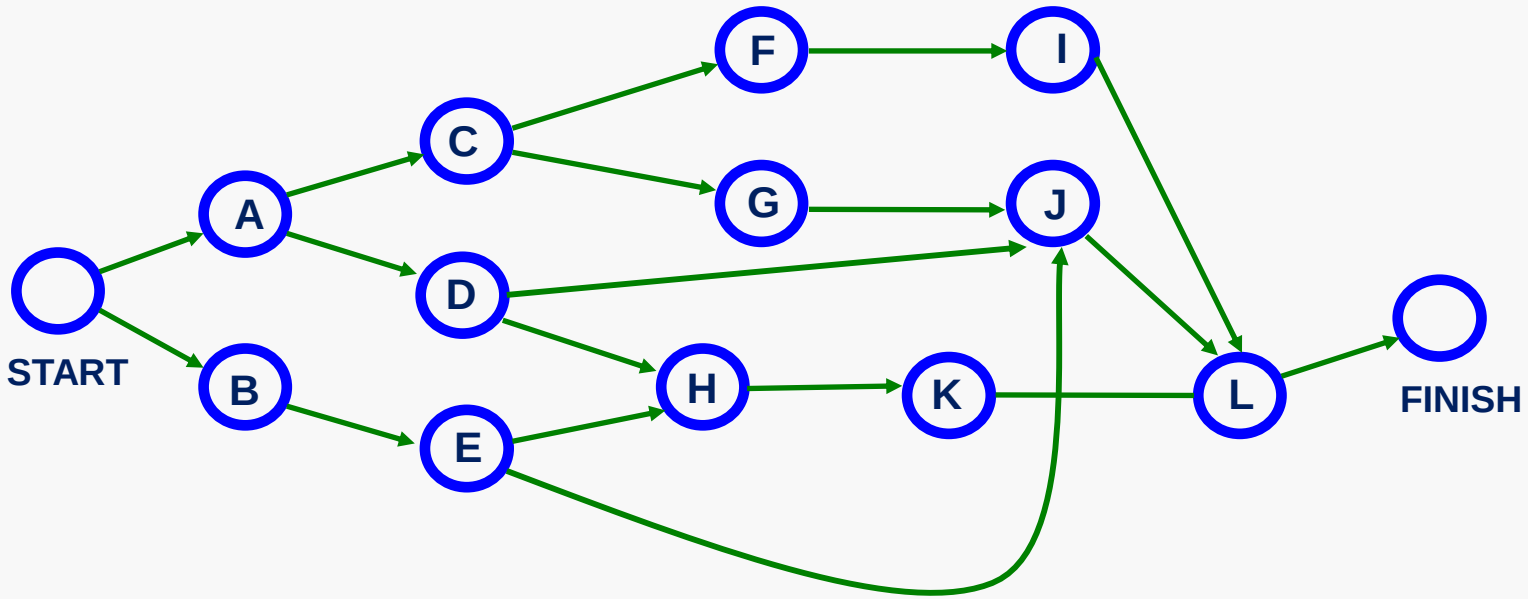


Note:

R does not follow T (and so does not need to wait for T to be completed before starting.

But S must wait for both T and P to finish before it can start.

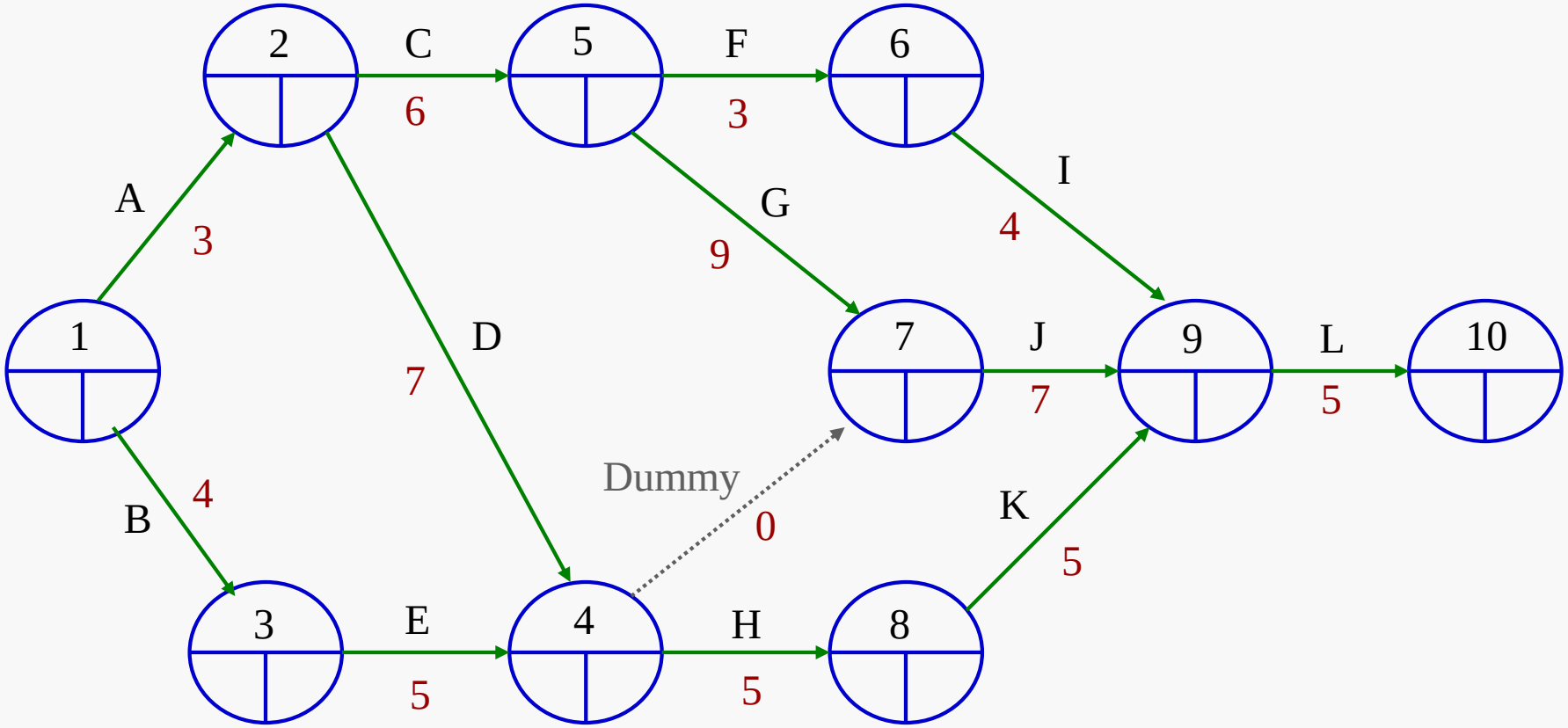
Alternative Type of Graphical Representation - **Activity-on-Node Diagram**

