

Networks

Any large project will involve the completion of a number of smaller jobs or tasks. Some of these tasks can be started straight away, some need to await the completion of other tasks and some tasks can be done in parallel. A **network** is a way of illustrating the various tasks and showing the relationship between them. A network can be used to show clearly the tasks or activities that need to be **completed on time** to keep the project on time and also those tasks that can be delayed without affecting the project time.

The technique of drawing up networks was developed during World War II and in the late 1950s in both the UK and the USA. In the UK it was developed by the Central Electricity Generating Board where its application reduced the overhaul time at a power station to 32% of the previous average. The US Navy independently developed the Programme Evaluation and Review Technique (PERT), whilst the Du Pont company developed the critical path method, said to have saved the company \$1 million in one year. All of these techniques are similar and have found applications in the building industry, in accountancy, and in the study of organisations, as well as their original uses.

Networks provide a planned approach to project management. To be effective, networks require a clear definition of all the **tasks** that make up the project and pertinent **time estimates**. If the project manager cannot clarify the necessary tasks and the resource requirements, then no matter how sophisticated the network, it will not compensate for these shortcomings. A number of claims have been made about the benefits of project management techniques but others have argued that in part, the benefits are due to managers having to know and clarify the tasks rather than the diagram which follows (which may by then be self-evident).

The objectives of network analysis are to locate the activities that must be kept to time, manage activities to make the most effective use of resources and look for ways of reducing the total project time. For any but the smallest projects, this analysis is likely to be done using a computer package, but your understanding of the output will only develop if you have some experience of the basic steps of analysis.

OBJECTIVES:

After working through this section, you should be able to:

- construct a network diagram;
- determine the earliest and latest start times;
- identify the critical path;
- explain the use of and calculate 'float' values;

1. Notation and construction

To construct and analyse networks you need to be familiar with the notation and language.

An **activity** is a task or job that requires time and resources, such as counting the number of defective items, constructing a sampling frame or writing a report. An activity is represented by an unbroken arrow:



It should be noted that the method of network construction presented in this book is '**activity on the arrow**' (the alternative is referred to as 'activity on the node').

An event or **node** is a point in time when an activity starts or finishes, for example, start counting the number of defective items or complete writing the report. An event or node is represented by a circle:



A **dummy activity** is used to maintain the logic of the network and does not require time or resources. A dummy activity is represented by a broken line with an arrow:



A **network** is a combination of activities and nodes which together show how the overall project can be managed.

CASESTUDY

The Ressembler Group is looking at the possible test launch of a new type of picture frame called 'Dale'. The main activities have been identified and times estimated as shown in Table 1.

Table 1 Activities necessary for test launch

Activity label	Description	Preceding activities	Duration (days)
A	Decide test market area	—	1
B	Agree marketing strategy	—	2
C	Agree production specification	—	3
D	Decide brand name	B	1
E	Prepare advertising plan	A	2
F	Agree advertising package	E	3
G	Design packaging	D	2
H	Production of test batch	C	5
I	Package and distribute	G, H	10
J	Monitor media support	F, D	3

The speedy construction of a network is a matter of practice and experience. A number of computer packages will construct the network diagram, but activities and precedence need to be fully specified. Network construction is an iterative process and several attempts may be needed to achieve a correct representation. Every network starts and finishes with a node; for good practice, you should avoid arrows that cross and arrows that point backwards.

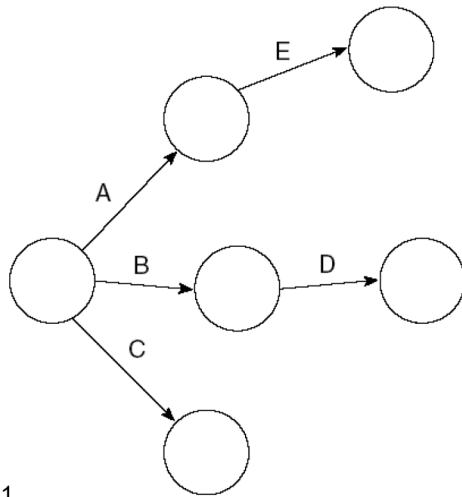


Figure 1

In Figure 1, we see the beginnings of the network for the project outlined in Table 1. Activities A, B and C can all begin immediately, since none have prerequisites. Once activity B is complete then activity D can begin. Each arrow is labelled, indicating that the method of construction is **activity on the arrow**.

