3.3 Costs and revenues

Tool: Decision tree

A decision tree, also called a probability tree, is a tool that helps businesses make decisions by putting an estimated value on various options. It is particularly useful when a business needs to choose between investment decisions.

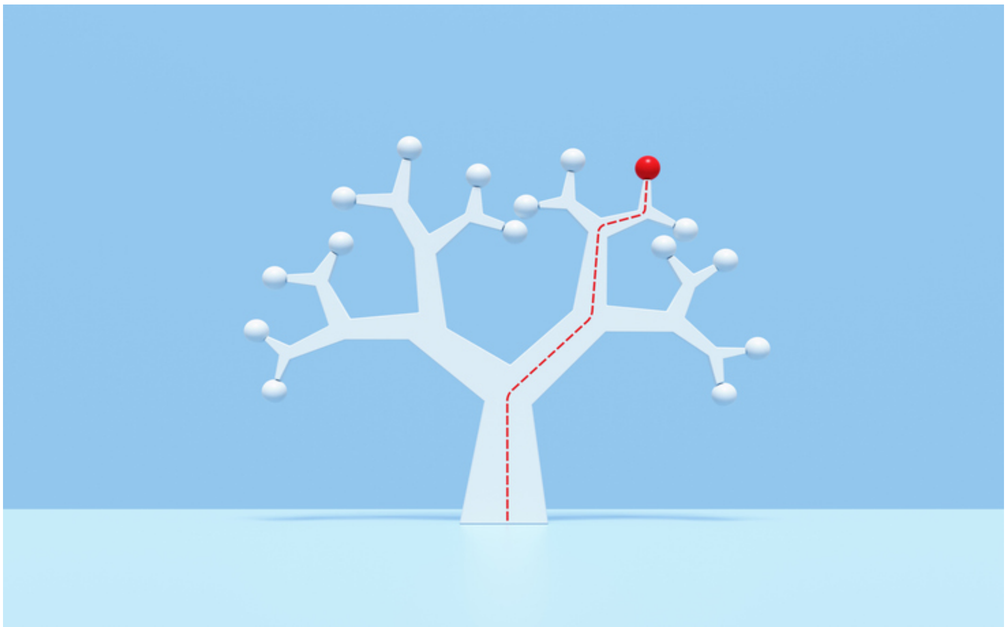

Figure 1. A decision tree enables a business to evaluate its alternatives.

Credit: Jorg Greuel, Getty Images

A decision tree is a quantitative, forward-looking tool. Decision trees are designed to answer questions such as, ‘Given a 60% chance that a company can succeed in a new market, should it pursue its plans to expand its factory?’ Decision trees are drawings that use particular elements, as shown in **Figure 2**.

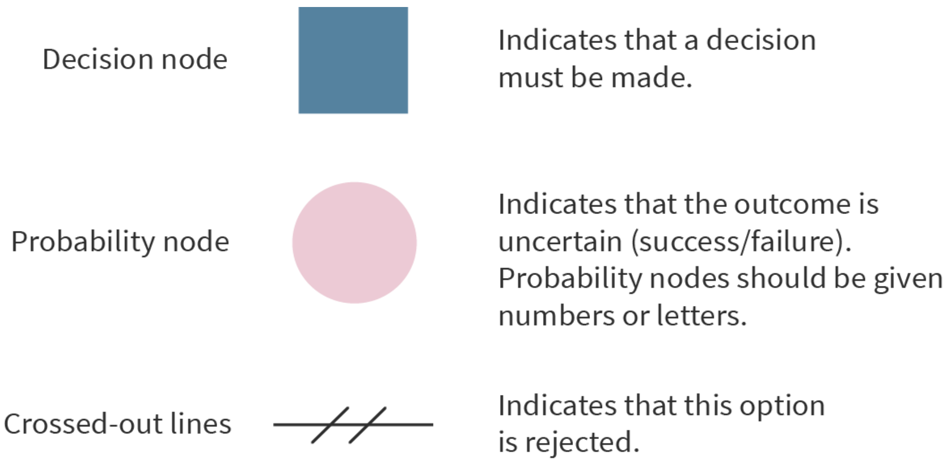

Figure 2. Elements of a decision tree.

Exam tip

When drawing a decision tree in the exam, make sure you include a key that outlines the elements of the decision tree: the decision node, the probability node and the rejected options. It is usually not possible to earn full marks unless this key is included.

When you construct a decision tree, you need to do two things. The first is to draw the decision tree; the second is to solve the decision tree. Drawing and solving a decision tree are explained in the following example.

Drawing a decision tree

Imagine you run a business that manufactures machine components, and you decide to enter a new market. Based on research, the probability that the business will succeed in the new market is 60%, while the probability that it will not succeed in the new market is 40%. You need to decide whether or not to expand the factory. Such an expansion would enable you to meet possible new demand in the new market. Assume such an expansion to the factory would cost $10 million.