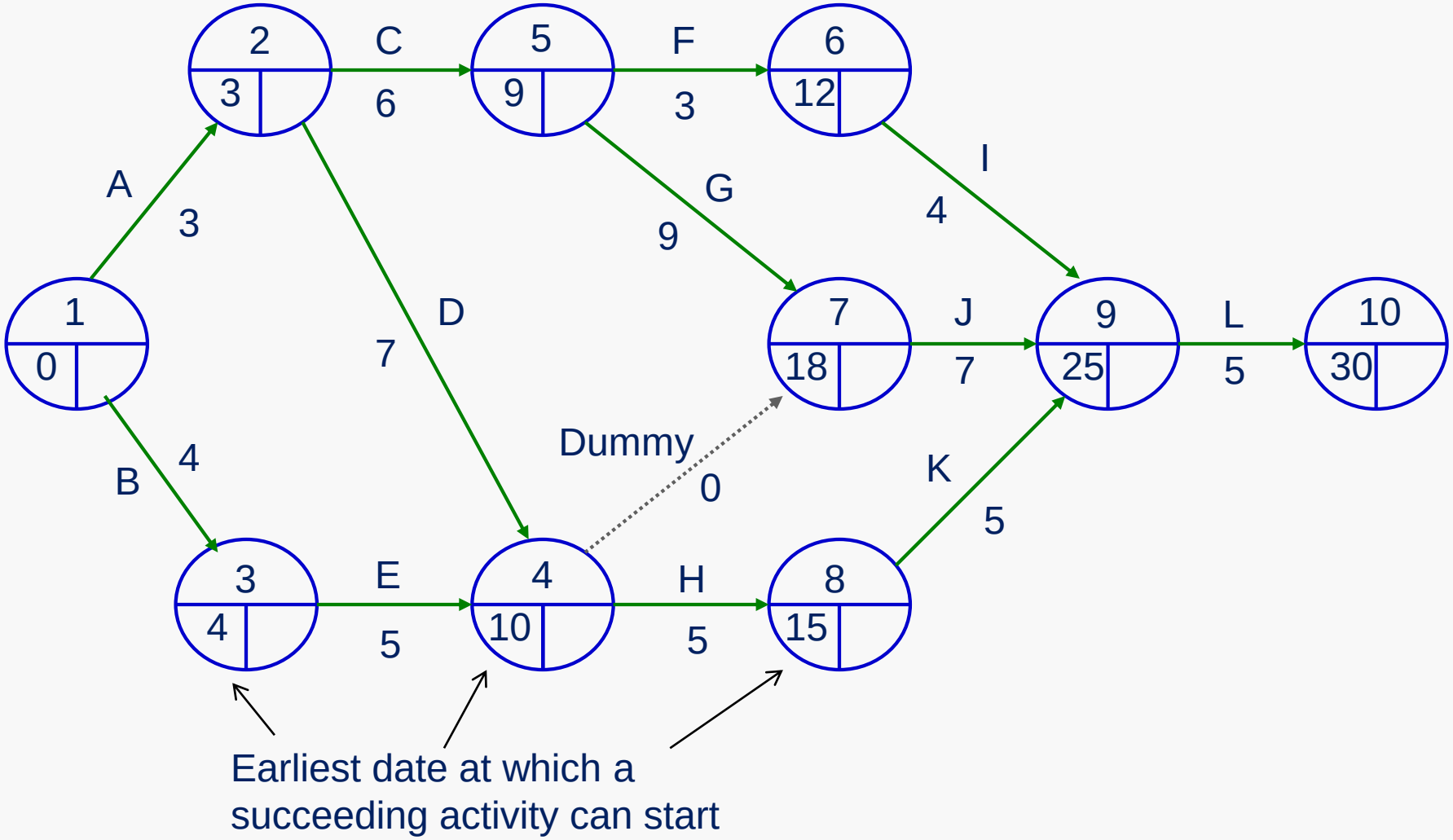


This type of diagram is often also referred to simply as a 'Precedence Diagram'.

Do not confuse the two types of diagram; we will be using only the <u>Activity on Arrow</u> convention

How can we find the shortest possible duration for the project?




1
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12
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18
8
15
9
25
10
30
A
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C
6
D
7
E
5
F
3
G
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H
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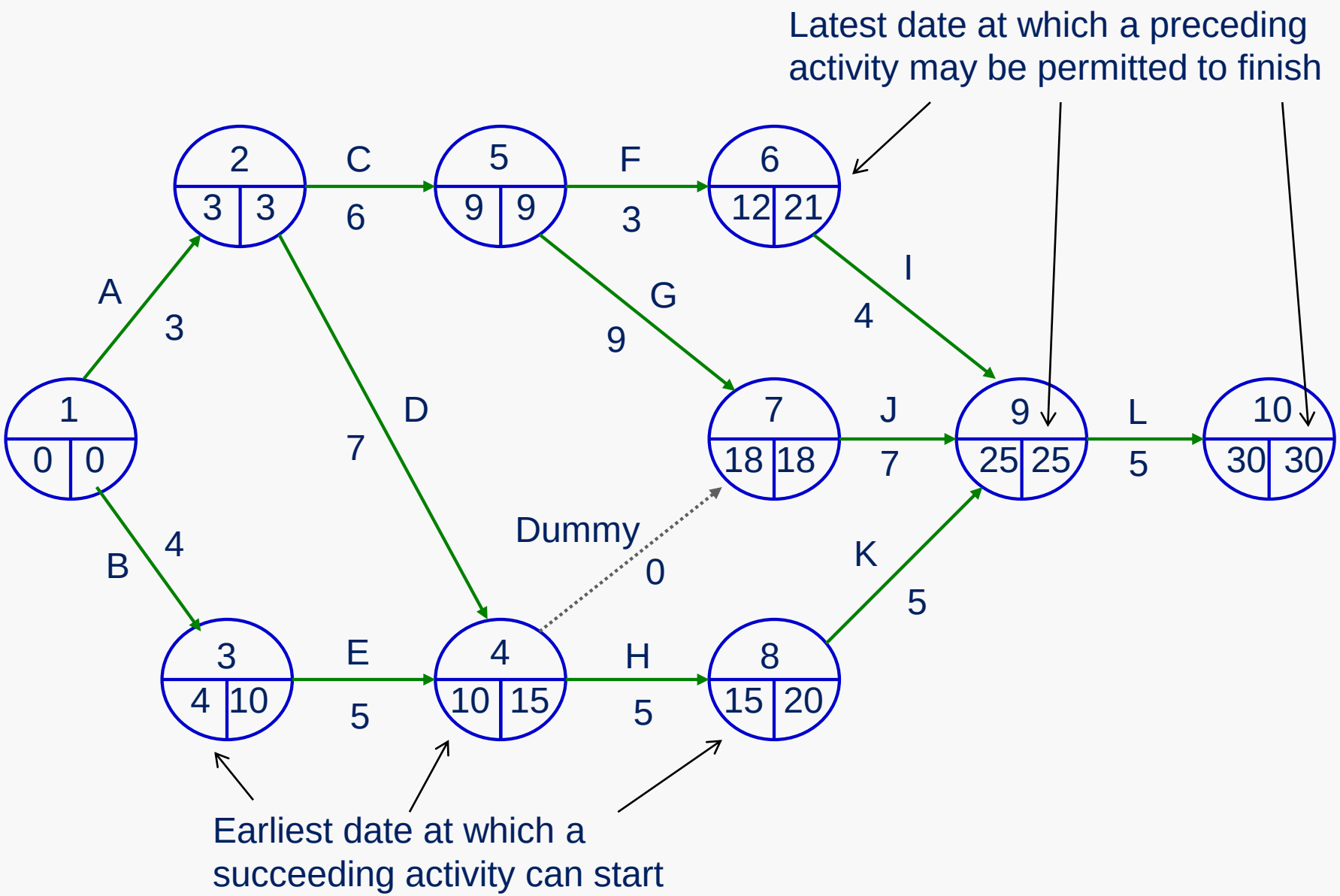
I
4
J
7
K
5
L
5
Dummy
0
Earliest date at which a
succeeding activity can start


