37 Project management

This chapter covers syllabus section 5.8 (Higher level only)

On completing this chapter you should be able to:

- H construct and interpret a network diagram
- H analyse how critical path analysis (CPA) and network diagrams can be used to help with project management
- H apply CPA to different projects
- H evaluate the usefulness of a network in the management of projects.

SETTING THE SCENE

Building a new bridge

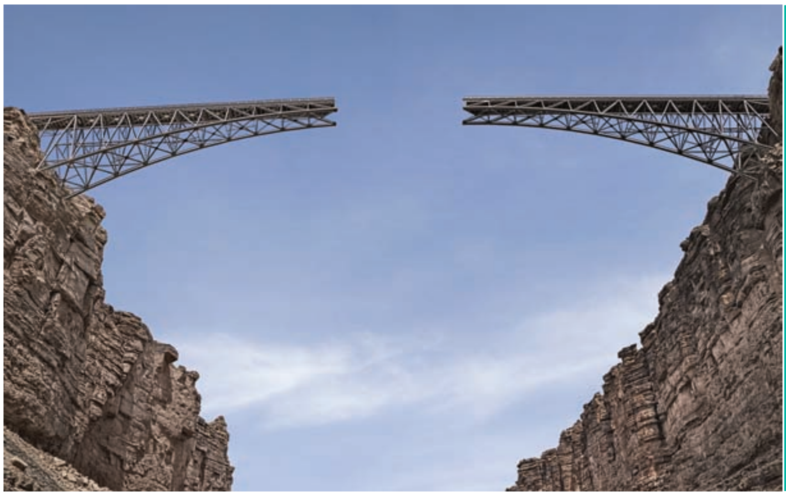
The Eastern Construction Company has just received its first major bridge-building contract from a foreign government. The company managers have been keen to sign this contract as it means that they will be able to add to the range of building projects that they have worked on. Jimmy Chen has been appointed project manager for this key contract. He has seen government officials on several occasions to obtain agreement on:

- the exact size and specifications of the bridge
- the expected completion date
- the value of the contract – the price the government has agreed to pay for the completed bridge.

Jimmy has a team of managers to help him calculate the exact materials and equipment needs of this building project – they will take responsibility for seeing the project through to completion. IT specialists have been asked to draw up a diagram showing all of the different tasks of the project, the estimated time for each task and the resources needed for each. This diagram has shown that some tasks can be done together – such as laying the tarmac on the road and painting the steel structure, and other tasks must be completed before any other work can start – such as building an access road and laying foundations for the bridge.

After six months, building work has started and the project is on time – so far. Some costs have exceeded estimates – but others are lower than expected. Both Jimmy and his senior managers hope that if the project is seen as a success, other bridge contracts will be awarded to the company.

37 Project management



Points to think about:

- Why is careful management of this project particularly important to this company?
- Why would a diagram of activities be useful to Jimmy and his team?
- What problems might there be in making sure this diagram was as accurate as possible?

Introduction

KEY TERMS

project a specific and temporary activity with a start and end date, clear goals, defined responsibilities and a budget

project management using modern management techniques to carry out and complete a project from start to finish in order to achieve pre-set targets of quality, time and cost

Examples of business projects include:

- setting up a new IT system
- relocating the company operations
- installing machinery
- developing and launching a new product
- building a factory.

To be completed successfully, a project needs to be planned and managed, costs determined and times allocated, problems dealt with and, eventually, concluded. Formal methods of managing a project offer clear guidelines and deadlines. The key elements of project management include:

- defining the project carefully, including the setting of clear objectives
- dividing the project up into manageable tasks and activities
- controlling the project at every stage to check that time limits are being kept to
- giving each team member a clear role
- providing controls over quality issues and risks.

Failure to manage projects successfully can have serious consequences for any organisation. In the 'Setting the scene' case study above, any failure to complete the building of the bridge on time and within budget could result in:

- penalty payments having to be paid to the customers
- bad publicity in the construction industry
- loss of future contracts.

