Edexcel

A Level

Business studies

(Code: WEC13 01)

Unit 03-Section 03

Decision – making techniques

CALCULATING TIME-SERIES ANALYSIS

It is often important for businesses to forecast future sales levels. are statistical methods which use past sales data to predict future sales. One important quantitative sales forecasting method involves using time-series analysis. The four main components that a business wants to identify in time-series analysis are:

- trend
- seasonal fluctuations
- cyclical fluctuations (i.e. fluctuations that are repeated lots of times in the same order)
- random fluctuations.

Year	2006	2007	2008	2009	2010
Sales ($ 000)	125	130	130	150	140

Year	2011	2012	2013	2014	2015
Sales ($ 000)	155	180	190	210	230

▲ Table 2 Yearly sales of a garden furniture manufacturer

IDENTIFYING THE TREND

An analysis of figures will tell a business whether there is an upward, downward or constant trend. Identifying the trend allows the business to predict what is likely to happen in future. The first step is to 'smooth out' (i.e. make the difficulties disappear from) the raw data. For example, look at the yearly sales of a garden furniture manufacturer over ten years (see Book 1, Chapter 30) shown in Table 2.

It is possible to calculate a trend by using a moving **average**. The average can be taken for any period the business wants, such as a year, a month or a quarter. For now we will assume the garden furniture manufacturer uses a three-year average.

The average of sales in the first three years was:

$$= \frac{125 + 130 + 130}{3} = \frac{385}{3} = 128.3$$

To calculate the moving average, the first year's sales drop out and the next year's sales (2009) are added. The average for the next three years was:

$$= \frac{130 + 130 + 150}{3} = \frac{410}{3} = 136.7$$

Year	2006	2007	2008	2009	2010
Sales ($000)	125	130	130	150	140
		128.3	136.7	140	148.3

Year	2011	2012	2013	2014	2015
Sales ($000)	155	180	190	210	230
	158.3	175	193.3	210	

▲ Table 3 Three-year moving average for sales of a garden furniture manufacturer

What if the firm had used a four-year period instead of three years? No one year is the centre point, and simply placing the figure in between two years may result in misleading predictions in future. The solution is to use centring. This uses a four- and eight-year moving total to find a mid-point, as shown in Table 4.

Year	2006	2007	2008	2009	2010
Sales ($000)	125	130	130	150	140

▲ Table 4 Centring

535 + 550 = 1085
(Four-year moving totals) (Eight-year moving total)

Here, the mid-point is 2008. The trend or four-period centred moving average can be found by dividing the eight-year moving total by 8, the number of years, as shown in Table 5.

Year	Sales	Four-year moving total	Eight-year moving total	Trend (four-year centred moving average = eight-year moving total / 8)
2006	125			
2007	130			
2008	130	535	1085	135.63
2009	150		1125	140.63
2010	140	550	1200	150
2011	155	575	1290	161.25
2012	180	625	1400	175
2013	190	665	1535	193.13
2014	210	735		
2015	230	810		

▲ Table 5 Calculating a four-year moving average for a garden furniture manufacturer

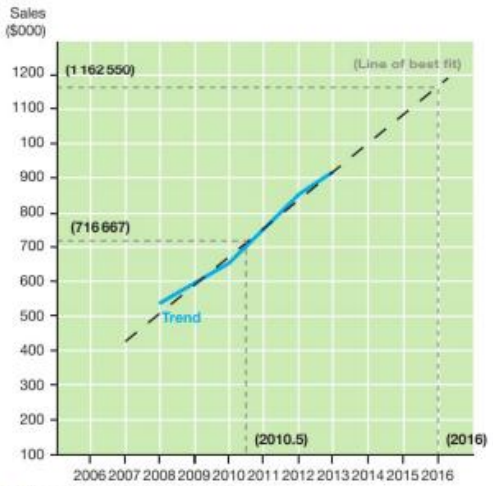
PREDICTING THE LINE OF BEST FIT FROM THE TREND

Having identified a trend that is taking place, it is possible for a business to now predict what may happen in future. Consider the business represented in Table 7.

Year	Sales ($000)	Four-year moving total	Eight-year moving total	Trend (four-year centred moving average = eight-year moving total/8)
2006	300			
2007	500			
2008	600	1950	4200	525.00
2009	550	2250	4750	593.75
2010	600	2500	5250	656.25
2011	750	2750	6050	756.25
2012	850	3300	6800	850
2013	1100	3500	7350	918.75
2014	800	3850		
2015	1100			

▲ Table 7 Four-year moving average and trend for a toy manufacturer

Consider the sales of this business during the period 2006-15. These data have been used to calculate four-year moving averages and this information used to calculate the trend. **Extrapolation** involves the use of past sales data to forecast future sales.



▲ Figure 2 Annual sales of a toy manufacturer

Secondly, the sales figures are predicted by drawing a line through the trend figures and extending it to the year 2016. The broken line through the trend in Figure 2 is called the **line of best fit**.

To help draw the line, it should pass through the co-ordinates (X,Y) where X is the average of the years and Y is the average sales. These co-ordinates can be calculated using the figures in Table 7:

$$\bar{X} = \frac{\Sigma X \text{ (the total years)}}{N \text{ (the number of years)}}$$

$$= \frac{2008 + 2009 + 2010 + 2011 + 2012 + 2013}{6}$$

$$= \frac{12\,063}{6} = 2010.5$$

$$Y = \frac{\Sigma Y \text{ (the total sales in the trend)}}{N \text{ (the number of years)}}$$

$$= \frac{\$525\,000 + \$593\,750 + \$656\,250 + \$756\,250 + \$850\,000 + \$918\,750}{6}$$

$$= \frac{\$4\,300\,000}{6}$$

$$= \$716\,667$$

VARIATIONS FROM THE TREND

How accurate is the prediction of around $1 160000 sales of toys by the year 2016? Even allowing for the assumptions on the previous page, the prediction may not be accurate. This is because it is taken from the trend, and the trend 'smoothed out' variations in sales figures. To make an accurate prediction, the business will have to find the average variation over the period and take this into account. We can find how much variation there is from the trend by calculating:

Actual sales − trend

So, for example, the cyclical variation in Table 7 would be as shown in Table 8. The average of the variations over the period 2006–15 is (in $000):

$$= \frac{+75 - 43.75 - 56.25 - 6.25 +/- 0 + 181.25}{6}$$

$$= \frac{+150}{6} = +25 \text{ (or } +\$25\,000)$$

			($000)
Year	Sales	Trend (four-year centred moving average)	Variation in each year
2006	300		
2007	500		
2008	600	525.00	+75.00
2009	550	593.75	−43.75
2010	600	656.25	−56.25
2011	750	756.25	−6.25
2012	850	850.00	+/− 0
2013	1100	918.75	+181.25
2014	800		
2015	1100		

▲ Table 8 Cyclical variations

SEASONAL VARIATIONS

Predictions can be made using trends and seasonal variations. Table 9 shows sales over a three-year period, including quarterly variations. A four-quarter moving average and seasonal variation can be used to predict sales. A more accurate prediction is to calculate the average seasonal variation in the fourth quarter.

$$\frac{-97.125 - 117.5}{2} = \frac{-214.625}{2} = -107.313$$

By subtracting $107 313 from the total of $470 000, this gives a more accurate prediction of $362 687.

				($000)
Year	Quarter	Sales	Four-quarter moving average	Variation
2012	3	460		
	4	218		
2013	1	205	328.5	−123.5
	2	388	346.0	+42.0
	3	546	358.25	−187.75
	4	272	369.125	−97.125
2014	1	249	383.625	−134.625
	2	431	396.625	+34.375
	3	619	404.0	+215.0
	4	303	420.5	−117.5
2015	1	277		
	2	535		

▲ Table 9 Seasonal variations

THE LIMITATIONS OF QUANTITATIVE SALES FORECASTS

Quantitative sales forecasts are powerful tools for businesses and are used to help make important decisions.

Sales forecasts are likely to be more reliable when:

- the forecast is for a short period of time in the future, such as six months, rather than a long time, such as five years
- they are revised frequently to take account of new data and other information
- the market is slow-changing
- market research data, including test marketing data, is available
- those preparing the forecast have a good understanding of how to use data to produce a forecast
- those preparing the forecast have a good 'feel' for the market and can adjust the forecast to take account of their predictions for the future.

CAUSAL MODELLING AND LINE OF BEST FIT

Time-series analysis only describes what is happening to information. Causal modelling tries to explain data, usually by finding a link between one set of data and another.

Table 11 shows data that has been collected about advertising and sales by a business at different times. The data in the table is plotted onto a **scatter graph** in Figure= Advertising (the independent variable) is shown on the horizontal (X) axis. Sales (the dependent variable) are shown on the vertical (Y) axis.

Period	Advertising expenditure (€ 000)	Sales (000)	(€ million)	(million)	(€ million)
	X	Y	X^2	Y^2	XY
A	1.0	3.2	1.0	10.24	3.2
B	2.0	4.5	4.0	20.25	9.0
C	3.0	1.8	9.0	3.24	5.4
D	4.0	3.0	16.0	9.0	12.0
E	1.5	1.8	2.25	3.24	2.7
F	2.5	1.6	6.25	2.56	4.0
G	3.5	5.8	12.25	33.64	20.3
H	1.2	4.7	1.44	22.09	5.64
I	2.7	5.9	7.29	34.81	15.93
J	3.0	3.5	9.0	12.25	10.5
K	3.6	3.1	12.96	9.61	11.16
L	0.7	3.5	0.49	12.25	2.45
			$\Sigma X^2 = 81.93$	$\Sigma Y^2 = 173.18$	$\Sigma XY = 102.28$

▲ Table 11 Advertising and sales data

Looking at the graph, there appears to be a positive **correlation** between the two variables (sales and advertising expenditure in this case). The more that is spent on advertising, the higher the level of sales. The line of best fit is drawn through the data to show this relationship better. It is also possible to calculate the extent of the relationship by means of a **correlation coefficient**, using the formula:

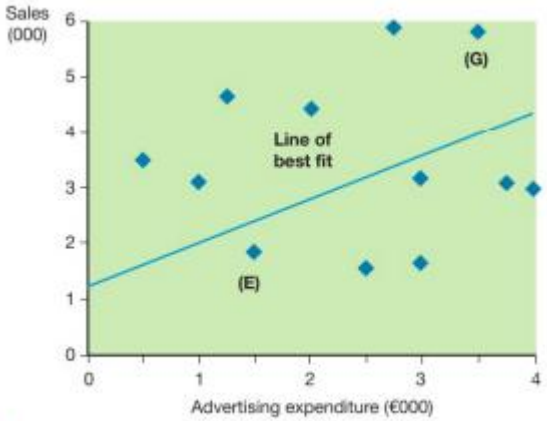
$$r = \frac{\Sigma XY}{\sqrt{(\Sigma X^2)\ (\Sigma Y^2)}}$$

Using the data in Table 11, the correlation coefficient for advertising and sales can be calculated as follows.

$$r = \frac{€102.28m}{\sqrt{€81.93m \times 173.18m}}$$

$$r = \frac{€102.28m}{€119.117m}$$

$$r = +0.86$$



▲ Figure 3 Advertising and sales data

• A correlation coefficient of +1 means that there is an absolute positive relationship between the two variables. All points in the scatter graph fall on the line of best fit and the line slopes upwards from left to right. As the values of the independent variable increase, so do the dependent variable values.

• A correlation coefficient of O means that there is no relationship between the variables.

• A correlation coefficient of -1 means that there is an absolute negative relationship between the two variables. All points in the scatter graph fall on the line of best fit and the line slopes downwards from left to right. As the values of the independent variable increase, the values of the dependent variable fall. The formula itself does not show positive and negative values.

Businesses must be careful when basing decisions on such calculations.

● A large quantity of sales in any period may be due to factors other than advertising, such as other forms of promotion.