Latest date at which a preceding activity may be permitted to finish
1
0 0
2
3 3
3
4
5
9 9
6
12 21
7
18 18
8
15 20
9
25 25
10
30 30
3
4 10
4
10 15
A
3
B
4
C
6
D
7
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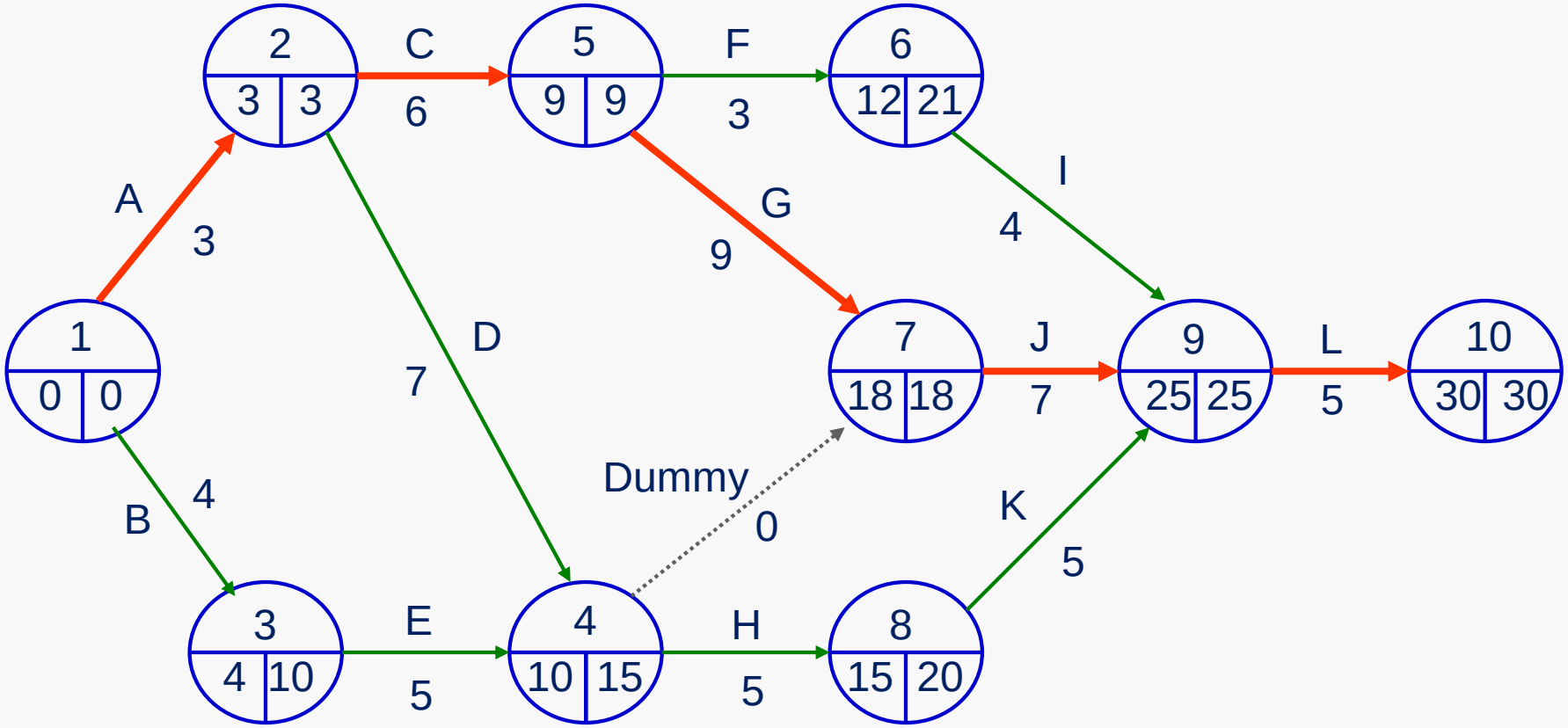
Dummy
0
Earliest date at which a succeeding activity can start



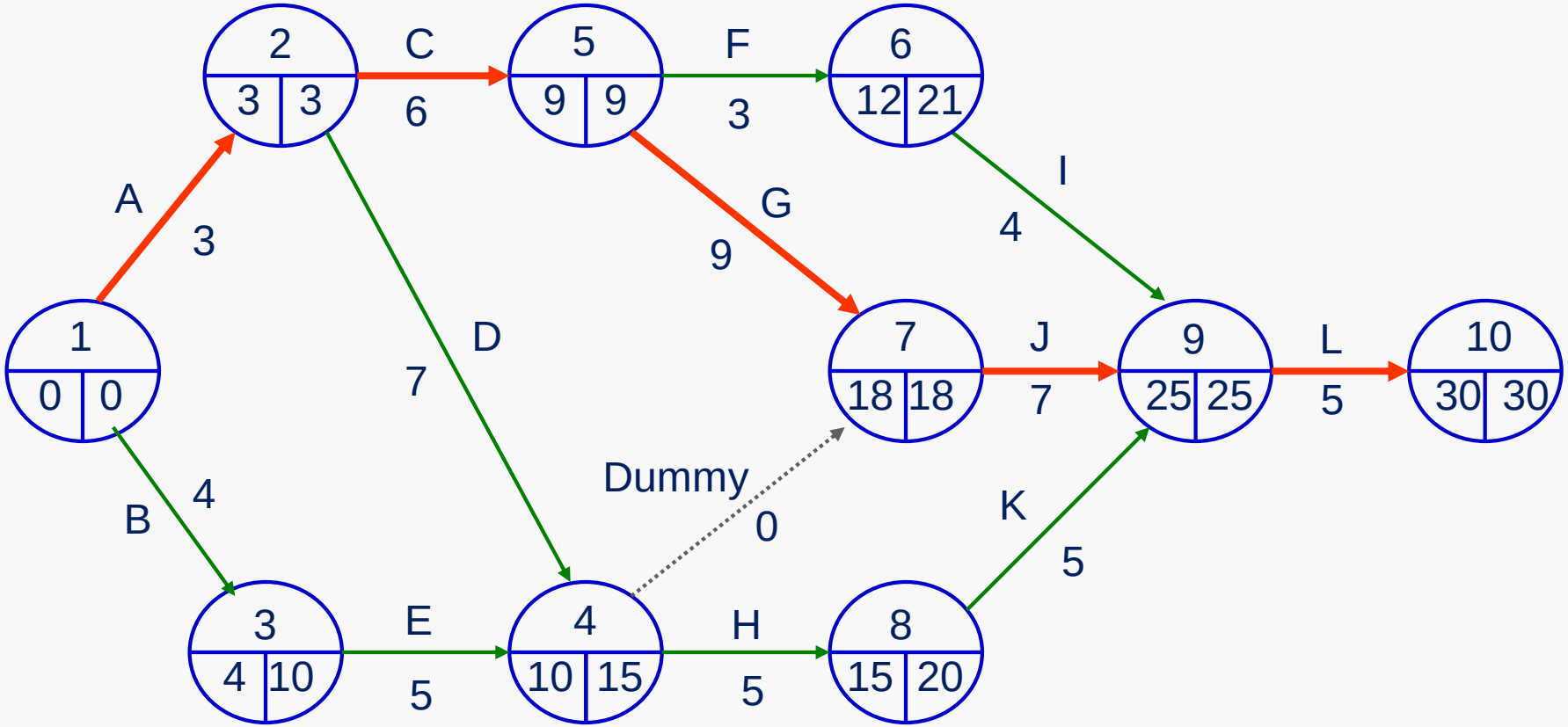
A-C-G-J-L is referred to as the **'Critical Path'**

Note:

The earliest project completion date is determined by the ***longest*** path through the network.