A Standish Report on project management suggested that major projects failed because:

- customers were not involved in the planning and development process
- the project had inadequate or no resources that were vital for its completion
- senior management did not seem interested in seeing the project through
- the project specification kept changing during the life of the project
- planning was poor
- the project's scope had become outdated due to change in the business environment
- the project team was technically incompetent.

Critical path analysis (CPA)

Operational resources are expensive and the most expensive resource is that which is unused or underused – unused stocks take up space and working capital; machinery left idle wastes capital and can require protective maintenance; labour waiting for supplies to arrive will add unnecessarily to the wages bill. Efficient firms will always aim to use their resources as intensively as possible and avoid wasted time and idle assets. Keeping assets busy is not always as easy as it sounds, especially when the project is a complex one.

Consider the construction of a house:

- The builder only wants to employ specialist staff on a subcontract basis when the job is ready for their particular skills.

- He also wants to order bricks and other materials to arrive just as they are needed, not weeks before, blocking up the site, wasting working capital and inviting theft.
- He certainly does not want them three days after the bricklayers require them.
- Specialist equipment is often hired and to keep this a day more than necessary will raise costs and affect cash flow.

How can all of the different tasks involved in building a house be put into order so that the right goods and labour can be employed just at the right time? The answer for many businesses is to use a technique known as critical path analysis (CPA) – also known as network analysis.

KEY TERM

critical path analysis planning technique that identifies all tasks in a project, puts them in the correct sequence and allows for the identification of the critical path

THE CRITICAL PATH ANALYSIS PROCESS

CPA involves drawing a network diagram that indicates the shortest possible time in which a project can be completed. The activities – that must be completed to achieve this shortest time – make up what is known as the critical path. The process of using CPA involves the following steps:

1. Identify the objective of the project, e.g. building a factory in six weeks.
2. Put the tasks that make up the project into the right sequence and draw a network diagram.
3. Add the durations of each of the activities.
4. Identify the critical path – those activities that must be finished on time for the project to be finished in the shortest time.
5. Use the network as a control tool when problems occur during the project.

KEY TERMS

network diagram the diagram used in critical path analysis that shows the logical sequence of activities and the logical dependencies between them – and the critical path can be identified

critical path the sequence of activities that must be completed on time for the whole project to be completed by the agreed date

USING CRITICAL PATH ANALYSIS

Constructing a simple network diagram to identify the critical path

The objective is to see if a new machine can be installed and the staff trained to operate it within three weeks (assume a five-day working week) (see Figure 37.1). A network diagram uses the following notation:

- An arrow indicates each activity.
- An activity takes up time and resources.
- A node (circle) indicates the end of each activity.

The activities involved in this project and the estimated time for each activity (duration) are as follows:

- Strip out old machine (A) – three days.
- Order new machine and await arrival (B) – one day.
- Prepare site for new machine (C) – two days.
- Assemble new machine (D) – two days.
- Install new machine (E) – one week.
- Demonstrate to workers (F) – two days.
- Obtain necessary raw materials (G) – one day.
- Trial test run (H) – three days.

You will notice from the diagram that from the first node, two activities can start. This is because stripping out the old machine and ordering the new one are independent activities. They can be done simultaneously and do not have to be done in sequence.