Start drawing a decision tree by representing your two options as separate lines extending to the right of the decision node (as shown in **Figure 3**). Option 1 is to expand the factory at a cost of $10 million. Option 2 is to leave the factory as it is and not to expand it. If the factory is not expanded, there will be no costs. The parentheses are used to indicate that these are negative numbers because they represent costs.

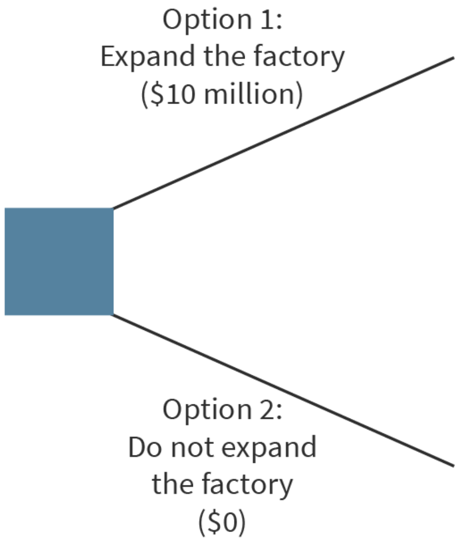

Figure 3. Drawing the first part of the decision tree to show the costs associated with the two options.

Now that you have drawn your options, you need to add the probabilities of the two outcomes (success or failure in the new market). Start by adding probability nodes to the decision tree. These are shown by the two circles numbered 1 (for option 1) and 2 (for option 2) in **Figure 4**. The probabilities of the two outcomes should be written along the lines extending to the right of these probability nodes.

The chance of a particular outcome occurring is given a value. If the outcome is certain, the probability will be 1; if there is no chance of the outcome occurring, the probability will be zero. In practice, the values of the probabilities will be between 1 and zero. In this case, 0.6 equates to the 60% chance that the business is successful in entering the new market; 0.4 equates to the 40% chance that the business is not successful.

The probabilities that extend from each probability node always total 1 or 100%, because there is a 100% chance that something will happen. In this case, there will either be a success, or there will not be a success. Note that in this simple example there is only one uncertain event; this is why the probabilities extending from probability nodes 1 and 2 are the same. However, it could be that in more complex scenarios, with more options, the probabilities will be different for each option.

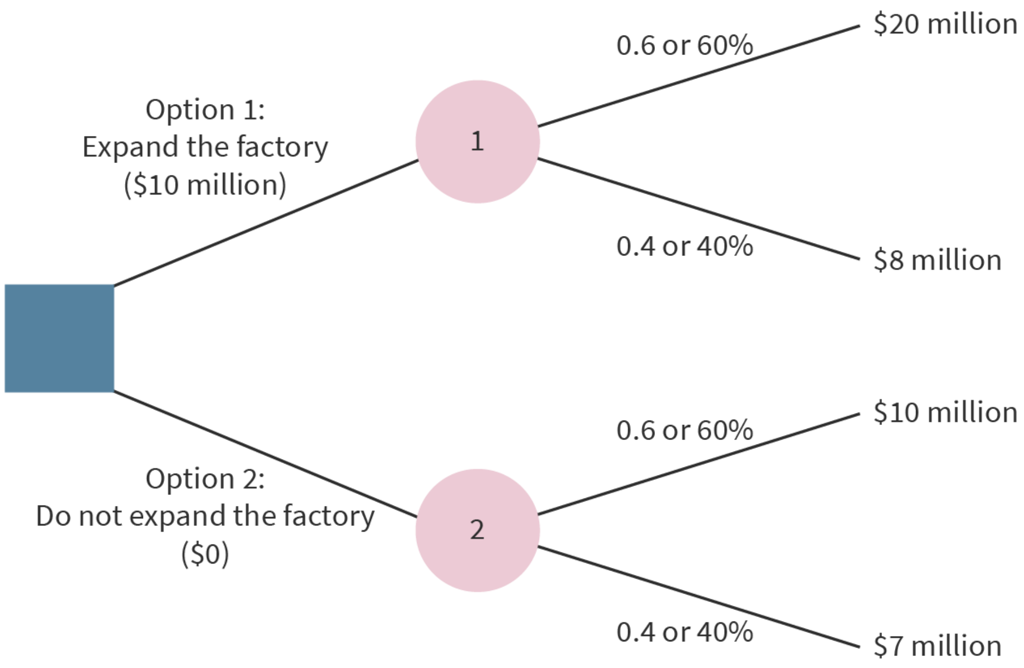

Figure 4. Drawing the second part of the decision tree to show the probabilities associated with each option.