In other words: The Critical Path is the ***longest*** path in the network.

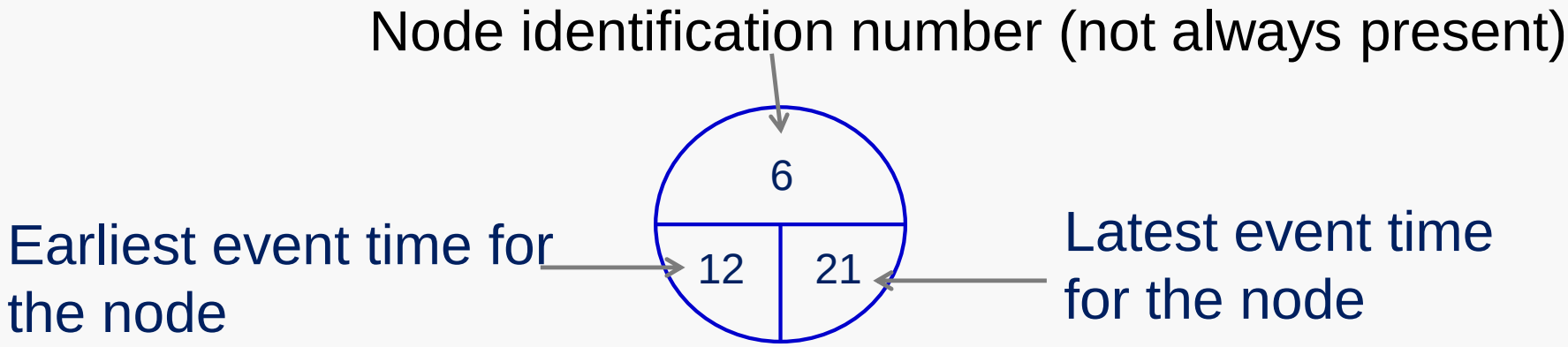
Moreover – A project can have several Critical Paths



ACTIVITY	CAN FINISH BY DAY	MUST FINISH BY DAY
B	4	10
D	10	15
E	9	15
F	12	21

ACTIVITY	CAN FINISH BY DAY	MUST FINISH BY DAY
H	15	20
I	16	25
K	20	25

Note that the numbers on the nodes are;



Note also that;

The earliest event time for the node is the earliest starting time for the activities which branch from that node.

The latest event time for the node is the latest starting time for the activities which branch from that node.

Earliest Starting Date (ES)

Earliest date at which work on an activity can start if we assume that no time has been lost on preceding activities

$$ES(i,j) = \begin{cases} ES_0 & \text{for } i = l \text{ (1st event)} \\ \max\limits_{(k,i)} [ES(k,i) + T(k,i)] & \end{cases}$$

where T(k,i) is the duration of activity (k,i)

ES(1,2) = 0 (by definition)
ES(2,4) = 14
ES(2,3) = 14
ES(3,4) = 21
ES(4,5) = 25

Earliest Finishing Date (EF)

Earliest date at which work on an activity can be finished

It follows that;

$$EF(i,j) = ES(i,j) + T(i,j)$$

ie
The earliest finish time of an activity [EF(i,j)] is its earliest start time [ES(i,j)] plus its duration [T(i,j)]

EF(1,2) = 14
EF(2,4) = 17
EF(2,3) = 21
EF(3,4) = 25
EF(4,5) = 35

Latest Finishing Date (LF)

Latest date at which work on an activity may be permitted to finish if the whole project is to be completed as soon as possible

$$LF(i,j) = \begin{cases} \underset{(k,j)}{\text{Max}}\ EF(k,j) & \text{for } j = s \text{ (last event)} \\ \underset{(j,k)}{\text{Min}}\ [LF(j,k) - T(j,k)] & \end{cases}$$

LF(4,5) = 35
LF(3,4) = 25
LF(2,3) = 21
LF(2,4) = 25
LF(1,2) = 14

Latest Starting Date (or time) (LS)

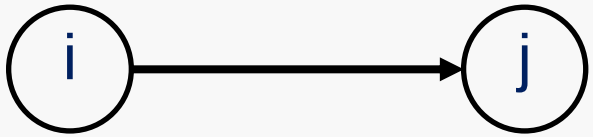
Latest date (or time) at which work on an activity may be started if it is to be finished by its LF

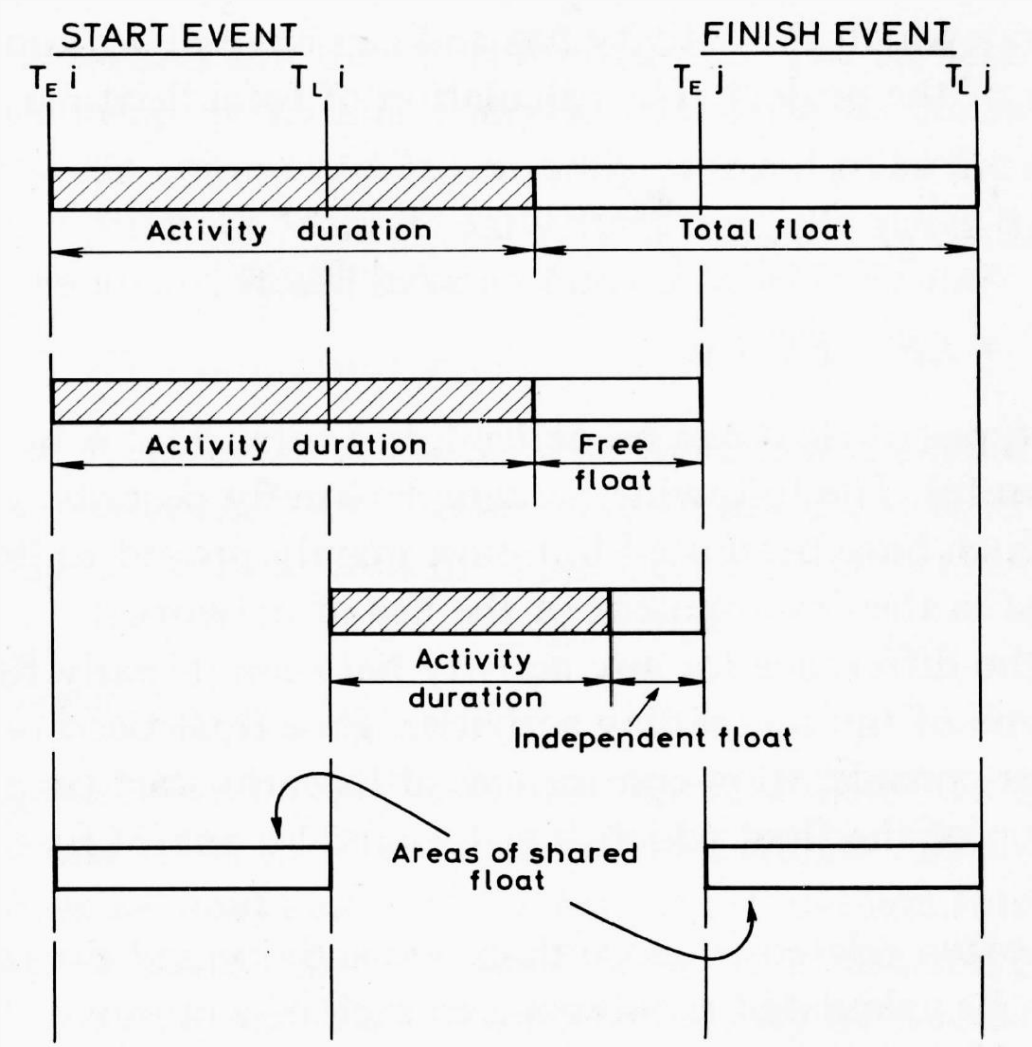
$$LS(i,j) = LF(i,j) - T(i,j)$$

ie the latest start date (or time) of an activity [LS(i,j)] is its latest finishing date [LF(i,j)] minus its duration [T(i,j)]

LS(4,5) = 25
LS(3,4) = 21
LS(2,3) = 14
LS(2,4) = 22
LS(1,2) = 0

For an activity





T_E i is the earliest event time for i

T_L i is the latest event time for i

T_E j is the earliest event time for j

T_L j is the latest event time for j

Total Float =
Latest finish event time - Earliest start even time - duration

Free Float =
Earliest finish event time - Earliest start event time - duration

Independent Float =
Earliest finish event time - Latest start event time - duration

(NB Be careful not to confuse event times with the activity times.)