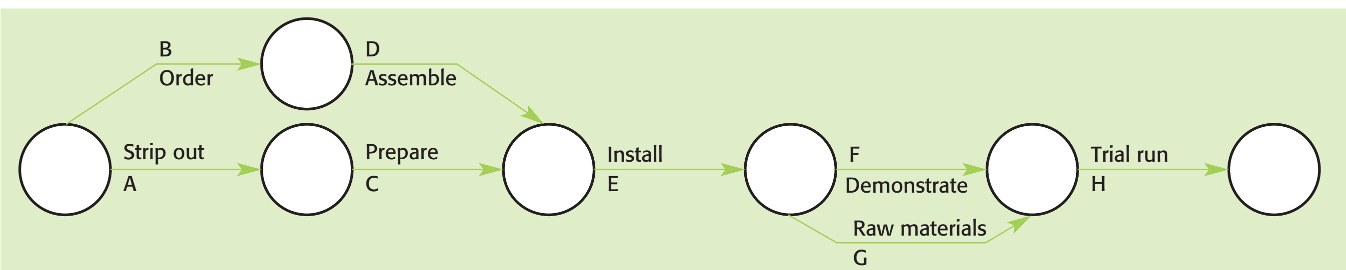


Figure 37.1 Installing a new machine – the network diagram

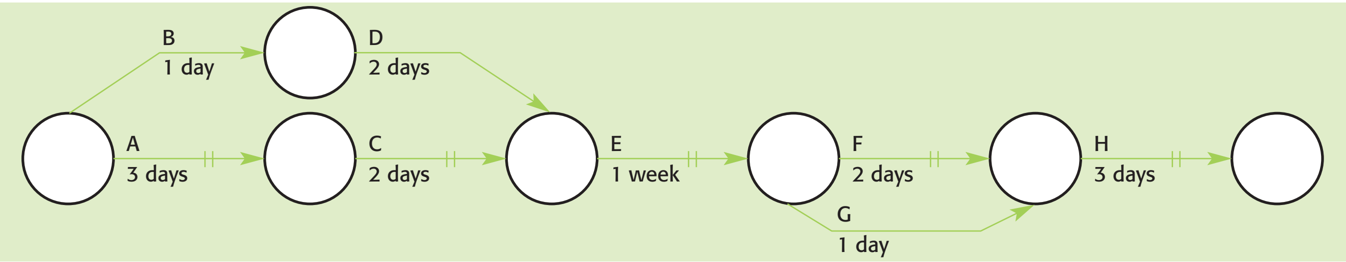


Figure 37.2 Adding durations to find the critical path

Clearly, this is a relatively simple project and, if these durations are added to the network diagram, it is possible to determine visually:

- which is the critical path of activities – these activities are indicated with pairs of short parallel lines
- that the project can be completed within three weeks – see Figure 37.2.

It is clear that the 'critical' activities are A, C, E, F and H. If these should be delayed in any way, for example if the preparation of the site takes more than two days, then the whole task will take longer than three weeks. It can be seen that the other activities are not critical – these, in fact, may have some spare time. This is termed float time. In more complex projects, this can be useful for achieving an even more efficient use of resources.

How the critical path is determined: a more complex example

The objective is to construct a house in 42 days. To create the network diagram, the tasks to be performed in order to build the house have been broken down into ten main activities, such as digging foundations and tiling the roof. These activities must be done in a certain order – the roof cannot be tiled before the walls are built, for instance – and this order of tasks is as shown in Table 37.1. The network diagram for these activities is shown in Figure 37.3.

Activity	Preceding activities
A	–
B	–
C	A
D	B and C
E	A
F	E
G	F and D
H	B and C
I	G and H
J	I

Table 37.1 *The order of tasks in building a house – the objective is to build a house in 42 days*

You will notice from the diagram that each of the nodes has been numbered for ease of reference. The duration times for each activity, shown in Table 37.2, can now be added to the network diagram (see Figure 37.4).

These durations are very important. They allow us to calculate both the critical path and the spare time – or float time – for the non-critical activities. The critical path is indicated by calculating, at each node, the earliest start time (EST) and the latest finish time (LFT). These have already been added to the nodes in Figure 37.4. Figure 37.5 opposite illustrates how the node numbering should be shown.