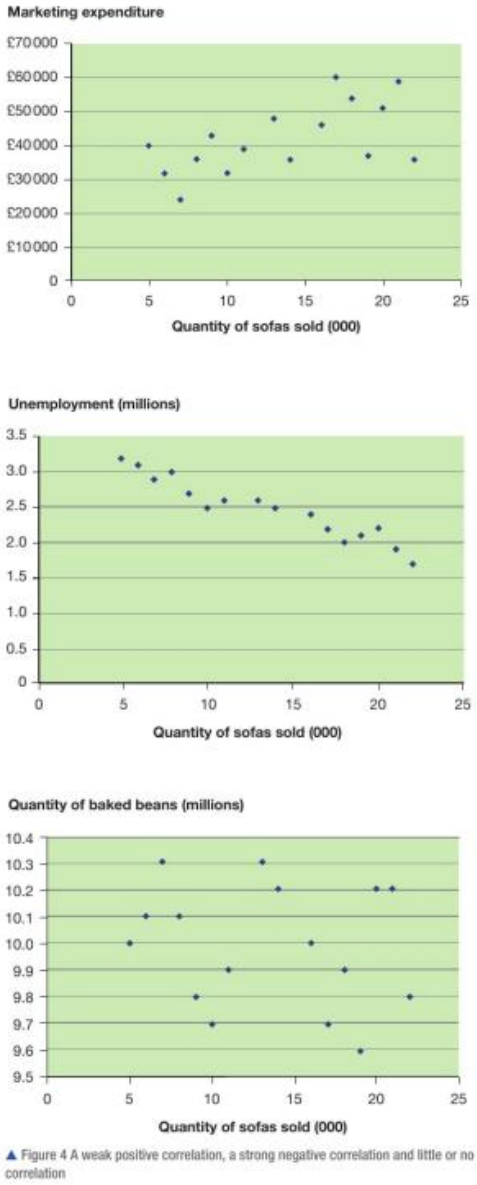
● There are sometimes examples of 'nonsense correlations'. These are correlation coefficients that appear to show a strong relationship between two variables even though the relationship between the figures is pure coincidence.

QUALITATIVE FORECASTING

Qualitative forecasting uses people's opinions or judgements rather than numerical data. A business could base its predictions on the views of 'experts', or on the opinions of experienced managers in the marketing or production department. Such methods are usually used by businesses:

● where there is insufficient numerical data

● where figures date quickly because the market is changing rapidly.



▲ Figure 4 A weak positive correlation, a strong negative correlation and little or no correlation

SUBJECT VOCABULARY

centring a method used to calculate a moving average, where the average is plotted or calculated in relation to the central figure
correlation the relationship between two sets of variables
correlation coefficient a measure of the extent of the relationship between two sets of variables
extrapolation forecasting future trends based on past data
line of best fit a straight line drawn through the centre of a group of data points plotted on a scatter graph
moving average a succession of averages derived from successive segments (typically of constant size and overlapping) of a series of values
scatter graph a graph showing the performance of one variable against another independent variable on a variety of occasions. It is used to show whether a correlation exists between the variables
time-series analysis a method that allows a business to predict future levels from past figures

10. Investment appraisal

INVESTMENT APPRAISAL

Investment appraisal describes how a business might objectively evaluate an investment project to determine whether or not it is likely to be profitable. It also allows businesses to make comparisons between different investment projects. There are several **quantitative** methods (i.e. measured with numbers) that a business might use when evaluating projects. However, they all involve comparing the **capital cost** of the project with the **net cash flow**.

- The capital cost is the amount of money spent when setting up a new venture.
- Net cash flow is **cash inflows minus cash outflows.**

SIMPLE PAYBACK

The payback period can also be found by calculating the **cumulative net cash flow**. This is the net cash flow each year, taking into account the initial cost of the machine. When the machine is first bought, in year O, there is negative cash flow of -$500000, the cost of the machine. Next year, the net cash flow minus operating costs is $100000. So, the cumulative net cash flow is -$500000 +$100000-$400000. In year 4 it is zero, so all costs have been covered.

						$000
	Yr 0	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5
Net cash flow	(500)	100	125	125	150	150
Cumulative net cash flow	(500)	(400)	(275)	(150)	0	150

▲ Table 2 Expected net cash flow from some new cutting machinery

ADVANTAGES OF THE PAYBACK METHOD

There are certain advantages to a business when using the payback method to appraise (i.e. examine) the potential success of an investment.

• This method is useful when technology changes rapidly, as it is important to recover the cost of investment before a new model or equipment is designed. This is true of the agriculture industry where new farm machinery is designed and introduced into the market regularly.

• It is simple to use.

• Firms might adopt this method if they have cash-flow problems. This is because the project chosen will 'pay back' the investment more quickly than others.

AVERAGE (ACCOUNTING) RATE OF RETURN (ARR)

The **average rate of return** or the accounting rate of return method measures the net return each year as a percentage of the capital cost of the investment.

$$\text{Average rate of return (ARR)(\%)} = \frac{\text{Net return (profit) per annum}}{\text{Capital outlay (cost)}} \times 100$$

ADVANTAGES OF THE ARR METHOD

The advantage of this method is that it shows clearly the profitability of an investment project. Not only does it allow a range of projects to be compared, the overall rate of return can be compared to other uses for investment funds. In the example in Table 6, if a company can gai 12 per cent by placing its funds in a bank account, it might choose to postpone the investment project until interest rates fall. It is also easier to identify the **opportunity cost** of investment.

DISCOUNTED CASH FLOW (NET PRESENT VALUE OR NPV)

Both the payback and the ARR methods of investment appraisal do not take into account the time value of money. When making an investment decision, a business might take into account what cash flow or profit earned in the future is worth at the present value.

● In one year's time, the investment would be worth US$110. Of this, US$10 would be the interest and US$100 would be the initial investment.

● investment but on the investment at the end of the first year. So, interest is 10 per cent of US$110, making US$11. Then this has to be added to the US$110 value at the end of the first year to make a total of US$121 for the second year.

● This carries on until the value after five years is US$161.

Year	1	2	3	4	5
Value of US$100	US$110	US$121	US$133	US$146	US$161

▲ Table 8 Value of US$100 invested over five years at 10 per cent per annum compound interest

If US$100 today is worth US$161 in five years' time, it must be true that US$161 in five years' time is worth just US$100 today. This is an example of an important insight of **discounted cash-flow** techniques. Money in the future is worth less than the same amount now (the **present value**). This is because money available today could be invested and it could earn interest.

- The higher the rate of discount, the less the present value of cash flow in the future. This is the reverse of saying that the higher the rate of interest, the greater the value of an investment in the future.
- The further into the future the cash flow or earnings from an investment project, the less is their present value. So, US$71000 earned in five years' time is worth less than US$71 000 earned in one year's time. Again, this is simply the opposite way of saying that US$71 000 invested today at a fixed rate of interest will be worth more in five years' time than in one year's time.

Calculating NPV: The net present value method makes use of discounted cash flow. It calculates the rate of return on an investment project taking into account the effects of interest rates and time. Using discount tables, it is possible to calculate the net present value of an investment project.