The completed network is shown as Figure 2. The use of the dummy variable to maintain the logic should be noted; activity G follows only activity D whereas activity J follows both activity D and F.

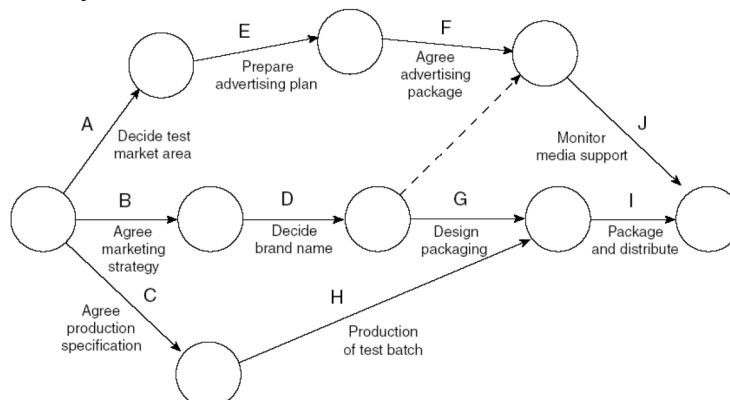


Figure 2 Completed network diagram.

Two situations when a dummy variable is likely to be required are shown in Figure 3.

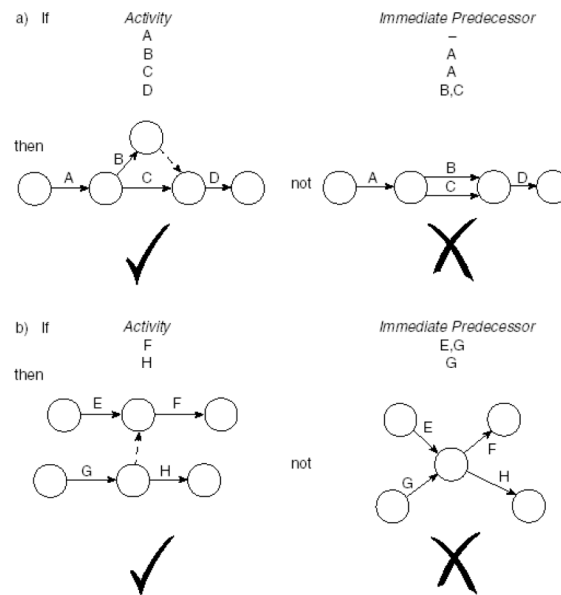


Figure 3 Diagramming a dummy activity.

EXERCISE

Check that you can use the information given in Table 2 to draw the network shown in Figure 4

Table 2

Activity	Duration (days)	Preceding activities
A	10	—
B	3	A
C	4	A
D	4	A
E	2	B
F	1	B
G	2	C
H	3	D
I	2	E, F
J	2	I
K	3	G, H