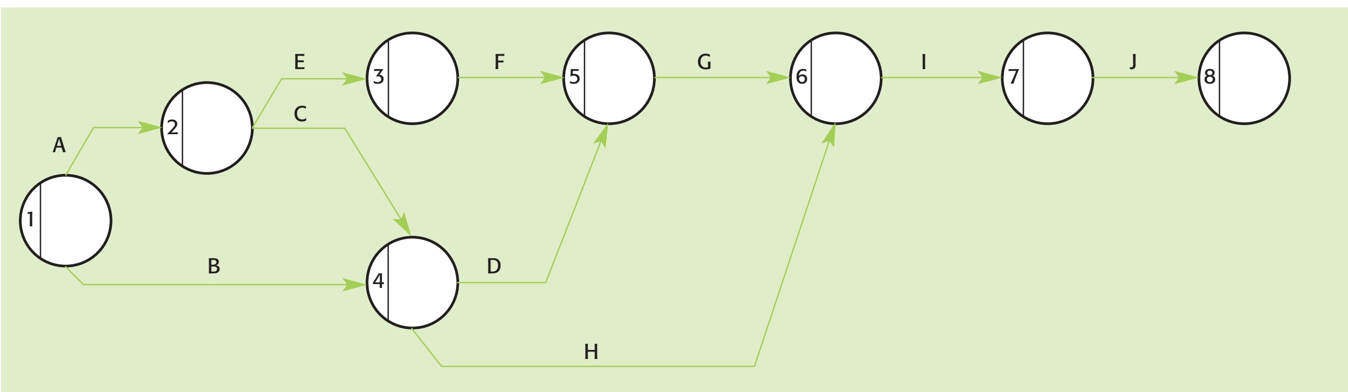


Figure 37.3 The main stages of building a house

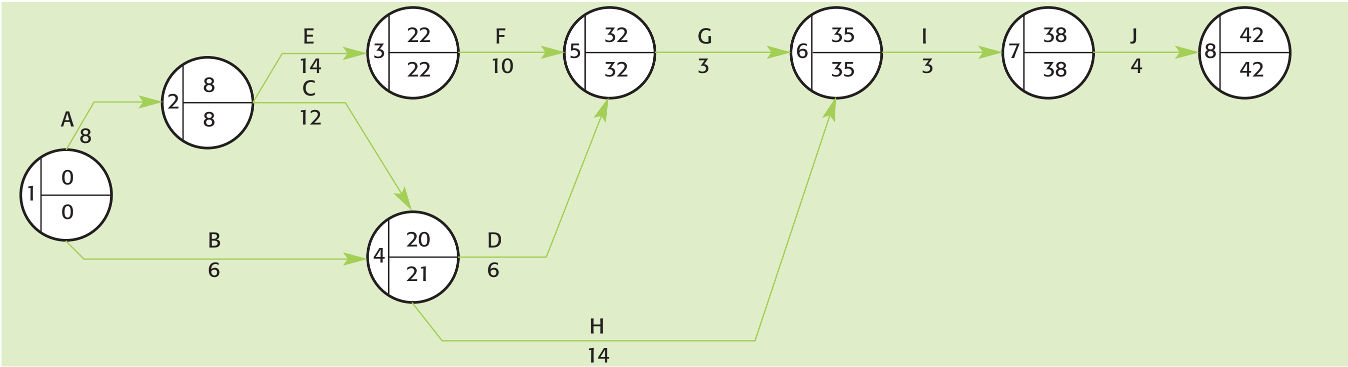


Figure 37.4 *Adding in the activities and durations*

Activity	Duration (days)
A	8
B	6
C	12
D	6
E	14
F	10
G	3
H	14
I	3
J	4

Table 37.2 *Duration times of the tasks in building a house*

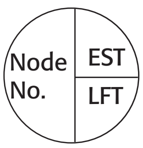


Figure 37.5 *Node numbering*

Critical path analysis helps avoid delays on construction projects

ACTIVITY 37.1

Verify the ESTs in Figure 37.4 by working through the diagram from left to right, taking the longest route, in days, to each node.