Rate of discount					
Year	5%	10%	15%	20%	25%
0	1.00	1.00	1.00	1.00	1.00
1	0.95	0.91	0.87	0.83	0.80
2	0.91	0.83	0.76	0.69	0.64
3	0.86	0.75	0.66	0.58	0.51
4	0.82	0.68	0.57	0.48	0.41
5	0.78	0.62	0.50	0.40	0.33
6	0.75	0.56	0.43	0.33	0.26
7	0.71	0.51	0.38	0.28	0.21
8	0.68	0.47	0.33	0.23	0.17
9	0.64	0.42	0.28	0.19	0.13
10	0.61	0.39	0.25	0.16	0.11

▲ Table 9 Discount table

ADVANTAGES OF THE DISCOUNTED CASH-FLOW METHOD

• The discounted cash-flow method, unlike the payback method and the average rate of return, correctly accounts for the value of future earnings by calculating present values.

• The discount rate used can be changed as risk and conditions in financial markets change. For example, in the 1990s, the cost of bank borrowing for many businesses fell from over 15 per cent to 7-8 per cent. Investment projects therefore did not need to make such a high rate of return to be profitable and so the rate of discount could be lowered. Since 2008 rates have been even lower - as low as 1 per cent in some countries.

LIMITATIONS OF THESE TECHNIQUES

Each of the three methods of investment appraisal outlined above has some limitations. These are summarised in Table 11.

Appraisal method	Limitations
Simple payback.	Cash earned after the payback period is ignored. The profitability of the method is overlooked.
Average rate of return.	The effects of time on the value of money are ignored.
Discounted cash flow.	The calculation is more complex than the other methods. The rate of discount is critical – if it is high, fewer projects will be profitable.

▲ Table 11 Limitations of the methods of investment

SUBJECT VOCABULARY

average rate of return or accounting rate of return (ARR) a method of investment appraisal that measures the net return per annum as a percentage of the initial spending
capital cost the amount of money spent when setting up a new venture
cash inflow the cash coming into the business such as that from sales or bank loans
cash outflow the cash going out of the business when payments are made to workers or suppliers, for example
discounted cash flow (DCF) a method of investment appraisal that takes interest rates into account by calculating the present value of future income
investment the purchase of capital goods
investment appraisal the evaluation of an investment project to determine whether or not it is likely to be worthwhile
net cash flow cash inflows minus cash outflows
net present value (NPV) the present value of future income from an investment project, minus the cost
opportunity cost when choosing between different alternatives, the opportunity cost is the benefit lost from the next best alternative to the one that has been chosen
payback period the amount of time it takes to recover the cost of an investment project
present value the value today of a sum of money available in the future
qualitative represented by words
quantitative represented by numbers

11. Decision trees

MAKING DECISIONS

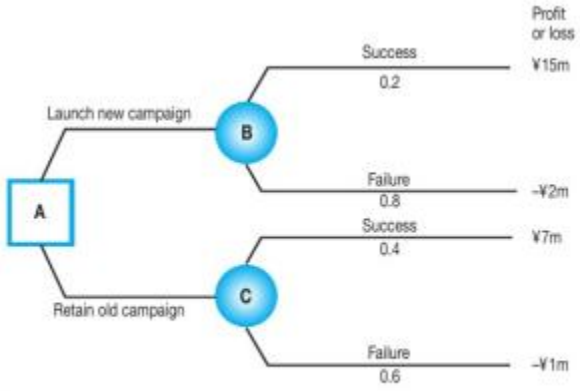
Businesses make decisions daily, often involving risk due to limited information and uncertain outcomes. Decision trees can help businesses make decisions that minimize risk and maximize return, such as investing in a new printing press or waiting for a more efficient machine. By analyzing the potential outcomes, businesses can make informed decisions that minimize risk and maximize return.

WHAT ARE DECISION TREES?

A decision tree is a visual tool used to compare alternative outcomes of a decision, allowing businesses to find the most profitable option. It uses numerical values to represent decision-making information and provides a pictorial approach, resembling the branches of a tree. This method is considered more effective when considering quantitative approaches.

FEATURES OF DECISION TREES

Decision trees have a number of features. These can be seen in Figure 1, which shows the decision tree for a Japanese business that has to decide whether to launch a new advertising campaign or retain an old one.



▲ Figure 1 A simple decision tree, based on a decision whether to retain an existing advertising campaign or begin a new one

Decision points: Points where decisions have to be made in a decision tree are represented by squares and are called decision points. The decision maker has to choose between certain courses of action. In this example, the decision is whether to launch a new campaign or retain the old one. The square labelled 'A' represents this point.

Outcomes: Points where there are different possible outcomes in a decision tree are represented by circles and are called chance nodes. At these chance nodes it can be shown that a particular course of action might result in a number of outcomes. In this example, at 'B' there is a chance of failure or success of the new campaign.

Probability or chance: The likelihood of a possible outcome happening is represented by probability in a decision tree. The chance of a particular outcome occurring is given a value.

Expected monetary values: This is the financial outcome of a decision. It is based on the predicted profit or loss of an outcome and the probability of that outcome occurring. The profit or loss of any decision is shown on the right-hand side of Figure 1. For example, if the launch of a new campaign is a success, a ¥15 million profit is expected. If it fails, a loss of ¥2 million is expected.

CALCULATING EXPECTED MONETARY VALUES (EMV)

What should the firm decide? It has to work out the expected values of each decision, taking into account the expected profit or loss and the probabilities. So, for example, the expected value of a new campaign is:

	Success	Failure
Expected value	= 0.2 × ¥15m	+0.8 × (–¥2m)
	= ¥3m – ¥1.6m	
	= 1.4m	

The expected value of retaining the current campaign is:

	Success	Failure
Expected value	= 0.4 × ¥7m	+0.6 × (–¥1m)
	= ¥2.8m – ¥0.6m	
	= 2.2m	

From these figures the firm should continue with the existing campaign because the expected value is higher.

NUMEROUS OUTCOMES

It is possible to have more than two outcomes at a chance node. For example, at point 'B' in Figure 1 there might have been three outcomes.

- The probability of great success may be 0.2 with a profit of ¥15 million.
- The probability of average success may be 0.4 with a profit of ¥6 million.
- The probability of failure may be 0.4 with a loss of –¥2 million.