If you decide to expand the factory (option 1) and if the company is successful in the new market, it will be able to sell more components. As a result, the estimated revenues are $20 million over the life of the project. If you decide to expand the factory and the company is not successful in the new market, revenues earned by the enlarged factory will be lower, at $8 million.

If you decide not to expand the factory (option 2), the company will be unable to meet a higher level of demand. As a result, if the company is successful in the new market, the estimated revenues will only be $10 million. If the company is not successful with its current factory capacity, expected revenues would be $7 million.

All these expected revenues should be written at the end of the branches of the decision tree (as shown in **Figure 4**).

Solving the decision tree

Once you have drawn the decision tree, you can calculate the expected value (EV) of expanding the factory compared to the expected value of not expanding the factory, given the uncertainty of the success. Solving the decision tree to find these expected values involves three steps, as follows:

Step A: Calculate the expected value (EV) of revenues from each possible outcome. The expected value of revenues is the estimated revenue multiplied by the probability that it will happen. It can be helpful to write the EVs at the end of the branches as shown in **Figure 5**.

Expected values for option 1 (expanding the factory):

- If successful: $0.6 \times \$20$ million $= \$12.0$ million
- If unsuccessful: $0.4 \times \$8$ million $= \$3.2$ million

Expected values for option 2 (**not** expanding the factory):

- If successful: $0.6 \times \$10$ million $= \$6.0$ million
- If unsuccessful: $0.4 \times \$7$ million $= \$2.8$ million

Step B: Calculate the **total** expected value of each of the two possible outcomes (success or not) for each option (expand the factory or not). It can be helpful to write the total expected value of each option above or below the probability node, as shown in **Figure 5**.

Total expected value for option 1 (expanding the factory):

- $\$12$ million $+ \$3.2$ million $= \$15.2$ million

Total expected values for option 2 (**not** expanding the factory):

- $\$6$ million $+ \$2.8$ million $= \$8.8$ million

Step C: Calculate the **net** expected value of each option by subtracting the initial costs. This number can be written next to the decision node, as in **Figure 5**.

Net expected value for option 1 (expanding the factory):

- $\$15.2$ million $- \$10$ million $= \$5.2$ million

Net expected value for option 2 (**not** expanding the factory):

- $8.8 million – $0 = $8.8 million

The completed tree will be as shown in **Figure 5**.

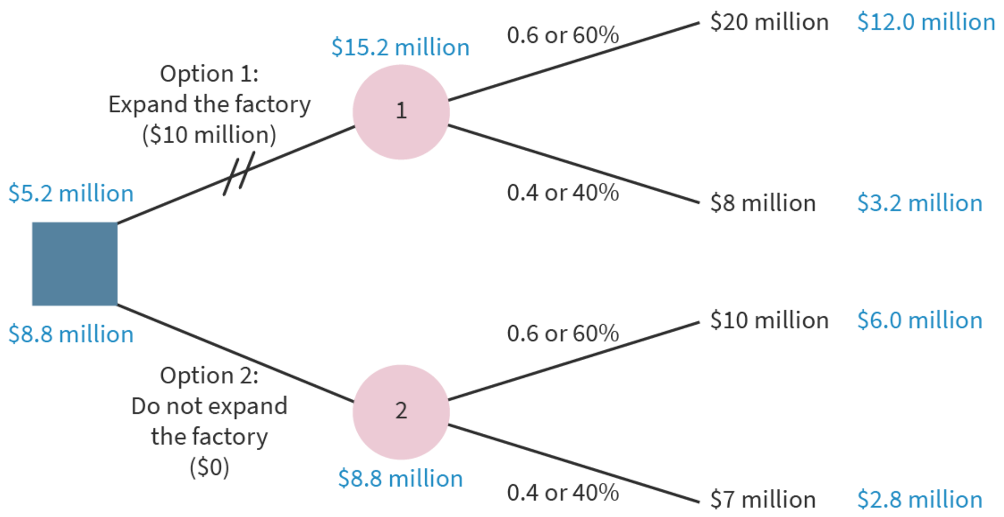

Figure 5. Solving the decision tree.

The following equations summarise the calculations involved in solving the decision tree. EV stands for expected value, which is the predicted profit of each outcome given the expected probabilities and the forecast profits.

EV of expanding the factory net of costs
= (0.6 × \$20 million) + (0.4 × \$8 million) – \$10 million

= \$5.2 million

EV of not expanding the factory net of costs
= (0.6 × \$10 million) + (0.4 × \$7 million) – \$0

= \$8.8 million

On purely estimated financial grounds, the factory should not be expanded, since the expected value of this option (option 2) is \$8.8 million, while the expected value of expanding the factory (option 1) is only \$5.2 million. The rational decision, based only on this quantitative data, is therefore not to expand the factory. The option to expand (option 1) is therefore the 'rejected option'; that line on the decision tree is therefore crossed out.