What is the earliest start time and how is it calculated?
It is the earliest time each activity can begin, taking into account all of the preceding activities. So, activity E cannot start before day 8 because A will not be finished before then. And D cannot start before day 20 because both A and C have to be completed first.

What is the latest finish time and how is it calculated?
It is the latest time an activity can finish without delaying the whole project. So, I (and all preceding activities) must be finished by day 38 or the entire project will take longer than 42 days (because 4 days must be allowed to finish J itself). Task F (and all preceding activities) must finish by day 32 or the time taken to complete G, I and J will take the total project time over 42 days.

The easiest way to calculate the LFTs is to work from right to left. The LFT at node 8 must be 42 – the total project time. The duration of activity J is now subtracted from this to give 38. This is the LFT at node 7.Where there is a choice of routes back to a node, the aim is to achieve the lowest number for LFT. The LFT for node 4 is therefore 21, achieved by working back through J, I and H, even though a higher number could be reached by working through J, I, G and D. Remember, the lowest number at each node is what is required for the LFT.

ACTIVITY 37.2

Verify all of the LFTs by your own calculation.

ACTIVITY 37.3

Activity	Preceding activities	Duration
A	–	4
B	A	6
C	A	7
D	B	12
E	C	9
F	D and E	3
G	A	16
H	G and F	3

Activities and durations for Project X

20 marks, 35 minutes

1 Draw the network for Project X. [6]

2 Use the duration times to calculate the EST and LFT of each activity. [6]

3 Identify the critical path. [2]

4 Explain the importance of this critical path to the operations manager. [6]

What is the critical path for this project?
Those activities that have no spare time are the critical ones. These activities are shown by those nodes where EST and LFT are equal. Take node 3 as an example. The EST of F is 22. This is the same as the LFT of E. Therefore no delay is possible – F must start on time or the whole project will over-run. Therefore, the critical path is made up of activities A, E, F, G, I and J. These will take 42 days to complete, so this becomes the project duration. Float times have very significant applications in managing resources – see advantages of network analysis.

Calculating float times for non-critical activities
Look at the network diagram for building a home (Figure 37.4). Non-critical activities B, C, D and H will have 'float' time. All of the non-critical activities, those not on the critical path, will have a certain amount of spare time. This spare time is called float. There are two types of float:

- Total float is the amount of time an activity can be delayed without delaying the whole project duration. This is calculated by the formula:

  total float = LFT – duration – EST

  Take task D as an example:

  LFT of D is 32
  Duration is 6
  EST of D is 20 and therefore:

  total float for D = 32 – 6 – 20 = 6 days

  D could be delayed by up to 6 days without extending the total project duration or changing the critical path.

- Free float is the length of time an activity can be delayed without delaying the start of the following activities. This is calculated by the formula:

  free float = EST (next activity) – duration – EST (this activity)

  Take task B as an example:

  EST of next activity after B is 20
  Duration of B is 6
  EST at the start of B is 0 and, therefore:

  free float for B = 20 – 6 – 0 = 14

B could be delayed by 14 days without delaying the start of either H or D, the following activities. See Table 37.3.

Activity	Total float	Free float
B	15	14
C	1	0
D	6	6
H	1	1

Table 37.3 *Float time for all non-critical activities*

Dummy activities
A dummy activity is not strictly an activity at all. It is shown by a dotted line on a network diagram. It does not consume either time or resources. What it shows is a 'logical dependency' between other activities that must be included in certain networks to prevent an illogical path from being created. Consider these activities and the relationships between them:

- The activities A and B are the start of the project. They have no preceding activities.
- C follows A.
- D follows A and B.

How can the network be drawn? Figure 37.6 shows one attempt – but it is wrong. Can you see why? The network shows that both C and D require A and B to be finished, whereas C only requires A to finish before it can start.