The expected value is now:

= (0.2 × ¥15m) + (0.4 × ¥6m) + (0.4 × –¥2m)

= ¥3m + ¥2.4m – ¥0.8m

= ¥4.6m

DECISIONS, OUTCOMES AND COSTS

In practice, businesses face many alternative decisions and possible outcomes. For example, consider a farmer from the UK who has inherited some land, but does not wish to use it with his existing farming business. There are three possible decisions the farmer could make.

• Sell the land. The market is depressed and this will earn £0.6 million.

• Wait for one year and hope that the market price improves. A land agent has told the farmer that the chance of an upturn in the market is 0.3, while the probabilities of it staying the same or worsening are 0.5 and 0.2 respectively.

The likely proceeds from a sale in each of the circumstances are £1 million, £0.6 million and £0.5 million.

• Seek planning permission to develop the land. The legal and administration fees would be £0.5 million and the probability of being refused permission would be 0.8, which means the chance of obtaining permission is 0.2.

A rollback technique can then be used to work out the expected value of the third option - seeking planning permission. This means working from right to left, calculating the expected values at each node in the diagram. The expected value at node D is:

Expected value = 0.3 × £1m + 0.5 × £0.6m + 0.2 × £0.5m

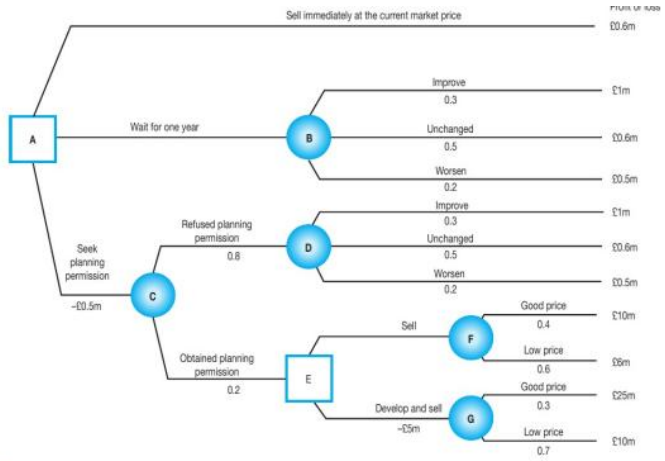
= £0.7m

The expected monetary value at node F is:

Expected value = 0.4 × £10m + 0.6 × £6m

= £4m + £3.6m

= £7.6m



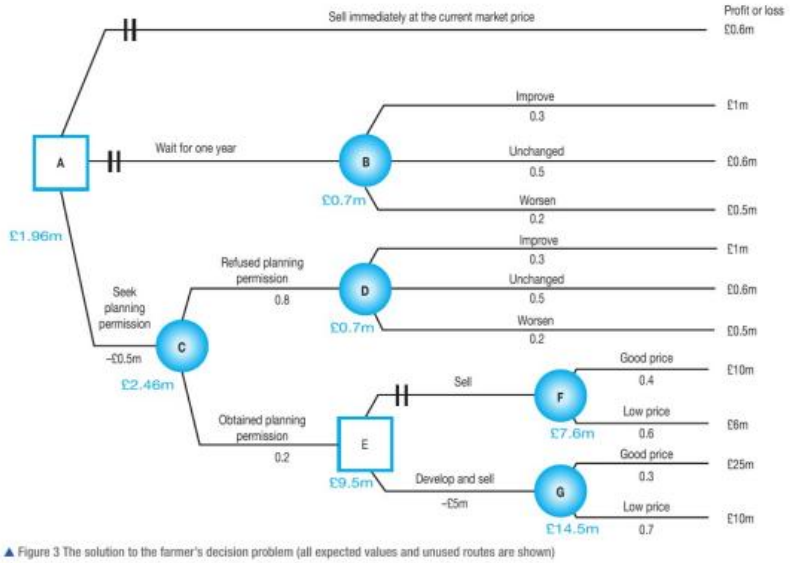
▲ Figure 2 The decisions faced by a farmer in the disposal of land

The expected value at node G is:

Expected monetary value = 0.3 × £25m + 0.7 x £10m
= £7.5m + £7m
= £14.5m

At node E, a decision node, the farmer would choose to develop the land before selling it. This would yield an expected return of £9.5 million (£14.5 million − £5 million) which is higher than £7.6 million, i.e. the expected return from selling the land undeveloped. Thus, in Figure 3 the path representing this option can be crossed. The expected value at node C is now:

Expected monetary value = 0.2 × £9.5m + 0.8 × £0.7m
= £1.9m + £0.56m
= £2.46m



▲ Figure 3 The solution to the farmer's decision problem (all expected values and unused routes are shown)

ADVANTAGES OF DECISION TREES

Decision trees can be applied to much more complicated problems. They have some major advantages.

- Constructing the tree diagram may show possible courses of action not previously considered.
- They involve placing numerical values on decisions. This tends to improve results.
- They force management to take account of the risks involved in decisions and help to separate important from unimportant risks.
- People can often get a better idea of what is involved in a particular decision if the choices are laid out clearly in a diagram.
- They involve placing numerical values on decisions. This tends to improve results. This is because it is far easier to make comparisons between different outcomes if they are presented quantitatively.
- They force management to take account of the risks involved in decisions and help to separate important from unimportant risks. For example, outcomes with low probabilities are less likely to happen than those with higher probabilities.

LIMITATIONS OF DECISION TREES

The technique also has some limitations.

- The information gathered when using the technique is not exact. It is based on probabilities which are often estimated.
- Decisions are not always concerned with quantities and probabilities. For example, they often involve people and are influenced by legal constraints or people's opinions. These factors cannot always be shown by numerical values. Qualitative data may also be important.
- Time lags often occur in decision making. By the time a decision is finally made, some of the numerical information may be out of date. The process can be quite time-consuming, using up valuable business resources. However, computerised decision-making models can be used to analyse decision trees which can save some time.
- It is argued that decision makers, in an attempt to encourage a particular course of action, may manipulate the data. For example, a manager might be 'biased' when attaching probabilities to certain outcomes. This will change the final results.
- Decision trees are not able to take into account the dynamic nature of business. For example, a sudden change in the economic climate might make a decision based on a decision tree outdated.