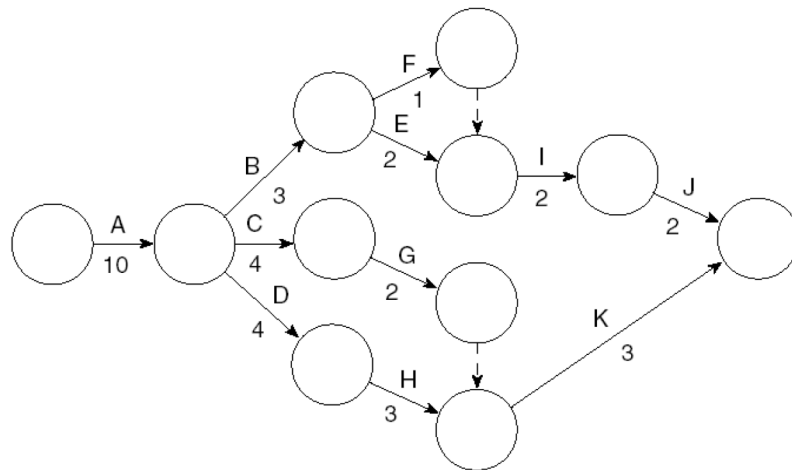


Figure 4

2. The critical path

The **critical path** is defined by those activities that must be completed on time for the project to be completed on time. To find the critical path we need to determine the earliest and latest times that an activity can begin and end. Each node is divided into three, as shown in Figure 5.

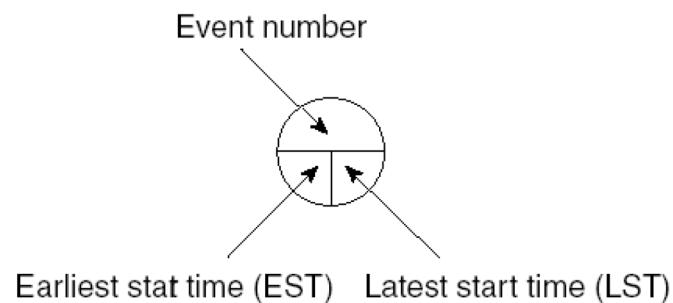


Figure 5

The earliest start time

The **earliest start time (EST)** is the earliest time that an activity could begin assuming all the preceding activities are completed as soon as possible. The convention is always to start with 0. As a rule of thumb the earliest start times are found by moving forward (from left to right) through the network adding activity times. If there are two or more routes leading to a node, the largest value is used.

The latest start times

The **latest start time (LST)** is the latest time an activity can begin without causing a delay in the overall duration of the project. It is necessary to use the overall duration given in the finish node and work backwards. As a rule of thumb the latest start times are found by moving backwards (from right to left) from the finish node, subtracting activity times. If two or more activities lead backwards to a node then the smallest value is used.

The critical path

In general, the critical path will pass through all those nodes where the EST is equal to the LST and this provides an easy way of scanning the network for the critical path. However, in some circumstances (see section 3, fig 8) this approach may suggest that a non-critical activity is critical.. To be sure, you need to check that a measure called **total float is equal to 0** (no spare time).

Total float

The **total float** for an activity is the difference between the maximum time available for that activity and the duration of that activity. The total float for an activity with a start node of i and a finish node of j is given as:

$$\text{total float} = \text{LST for } j - \text{EST for } i - \text{duration of activity}$$

The earliest and latest start times for the project described in Table 1 are given in Figure 6.