Float (or “Slack”)

Total Float (TF)

Amount of time that an activity may be delayed* without delaying project completion

* Delay with respect to the Earliest Starting Date

$$TF(i,j) = LS(i,j) - ES(i,j)$$

and therefore:

$$TF(i,j) = LF(i,j) - EF(i,j)$$

TF(1,2) = 0
TF(2,4) = 8
TF(2,3) = 0
TF(3,4) = 0
TF(4,5) = 0

TF = 0 ⟺ Activity is “critical”

Free Float* (FF)

: Amount of time that an activity may be delayed without delaying subsequent activities.

*Sometimes referred to as “Free Float/Early”

$$FF(i,j) = \begin{cases} \text{Completion date of project} - EF(i,j) & \text{if } j = s \\ \min\limits_{(j,k)} [ES(j,k) - EF(i,j)] & \end{cases}$$

FF(1,2) = 0
FF(2,4) = 8
FF(2,3) = 0
FF(3,4) = 0
FF(4,5) = 0

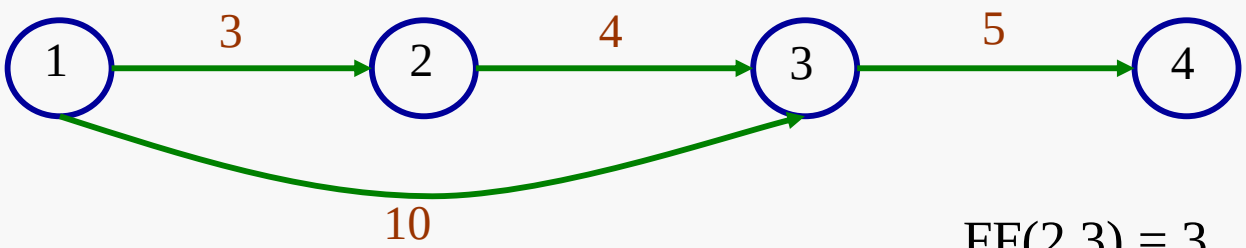
Clearly: $TF(i,j) \geq FF(i,j)$
(ie Total Float is greater or equal to the Free Float.

NB: Formula refers to non-dummy activities.

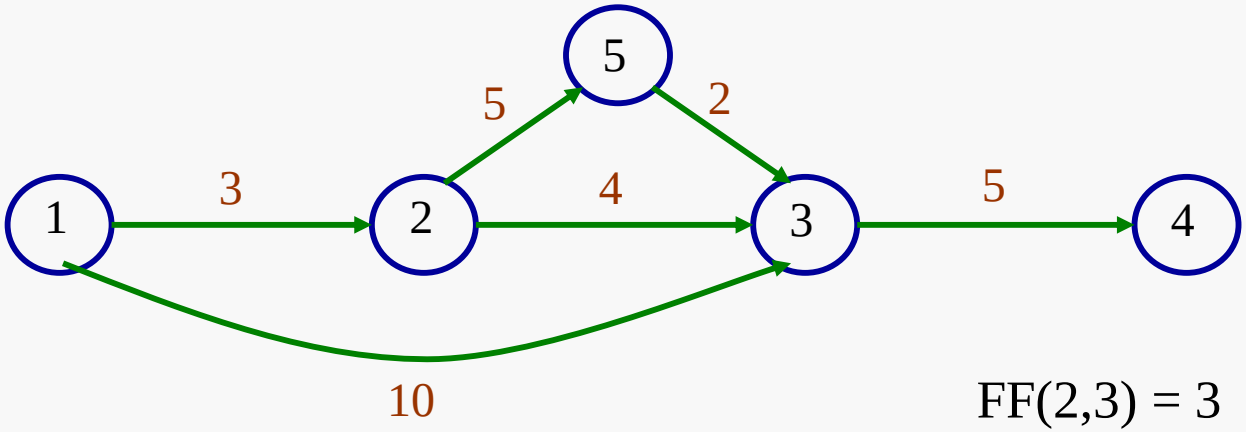
Independent Float (IF)

Amount of time that an activity may be delayed without delaying subsequent activities if all preceding activities start as late as possible

Example:



FF(2,3) = 3 IF(2,3) = 0



FF(2,3) = 3 IF(2,3) = 3

With practice and experience it is possible to be able to identify the critical path by inspection, but it is easy to make errors by that method and it is better to tabulate the information about each activity and then identify the Critical Path from the table.

(It is more “Poka-yoke”).

My favourite layout of the table is as follows.

Activity	Latest Finish(LF)	Earliest Start (ES)	Duration	Total Float
A				
B				
C				
D				

The **bigger** of the pair of numbers **at the end node** of the activity.

The **smaller** of the pair of numbers **at the start node** of the activity.

Total Float =
Latest Finish - Earliest Start - Duration

Additional information can be added to the table but get the three basic bits of information (LF, ES and duration) there correctly first and the calculation of the others becomes more straight forward.

Activity	Latest Finish (LF)	Earliest Start (ES)	Duration (D)	Latest Start (LS)	Earliest Finish (EF)	Total Float
A						
B						
C						
D						

Latest start = Latest finish - Duration

Earliest finish = Earliest start + Duration

<u>Reminder:</u> Note that there is a alternative convention for mapping CP networks – the Activity on Node (AON) method.

Remember this when you read texts so that you do not get confused between the two methods.

We **do not** cover the AON method in detail in this module.

Important assumptions made by the method:

Activities either parallel or consecutive

Activity duration known with certainty

No resource limitations

Activity duration independent of resource levels

A further, often overlooked, assumption is that the activities are all undertaken and are all undertaken only once.

Remember that a neat way of setting out the calculations for the total float is as follows;

(remembering that for an activity;

total float = latest finish time – earliest start time – duration;

Bigger of the pair of numbers at the end node

Smaller of the pair of numbers at the end node

Total Float =
Latest Finish - Earliest Start - Duration

Activity	Latest finish time	Earliest start time	Duration	Total Float
1-2	6	0	3	3
1-3	8	0	7	1
1-4	6	0	6	0 CR
2-5	13	3	4	6
etc				

Uncertainty in Activity Durations

P.E.R.T. - Programme Evaluation and Review Technique

Uses three estimates for activity duration:

t_o - optimistic
t_m - most likely
t_p - pessimistic

and applies a Beta probability distribution to these.