SUBJECT VOCABULARY

back data data obtained from a previous time period
chance node a point on a decision tree diagram (represented by a circle) where a number of outcomes are possible
decision tree a technique which shows all possible outcomes of a decision. The name comes from the similarity of the diagrams to the branches of trees
expected value the numerical value of an outcome multiplied by the probability of that outcome happening
probability the chances of an event happening
rollback technique the process of working back through a decision tree (from right to left) calculating the expected values at each node

12 Critical path analysis

NATURE AND PURPOSE OF CRITICAL PATH ANALYSIS

One established method used to improve the management of time and other resources is **critical path analysis (CPA)/network analysis**. The technique, which makes use of **network diagrams**, can be used to calculate the minimum time needed to complete a project.

Efficiency: Producing a network diagram can help a business to operate efficiently.

Decision making: The use of business models, such as network analysis, is argued to be a more scientific and objective method of making decisions. It is suggested that estimating the length of time a project will take based on past information and an analysis of the tasks involved should lead to deadlines being met more effectively.

Time-based management: Some businesses operate time-based management systems. These are techniques to minimise the length of time spent in business processes. Identifying tasks that have to be done in order, tasks that can be done together and tasks that may delay the whole project if not completed on time, will all help to ensure that the least time is taken to complete an operation.

Working capital control: Identifying when resources will be required in projects can help a business to manage its working capital cycle. Network diagrams allow a business to identify exactly when materials and equipment will be used in a project.

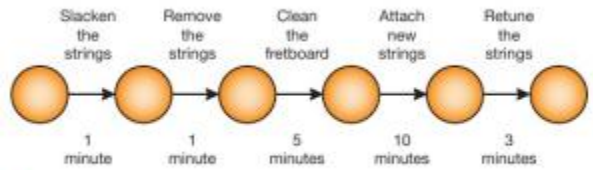
NETWORKS

Many of the operations carried out by businesses are made up of a number of tasks. The operation is only complete when all of the tasks have taken place. For example, the tasks involved in changing a set of strings on a guitar for an instrument repairer might include:

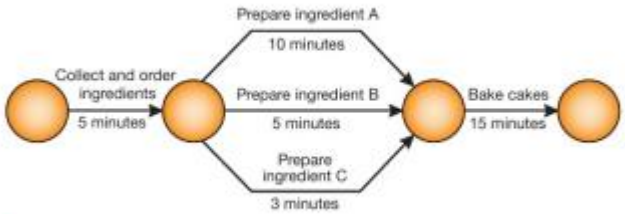
- slackening the strings (i.e. making them looser)
- attaching new strings
- removing the strings
- retuning the strings
- cleaning the fretboard.

These tasks must be carried out in order for the operation to take place. Each task will take a certain amount of time. The operation is shown in Figure 1 on a network diagram. The operation takes 20 minutes to carry out

(1 minute + 1 minute + 5 minutes + 10 minutes + 3 minutes).



▲ Figure 1 A simple network



▲ Figure 2 A more complex network

NETWORK ANALYSIS

Network analysis is crucial for businesses managing large projects involving complex tasks. It helps determine the minimum project duration and the potential delays caused by individual tasks. Network analysis helps identify critical tasks and their 'path', which can be managed using computers. Network planning is essential before starting a project, identifying tasks, durations, and order. This information can be based on previous experience or business research.

• Arrows and lines show the tasks or activities to be carried out to complete the project. For example, Task B involves removing and replacing brickwork and flooring in the home.

• Some tasks can be carried out at the same time. For example, Tasks B and C can take place together, but only after Task A has been completed.

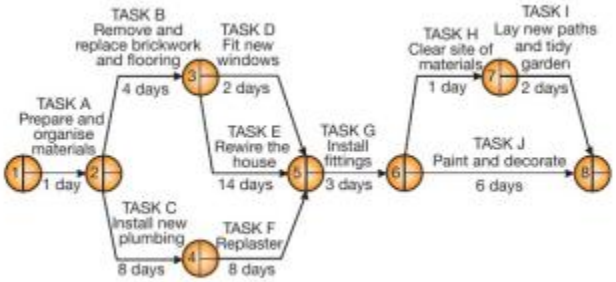
• Arrows and lines cannot cross.

• Each task takes a certain amount of time. For example, the business plans to take four days to complete Task B (removing and replacing the brickwork and flooring in the home).

• Tasks must be completed in a certain order. Certain tasks are dependent on others being completed.

• There is always a node at the start and end of the project.

• Nodes contain information about the timing involved in the project.



▲ Figure 4 Network for a home renovation

CALCULATING THE EARLIEST START TIMES

The first stage in finding the critical path in the network is to calculate the earliest time at which each of the tasks or activities can start, called the earliest start time (EST). These are shown in the top right of the nodes. Figure 5 shows the earliest start times for all tasks in the renovation of the home.

Node 1: Task A can begin immediately. So O is placed in the EST in Node 1.

Node 2: Task A takes one day to complete. Tasks B and C, which can be carried out at the same time, can only begin after Task A is completed. So they can only begin after 1 day. This is placed in the EST in Node 2.

Node 3: Task B takes 4 days to complete. Together with the day to complete Task A, this means that Tasks D and E can't start until after 5 days (4 days + 1 day). This is placed in the EST in Node 3.

Node 4: Task C takes 8 days to complete. Together with the 1 day to complete Task A, this means that Task F can't start until after 9 days (8 days + 1 day). This is placed in the EST in Node 4.

Node 5: What will be the earliest start time for Task G which begins at Node 5?

Tasks A, B and D take 7 days to complete

(1 day + 4 days + 2 days)

- Tasks A, C and F take 17 days to complete

(1 day + 8 days + 8 days)

- Tasks A, B and E take 19 days to complete

(1 day + 4 days + 14 days)

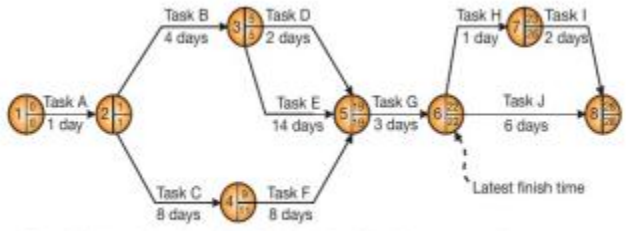
Task G can only begin when all tasks that come before are completed. It is dependent on earlier tasks. The longest time to complete these tasks is 19 days. So the EST in Node 5 is 19 days and Task G can't start until after 19 days. This highlights an important rule when calculating earliest start times. Always choose the longest amount of time when placing the ESTs in nodes.