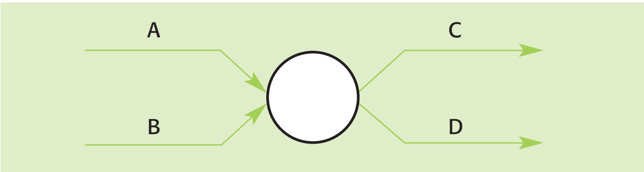


Figure 37.6 First attempt at drawing a network

The correct network is shown in Figure 37.7, which shows the correct logical dependencies – C starts when A is finished, but D has to wait before both A and B are finished. The dummy activity shows the relationship between B and D – with the arrow indicating the direction of the dependency.

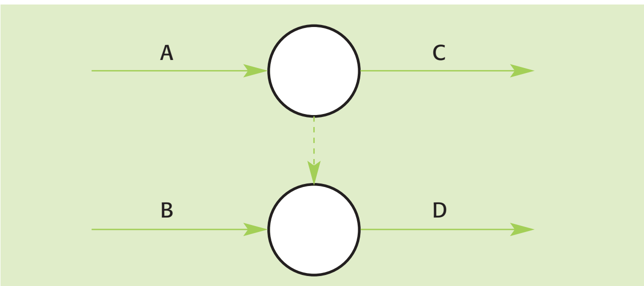


Figure 37.7 The correct network

THE ADVANTAGES OF NETWORK ANALYSIS

It has already been stated that network analysis can be used to assist the planning and management of complex projects. The following are some of the advantages that result from using the technique:

- Using the diagram to calculate the total project duration allows businesses to give accurate delivery dates. Customers may insist on a particular completion date and the critical time shows whether the firm can make this date or not.
- Calculating an EST for each activity allows the operations manager to order special equipment or materials needed for that task at the correct time. This ties the use of network analysis in with JIT strategies and assists in the control of cash flow and working capital.
- Calculating the LFT of each activity provides a useful control tool for the operations manager. The manager will be able to see whether the project is up to schedule by checking the actual completion times of activities against the network LFT.
- Knowing the critical path can be very useful. If there is a delay on a critical activity, there is no float because it is critical and the delay will, unless quick action is taken, put back the whole project. This could lead to expensive damage claims from the customer. By knowing the critical path, the operations manager can see which other activities need to be speeded up if one has been delayed. For instance, in the house-building example above, if E was delayed by two days due to bad weather or non-arrival of equipment, the operations manager would know that one of the following critical activities needs to be accelerated to catch up on time lost.
- The additional resources for speeding up a critical activity could come from the non-critical ones. To use the house-building example, if F is to be reduced to eight days to counter the delay on E, the resources of labour, materials and machinery could be taken from D or H, as they both have spare time. This will allow a better and more efficient use of the firm's resources. This shows how the existence of float times on D and H allows resources to be allocated more efficiently.
- The sequential and logical structure of the diagram lends itself well to computer applications and nearly all business applications of network analysis will now be run on computer.
- The need to put all activities into sequence in order to structure the diagram forces managers to plan each project carefully by putting activities in the correct order.
- The need for rapid development of new products has never been greater in the fast-changing consumer markets of today. Network analysis gives design and engineering departments a positive advantage by showing them the tasks that can be undertaken simultaneously in developing a new product. This will help to reduce the total time taken by the new project and supports the principle of 'simultaneous engineering'.

EXAM TIP

No planning technique, however good, can ensure that a project will reach a successful conclusion – refer to all of the reasons mentioned at the start of this chapter that can cause a project to fail.

NETWORK ANALYSIS – AN EVALUATION

Network analysis is a planning and control technique to assist with project management. It cannot guarantee a successful project by itself and, as with any plan, requires skilled and motivated staff to put it into effect. In addition, a plan is only as good as the management putting it into effect – if management of the project is poor, then even a good critical path network diagram will not ensure success. This is particularly true when attempting to make up for lost time on a critical activity – experienced managers will need to identify the cheapest option for using and switching resources from non-critical activities.

Staff will feel more committed to the plan of operation if they have been consulted during its construction, for example over likely duration times for each activity.