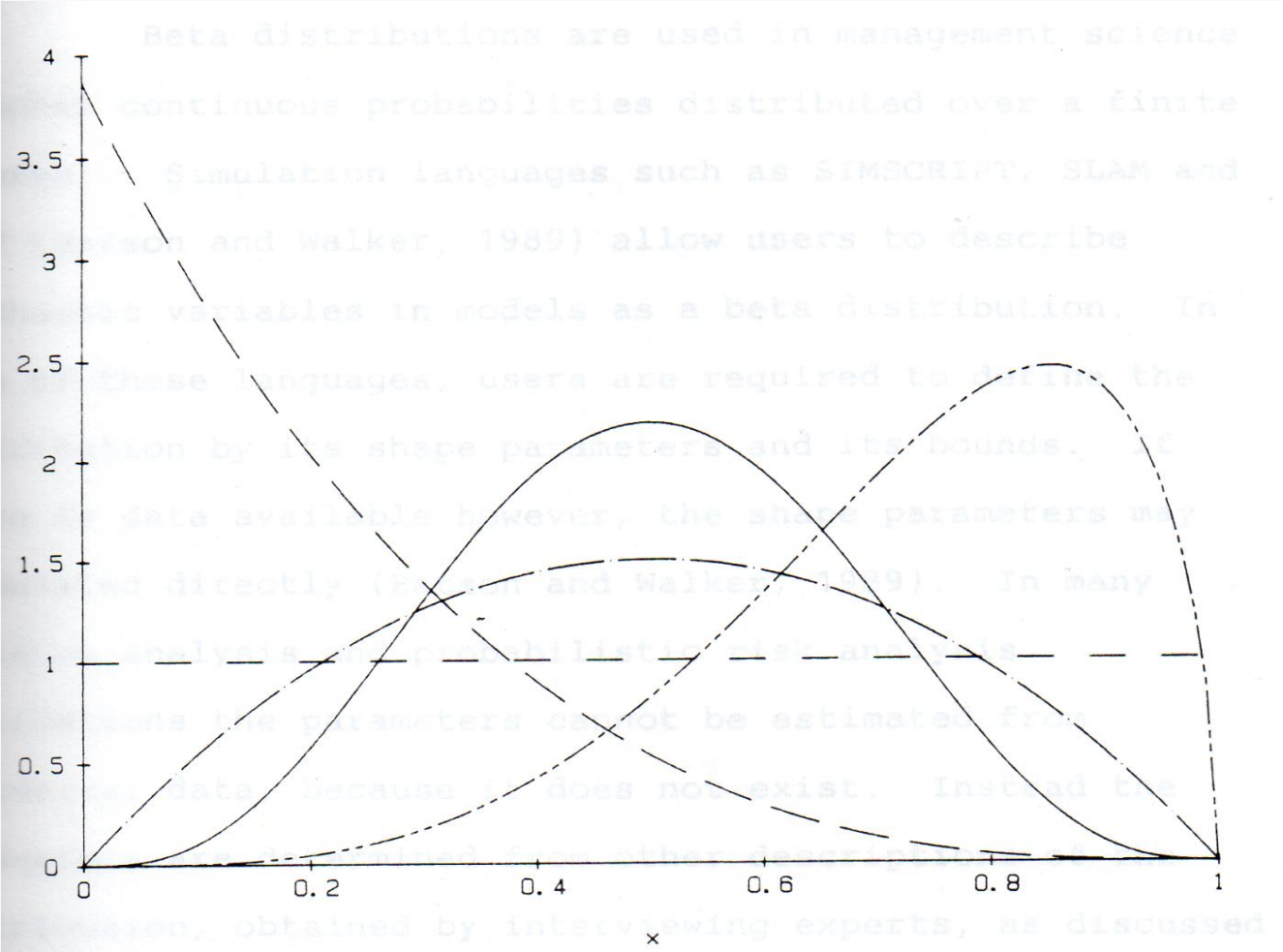
Characteristics of the Beta distribution.

Except at the extremes (where they go off to infinity) the distribution is;

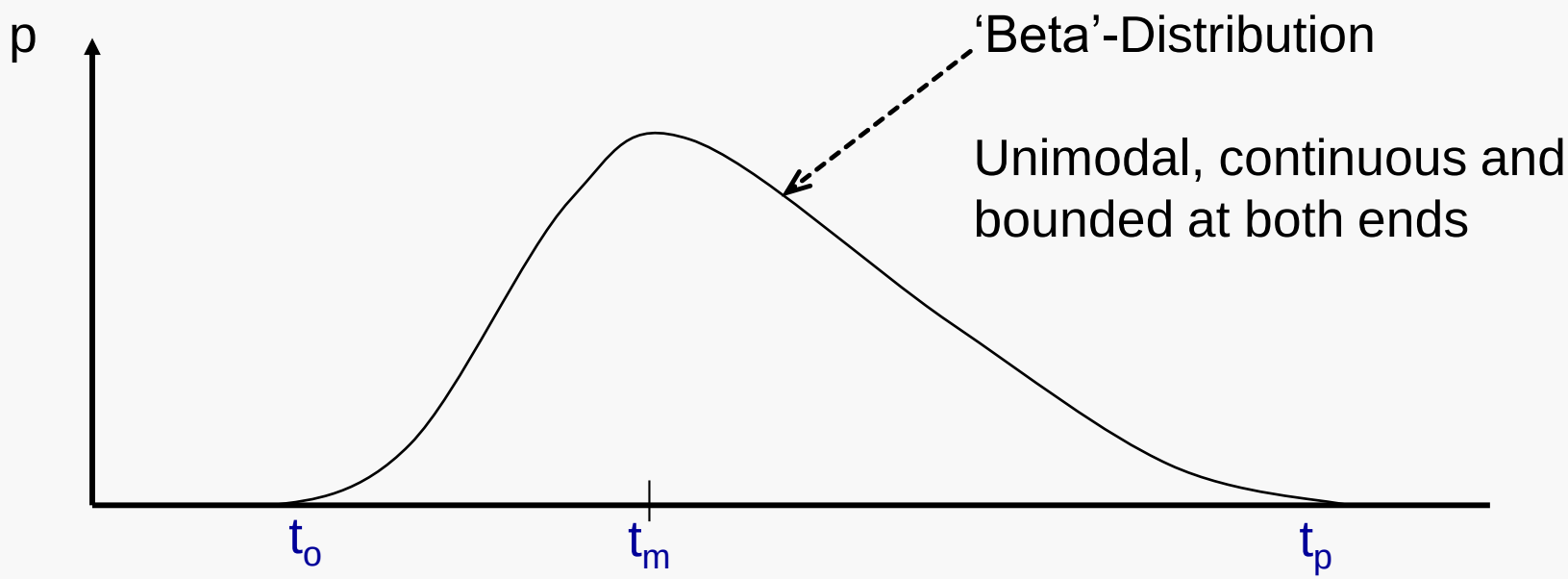
Unimodal and is bounded* at the upper and lower ends.

*Bounded – means that, unlike the Normal distribution for example, the Beta distribution meets the x axis at its upper and lower bounds.

Possible shapes of a Beta distribution



However we are interested only in certain types of the ‘Beta’-Distribution; only those which do not go off to infinity at the extremes.



For convenience, a further assumption is made which limits the shapes of the Beta distribution; namely that the distribution has a standard deviation of 1/6 th of its range.

This is analogous to a standard normal distribution which has a standard deviation of about 1/6 of its range between the 5th and 95th centiles.