Node 8: Another example of this can be found when calculating the final node, Node 8. Tasks up to Node 6 have taken 22 days to complete. So Tasks H and J can only begin after 22 days. The time taken to complete Task J is 6 days. This is longer than the time taken to complete Tasks H and I, which is 3 days (2 days + 1 day). So the EST placed in Node 8 is 22 days + 6 days = 28 days.

As Node 8 is the final node, then 28 days is the time taken to complete the entire project.

CALCULATING THE LATEST FINISH TIMES

The next step involves calculating the latest times that each task can finish without causing the project to be delayed. The **latest finish times (LFTs)** of the project to renovate a home are shown in Figure 7. They appear at the bottom right of the nodes.



▲ Figure 7 Network showing latest finishing times for the home renovation

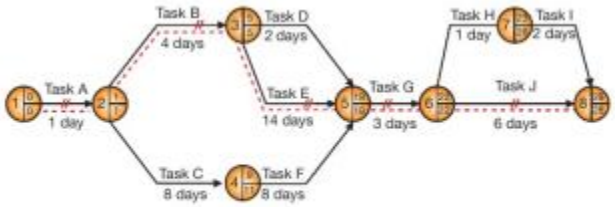
IDENTIFYING THE CRITICAL PATH

It is now possible to identify the critical path through the network. This shows the tasks which, if delayed, will lead to a delay in the project. The critical path on any network is where the earliest start times and the latest finish times in the nodes are the same. But it must also be the route through the nodes which takes the longest time.

Figure 8 shows the critical path and the tasks which can't be delayed if the renovation of the home is to be completed on time. These are tasks A, B, E, G and J. The critical path can be indicated by a broken line or crossed lines, or by some other method, such as highlighting the line in colour, by pen or on computer. Other tasks in the network do not lie on the critical path.

CALCULATING THE FLOAT

Business can calculate float time in a project by using network information. This is the time a task can delay without causing the project to be delayed, such as a 1 day delay in Task I.



▲ Figure 8 Critical path for the home renovation

How much delay can there be in tasks which do not lie on the critical path?

Total float: The total float is the amount of time by which a task can be delayed without affecting the project. It can be calculated as:

LFT of activity - EST of activity - duration

So, for Task B in Figure 8, for example, it would be:

5 days 1 day 4 days = 0 days

Activities which lie on the critical path will always have a zero total float value. For Task C, which does not lie on the critical path, the total float is:

11 days 1 day 8 days = 2 days

Table 1 shows the total float for all tasks.

Free float: The free float is the amount of time by which a task can be delayed without affecting the following task. It can be calculated by:

EST start of next task - EST start of this task - duration

So for Task C it would be:

9 -1- 8= 0 days

								(days)
Task/activity	LFT	EST	Duration	Total float	EST next	EST this	Duration	Free float
A	1	0	1	0	1	0	1	0
B	5	1	4	0	5	1	4	0
C	11	1	8	2	9	1	8	0
D	19	5	2	12	19	5	2	12
E	19	5	14	0	19	5	14	0
F	19	9	8	2	19	9	8	2
G	22	19	3	0	22	19	3	0
H	26	22	1	3	23	22	1	0
I	28	23	2	3	28	23	2	3
J	28	22	6	0	28	22	6	0

▲ Table 1 Float

LIMITATIONS OF CRITICAL PATH ANALYSIS

Critical path analysis has a number of clear advantages which are summarised in Table 2.

However, a business must not assume that because it produces a network its project will be completed without delay. There are some limitations that businesses need to be aware of when using this technique.

• Information used to estimate times in the network may be incorrect.

• Changes sometimes occur during the life of the project.

• Although critical path analysis identifies times when resources might be used somewhere else in the business, these resources may be inflexible.

• With very large projects, such as building a skyscraper, network analysis can become complex with hundreds of thousands of tasks to consider. However, the use of a computer may simplify the whole approach.

Critical path analysis	Advantages
Identifies the minimum completion time.	CPA enables managers to minimise the project length by monitoring the critical path.
Improves efficiency.	CPA helps to improve resource use. For example, it shows which tasks have 'float' which allows a business to use resources in alternative locations for a period without holding up the completion of the project. Time can also be saved when certain tasks are completed at the same time.
Helps decision making.	CPA is a quantitative technique and can be used to help managers make decisions about resource use, for example.
Helps project management.	Some projects are very large and complex. CPA helps to make clear the order in which tasks must be completed. This reduces the risks and costs associated with such projects.
An aid to planning.	CPA is carried out before work on a project is started. This helps to prepare more thoroughly for a large project. It identifies problems that might occur, so they can be dealt with in advance.

▲ Table 2 Advantages of critical path analysis

SUBJECT VOCABULARY

critical path the tasks involved in a project which, if delayed, could delay the project
critical path analysis (CPA)/network analysis a method of calculating the minimum time required to complete a project, identifying delays which could be critical to its completion
earliest start time (EST) how soon a task in a project can begin. It is influenced by the length of time taken by tasks which must be completed before it can begin
free float the time by which a task can be delayed without affecting the following task
latest finish time (LFT) the latest time that a task in a project can finish
network diagram a chart showing the order of the tasks involved in completing a project, containing information about the times taken to complete the tasks
nodes positions in a network diagram which indicate the start and finish times of a task
total float the time by which a task can be delayed without affecting the time needed to complete the project

13. Contribution

WHAT IS CONTRIBUTION?

In business, the word contribution has a specific meaning. It is the amount of money left over from a sale after variable costs have been covered.