When using CPA for a completely new project, there may be considerable guesswork involved in estimating the durations for each activity – as there will be no previous experience to go on. Although the manipulation of the network and of duration and float times is likely to be aided by computer, it can take skilled labour hours to put a complex project on to a computer. This time and the related expense must be justified by the subsequent cost and efficiency savings of applying the technique.

THEORY OF KNOWLEDGE

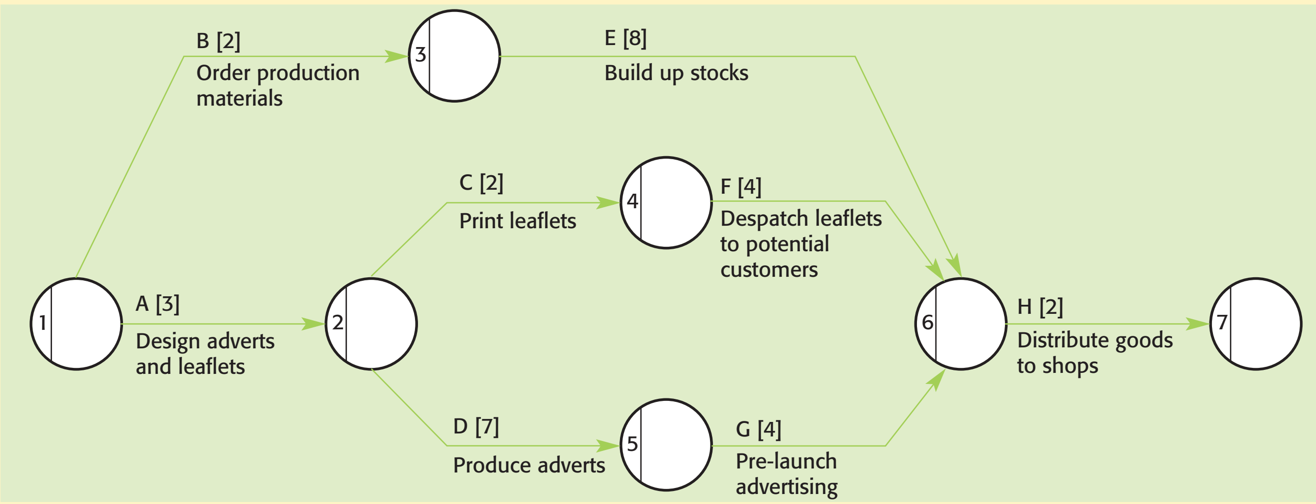
Business and Management has a number of planning tools and techniques.

a Examine how **two** techniques help business people make better decisions.

b 'Embarking on a project without a logically thought out plan risks a high probability of failure.' To what extent is logic an important part of business decision-making?

ACTIVITY 37.4

The launch of a new product



Network diagram showing the launch of a product

25 marks, 45 minutes

1 Calculate the EST and LFT at each node (all durations in weeks). [6]

2 Identify the critical path. [1]

3 Calculate the total floats and free floats for each non-critical activity. [6]

4 If D is delayed by an over-run in the production of the advertisements, suggest how the marketing manager might still be able to complete the launch in the original project time. [4]

5 Explain how the use of network analysis might have assisted the marketing manager during this project. [8]

OVER TO YOU

REVISION CHECKLIST

1 What is meant by 'project management'?
2 Why is it important to manage projects effectively?
3 What are the **four** key factors in project management?
4 What is meant by the 'critical path' in network analysis?
5 Explain why it important for an operations manager to monitor carefully the critical activities on a network diagram.
6 Explain the difference between the earliest start time of an activity and its latest finish time.
7 Distinguish between a non-critical activity's total float and free float in network analysis.
8 Outline **two** advantages for a road-building firm of using critical path analysis.
9 Suggest **one** other business that might benefit greatly from using critical path analysis.
10 Outline **two** limitations of critical path analysis.
11 Why might a project not be completed successfully, even though a detailed critical path analysis has been undertaken?