Therefore the assumed standard deviation is;

$$\sigma = \left(\frac{t_p - t_o}{6} \right)$$

and the associated Variance is

$$V = \sigma^2 = \left(\frac{t_p - t_o}{6} \right)^2$$

The approximate duration t_e of an Activity with :

t_o - optimistic
t_m - most likely
t_p - pessimistic

is

$$t_e = \frac{t_o + 4t_m + t_p}{6}$$

Summary : The Expected Duration of an Activity:

$$t_e = \frac{t_o + 4t_m + t_p}{6}$$

Associated Variance:

$$V = \left(\frac{t_p - t_o}{6}\right)^2$$

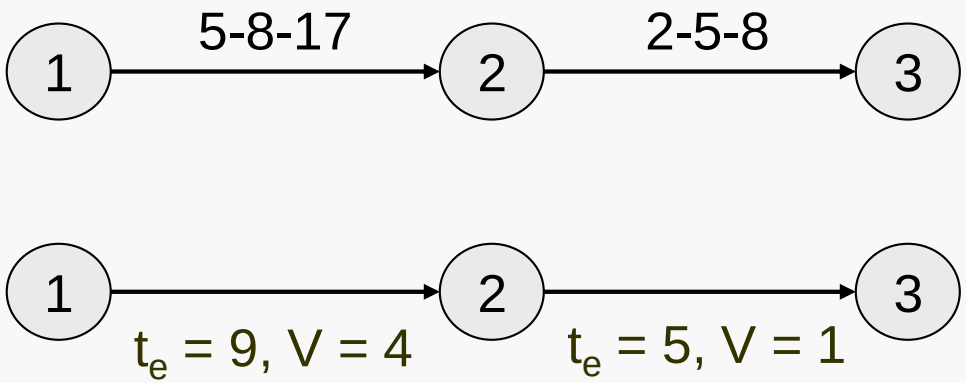
A simple example:

t_o = 5 days t_m = 8 days t_p = 17 days

$t_e = (5 + 32 + 17) / 6 = \underline{9 \text{ days}}$

$V = [(17 - 5) / 6]^2 = 2^2 = 4$

How can we use these two entities to get estimates of the length of a *path* (consisting of *several* activities)?



Assuming activity independence, the expected length of the path/project is simply the sum of the expected durations of the activities concerned:

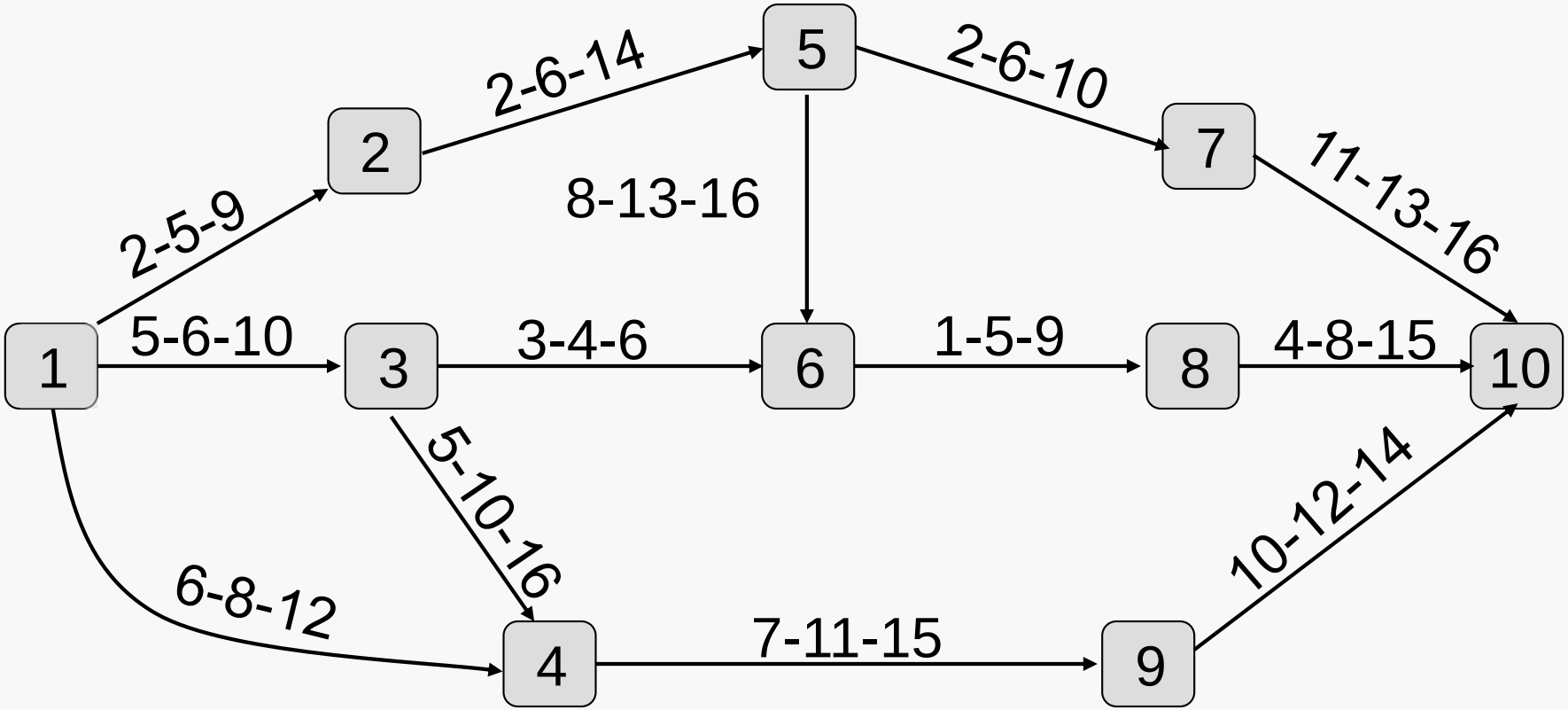
$$T_e = 9 + 5 = 14 \text{ days}$$

Similarly, for independent activities the variance of T_e is given by the sum of the individual variances:

$$V_t = 4 + 1 = 5$$

Note that if there is more than one critical path, it is the path with the greatest variance which is used to find the probability of completion by certain times.

Example:


1
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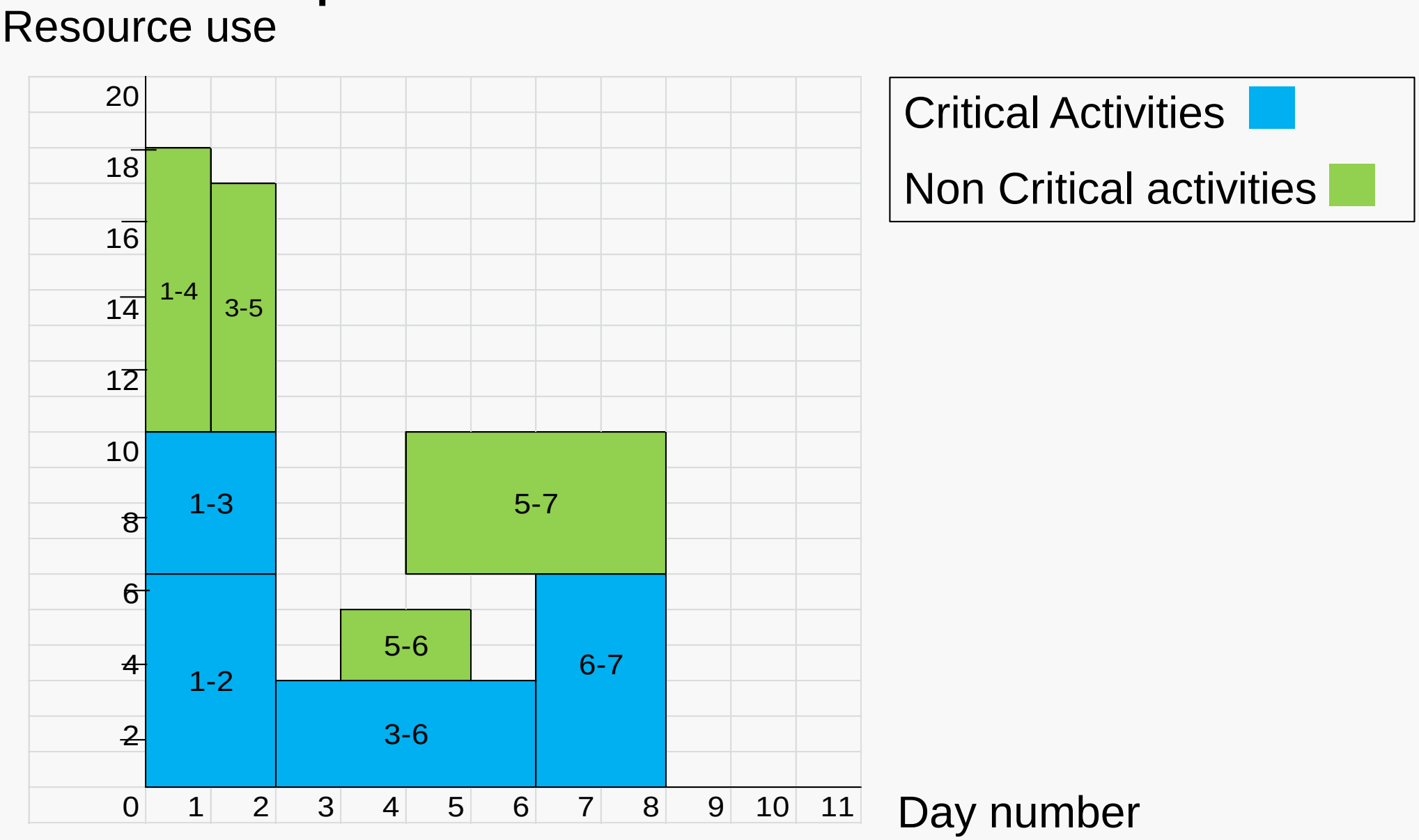
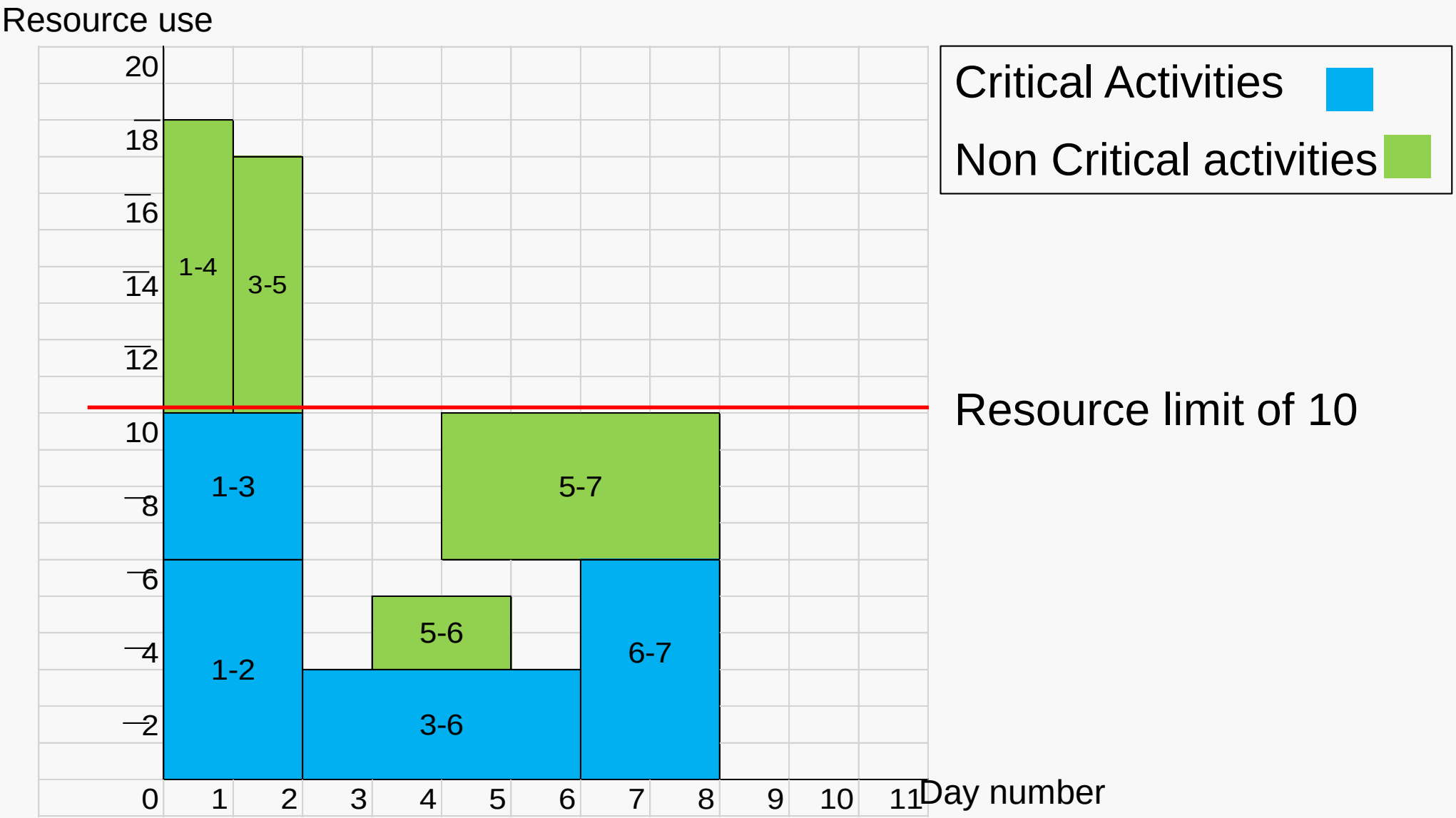
9
10
2-5-9
2-6-14
2-6-10
8-13-16
11-13-16
5-6-10
3-4-6
1-5-9
4-8-15
5-10-16
6-8-12
7-11-15
10-12-14

Activity	Expected activity duration	Variance	Earliest Start	Latest Start	Total Float	
(1,2)	5.2	1.36	0	1.6	1.6	
(1,3)	6.5	0.69	0	0	0	
(1,4)	8.3	1.00	0	8.4	8.4	
(2,5)	6.7	4.00	5.2	6.8	1.6	
(3,4)	10.2	3.36	6.5	6.5	0	
(3,6)	4.2	0.25	6.5	22.0	15.5	
(4,9)	11.0	1.78	16.7	16.7	0	
(5,6)	12.7	1.78	11.9	13.5	1.6	
(5,7)	6.0	1.78	11.9	20.5	8.6	
(6,8)	5.0	1.78	24.6	26.2	1.6	
(7,10)	13.2	0.69	17.9	26.5	8.6	
(8,10)	8.5	3.36	29.6	31.2	1.6	
(9,10)	12.0	0.44	27.7	27.7	0	

Expected length of critical path: 39.7 (and hence expected project duration =39.7
Associated variance: 6.27

Resource histogram when it is assumed that each activity starts at the earliest possible time



Resource histogram when it is assumed that each activity starts at the earliest possible time