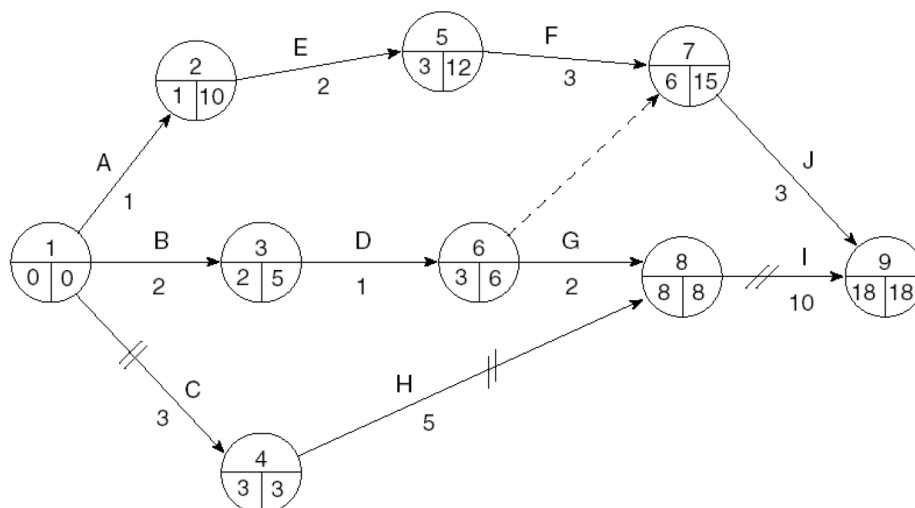


Figure 6

The calculation of time begins with a 0 EST in node 1. We would then add a 1, 2 and 3 to 0 to get the EST at nodes 2, 3 and 4. The activity times for E and D, 2 and 1, are then added to get the EST at nodes 5 and 6. At node 7, we need to consider the cumulative times from activity F and through the dummy. To ensure the inclusion of a route using a dummy, the dummy can be given the value 0. In this case, from node 5 to 7 we have 3 + 3 and from node 6 to 7 we have 3 + 0; the largest value is 6 and therefore becomes the EST at node 7. At node 8 we need to consider 3 + 2 (node 6 to 8) and 3 + 5 (node 4 to 8); the largest value is 8 and becomes the EST at node 8. Finally the largest sum at node 9 is 8 + 10 and 18 becomes the EST. It should be noted that even at this stage we can identify 18 days as the duration of the project. To find the LST's we work backwards using the duration of the project, 18, as the LST at the finish node.

Subtraction of activity times J and I gives the LST of 15 at node 7, and 8 at node 8. At node 6 we need to consider moving backwards from node 7 (15 - 3) and from node 8 (8 - 2); the smallest value is 6 and this becomes the LST. The process continues until all the time measures are calculated. The critical path is formed by the activities C, H and I and is shown by the // symbol. In this case, the nodes where the EST = LST define the critical path. (It is clear by observation that activities C, H and I have 0 total float and all other activities have some total float.)

EXAMPLE

Using the information given in Table 2 and the network given as Figure 4 check the times and critical path shown in Figure 7.

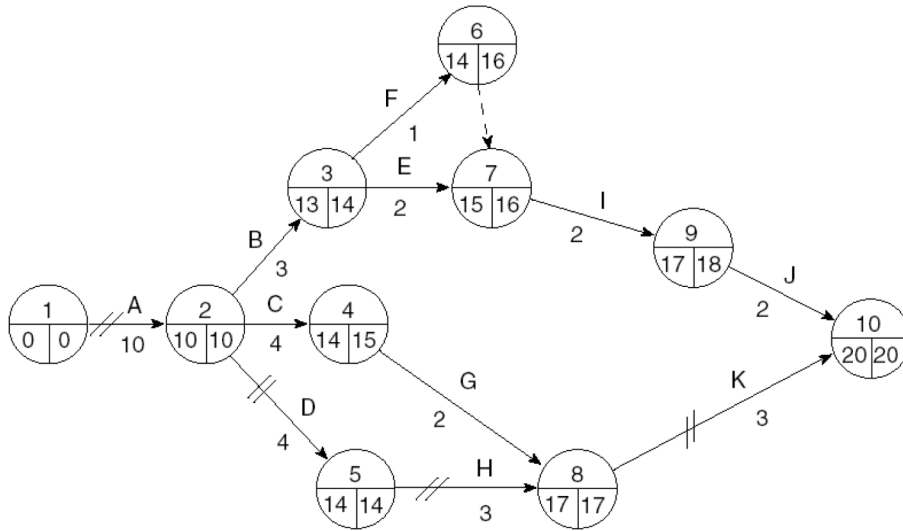


Figure 7

The EST's and LST's again make the critical path obvious: A, D, H, K. However, suppose that activities C and G were combined into a new activity L taking six days. This part of the network is shown in Figure 8.