Unit contribution: In the example, we have calculated the unit contribution. It was the contribution made by the sale of one bicycle by Varinder Patel. The formula for calculating unit contribution is given by:

Contribution per unit = selling price – variable cost
= INR8000 – INR5500
= INR2500

Total contribution: It is possible to calculate the total contribution made by a large order. For example, an Indian textile company sells 500 000 T-shirts to a customer for INR120 each. The variable cost for each T-shirt is INR90. The total contribution made by the order is given by:

$$\begin{aligned}\text{Total contribution} &= \text{total revenue} - \text{total variable cost}\\ &= \text{INR120} \times 500\,000 - \text{INR90} \times 500\,000\\ &= \text{INR60 million} \times \text{INR45 million}\\ &= \text{INR15 million}\end{aligned}$$

In this example, the INR15 million total contribution will contribute to the manufacturer's fixed costs and profit. We can also calculate the total contribution by multiplying the unit contribution by the number of units sold. In this example, the total contribution made by the T-shirt order would be given by:

$$\begin{aligned}\text{Total contribution} &= \text{unit contribution} \times \text{number of units sold}\\ &= (\text{INR120} - \text{INR90}) \times 500\,000\\ &= \text{INR30} \times 500\,000\\ &= \text{INR15 million}\end{aligned}$$

THE NATURE OF CONTRIBUTION AND ITS CALCULATION

Contribution has a number of purposes in business. We can use contribution to help make decisions and calculate some key financial values. For example, we can use it to:

- calculate the break-even level of output (see Student Book 1, Chapter 31)
- calculate the amount of profit made by a business
- calculate the amount that needs to be sold to reach a specific profit target
- help a business to decide which order to accept when faced with a choice
- help a business decide what price to charge for a product.

Contribution and break-even: The break-even level of output is given by:

$$\text{Break-even} = \frac{\text{fixed costs}}{\text{contribution}}$$

Contribution and profit: Profit can be calculated using the formula below.

$$\text{Profit} = \text{total contribution} - \text{fixed costs}$$

If the Indian T-shirt manufacturer produces 700000 T-shirts and fixed costs are INR6 million, the amount of profit made at this level of output is given by:

$$\begin{aligned}\text{Profit} &= \text{INR30} \times 700000 - \text{INR6 million}\\ &= \text{INR21 million} - \text{INR6 million}\\ &= \text{INR15 million}\end{aligned}$$

Contribution and profit target: Contribution can be used to work out how much a business needs to sell to reach a specific profit target. The formula needed to do this is given by:

$$\text{Output} = \frac{\text{fixed costs} + \text{profit target}}{\text{contribution}}$$

For example, if the Indian T-shirt manufacturer wanted to make a profit of INR12 million, the level of output that must be sold to reach this target is given by:

$$\begin{aligned}\text{Output} &= \frac{\text{INR6 million} + \text{INR12 million}}{\text{INR30}}\\ &= \frac{\text{INR18 million}}{\text{INR30}}\\ &= 600000 \text{ T-shirts}\end{aligned}$$

INTERPRETING CONTRIBUTION

The contribution margin ratio is the remaining money from a sale after variable costs are covered, which can be used to pay fixed costs and contribute to profit. It can be expressed as a percentage, such as 39.3% for a firm with annual sales of $1.68 million.

Contribution, fixed costs, variable costs and profit: The value of contribution can be illustrated in relation to variable costs, fixed costs and profit using a pie chart. In the example, assume that in November 2018, Varinder Patel's:

- total revenue is INR105300
- total variable costs are INR64 200

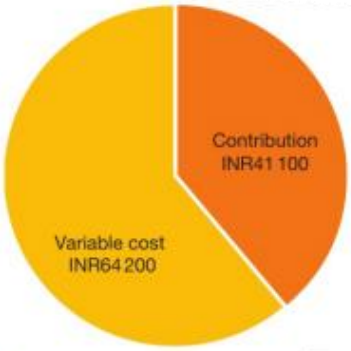
fixed costs are INR10000.

Figure 1(a) shows how the total revenue of INR105 300 is divided between total variable cost (INR64 200) and contribution (INR41 100).

Figure 1(b) shows how the same total revenue is divided between variable costs (INR64 200), fixed costs (10000) and profit (INR31 100). Note that the value of contribution (INR41 100) is equal to the value of fixed cost (INR10000) and profit (INR31 100) added together.

CONTRIBUTION AND DECISION MAKING

Contribution costing: A business might use contribution when making certain types of decision. For example, sometimes a business will have to decide which order(s) or contract(s) to accept when faced with a choice from different customers. This may be because the business does not have enough capacity to accept all the orders it receives. Or it may be that they are not all financially viable (i.e. capable of financial success). Contribution costing can help here.



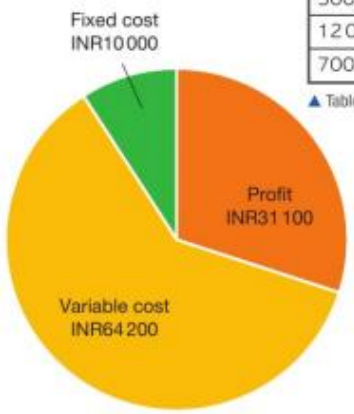
▲ Figure 1(a) Total revenue INR105 300 divided between total variable cost (INR64 200) and contribution (INR41 100)

Order	Variable costs ($ per unit)	Price ($ per unit)
5000 drive shafts	20	35
12 000 mountings	13	18
7000 brackets	16	29

▲ Table 1 Three orders received by Lee Chang Engineering

	Variable costs ($ per unit)	Price ($ per unit)	Unit contribution ($)	Total contribution ($)
5000 drive shafts	20	35	15	75 000
12 000 mountings	13	18	5	60 000
7000 brackets	16	29	13	91 000

▲ Table 2 Unit contribution and total contribution for the three orders received by Lee Chang Engineering



▲ Figure 1(b) Total revenue INR105 300 divided between variable costs (INR64 200), fixed costs (INR10 000) and profit (INR31 100)

Contribution pricing: A business can use contribution pricing to set a price that exceeds variable cost, ensuring a specific order or product always contributes when sold. This approach ignores fixed costs, but is more effective when fixed costs are low or known.

	Price (€)	Variable cost (€)	Contribution (€)
Order 1	45 000	32 000	13 000
Order 2	23 000	21 000	2000
Order 3	49 000	39 500	9500
Order 4	58 000	47 000	11 000
Total	175 000	139 500	35 500

▲ Table 3 Financial information for Rossi Shoes

SUBJECT VOCABULARY

contribution the amount of money left over from a sale after variable costs have been subtracted from revenue. The money contributes to fixed costs and profit
contribution costing the use of contribution to help make decisions based on costs, such as which order to accept
contribution pricing a pricing strategy that involves setting a price that exceeds the value of the variable cost
overheads an overhead cost or expense, for example lighting, equipment and any extras paid for out of a centralised budget
total contribution the amount of money left over from the sale of several units, or an order, after variable costs have been covered
unit contribution the amount of money left over from the sale of a single unit after variable costs have been covered