REVISION ACTIVITY

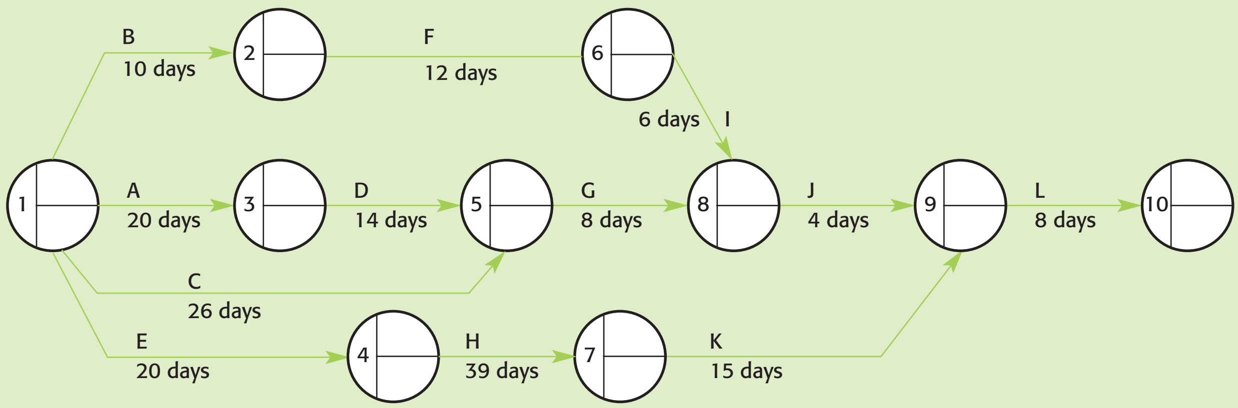
18 marks, 28 minutes

1 Calculate all ESTs and LSTs for the network shown in the diagram below. [6]

2 Calculate the duration of the critical path. [2]

3 Calculate total floats on all of the non-critical activities. [6]

4 Explain the disadvantages to the operations manager of ordering goods needed for task D to arrive on:
- day 25
- day 15. [4]



Critical path

EXAM PRACTICE QUESTION

Read the case study below and then answer the questions that follow.

SHUT DOWN AT JAMAICA PHOTOS

Jamaica Photos is a medium-sized private limited company. The firm specialises in photographic processing. It currently operates from two sites in Jamaica. After considerable consultation with employees, it is planning to close one of these sites, at Montego Bay, and to concentrate film processing at its Kingston branch. The managers of the company want to make sure that the closure should be carefully planned to reduce to a minimum the adverse effects on production and customer delivery times. A project management team has been drawn from all levels within the company to carry through this plan. The team has been offered a bonus if it can complete the task within 15 working days.

Closing the factory involves a number of activities as shown below:

Activity	Description	Duration (days)
A	End processing in Montego Bay; run down stocks of materials	2
B	Dismantle machinery	4
C	Knock out doorway to allow machinery to be moved	2
D	Pack office equipment	2
E	Transportation	3
F	Suspend processing at Kingston	8
G	Assemble machinery transported from Montego Bay	3
H	Re-organise production facilities in Kingston	2
I	Test new integrated processing system	2

The activities have the following dependencies:

- A is the start of the project.
- B, C and D cannot start until A is complete.
- E follows B, C and D.
- F has no preceding activity.
- F must be completed before I can commence.
- G and H follow E.
- I follows G and H.

25 marks, 45 minutes

1 Define the following terms:
   - **a** private limited company
   - **b** project management. [4]

2 Based on the information on the factory closure:
   - **a** construct a network diagram for closing the factory [6]
   - **b** calculate the ESTs and LFTs for each activity [4]
   - **c** identify the critical path. [2]

3 Evaluate the usefulness of critical path analysis to the management of Jamaica Photos. [9]