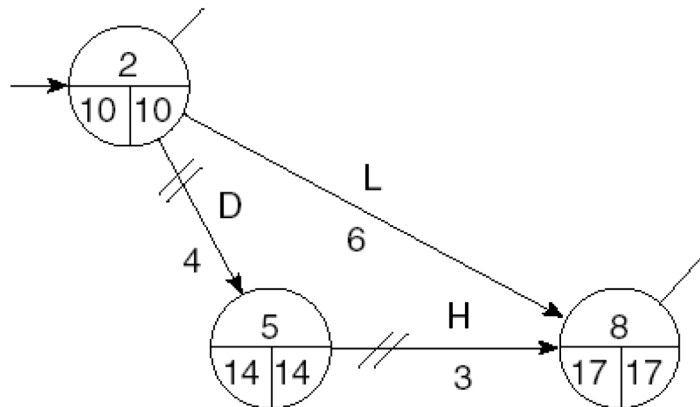


Figure 8

The EST's and LST's are equal on nodes 2 and 8 but activity L is not a critical activity. The total float for activity L is

$$\begin{aligned}
 &= \text{LST for } j \text{ (node 8)} - \text{EST for } i \text{ (node 2)} - \text{duration of activity L} \\
 &= 17 - 10 - 6 \\
 &= 1 \text{ day}
 \end{aligned}$$

The total float is 0 on activities D and H and they remain critical.

3. Measures of float

We have seen that if the difference between the maximum time available and the duration of the activity, the total float, is 0 then the activity is critical. There are two other important measures of float, **free float** and **independent float**.

Free float

Free float is the time that an activity could be delayed without affecting any of the activities that follow.

$$\text{Free float} = \text{EST for } j - \text{EST for } i - \text{duration of activity}$$

However, free float does assume that previous activities run to time.

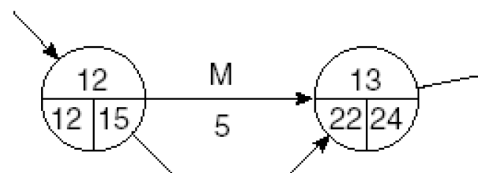
Independent float

The **independent float** gives the time that an activity could be delayed if all the previous activities are completed as late as possible and all the following activities are to start as early as possible.

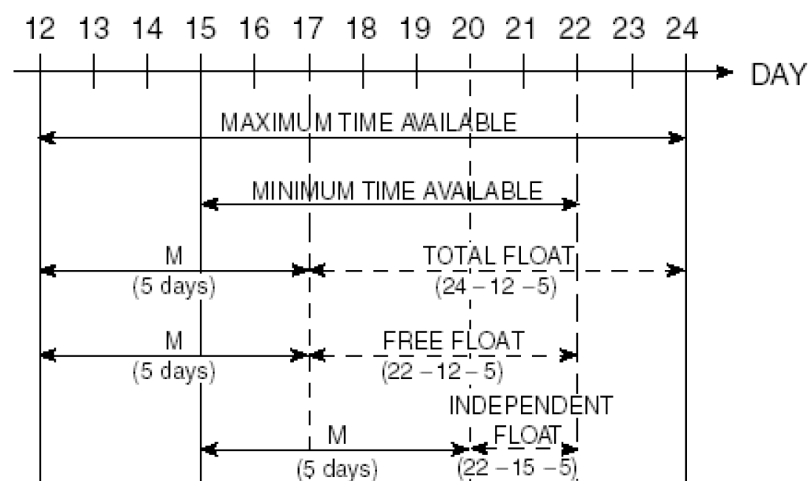
$$\text{Independent float} = \text{EST for } j - \text{LST for } i - \text{duration of activity}$$

The determination of total, free and independent float is illustrated in Figure 20.10.

Consider the following activity M:



The 'measures of float' can be represented:



It can be seen that total float is seven days, free float is five days and independent float is two days.

Figure 9