Exam tip

To access full marks, you are expected to write out the working, as above, in addition to providing the information on the decision tree.

Also, it is important to indicate the rejected option(s) on the decision tree.

Activity

The Doctrex laboratory has carried out research for new treatments for influenza. The researchers have identified three different programs (A, B and C) to develop a vaccination. The costs, probabilities and revenue of these programs are given in **Table 1**.

Table 1. Costs, probabilities and revenue of programs A, B and

Program	Costs (in thousands of $)	Probability of success	Revenue (in thousands of $)	Probability of failure
A	2000	0.3	20 000	0.7
B	2600	0.4	17 000	0.6
C	1400	0.5	9000	0.5

1. Construct a fully labelled decision tree. [4 marks]
2. Calculate the expected value (EV) of the three programs and recommend an option to follow based on this information. [2 marks]

Solving more complex decision trees

Decision trees can be more complex than the example outlined in this section. A branch with a decision can lead to further decisions or probabilities with their own probabilities and branches, which might look like the diagram shown in **Figure 7**. **Figure 7** illustrates a complex decision tree that has an additional subset of decision nodes (indicated by the squares).

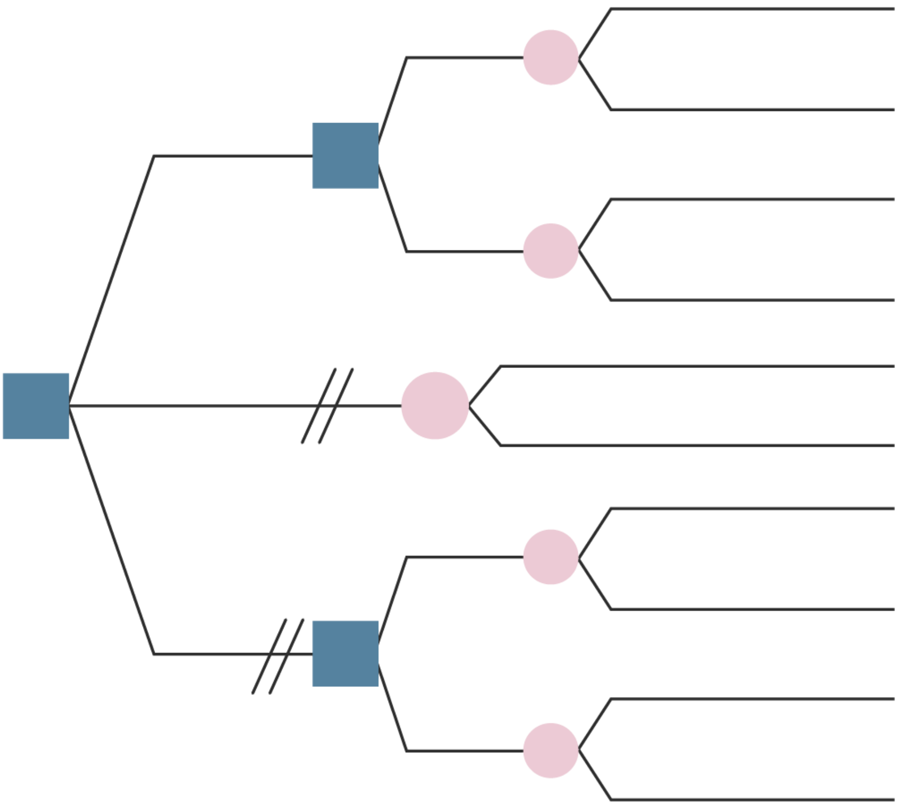

Figure 7. A more complex decision tree has additional nodes and branches.

Solving these more complex decision trees is no different from solving the simpler version you have worked with until now. You would construct the decision tree with the decision nodes and branches from left to right. You would then solve the decision tree from right to left to determine the estimated values.

It is also possible to put 'no change' on a decision tree branch. That way you can compare the results of various options to the revenues and costs associated with the current situation of the business.

Activity

Learner Profile: Knowledgeable
Approaches to Learning: Thinking skills (transfer)

Coffee Stop (CS) is a small cafe serving a variety of coffee drinks and healthy snacks. CS wants to increase its profits and is considering several options, as outlined below.

Option 1: Establish fair trade relationships with coffee farmers to better target ethical consumers.

Option 2: Buy a second coffee machine, that is either:

- **2a:** the same type of manual machine that the cafe currently owns
- **2b:** a new type of coffee machine that grinds and makes the coffee automatically, but still requires a person to operate

For both options 2a and 2b, the cafe would need to hire another employee, which would cost $75 000 over five years.

The probabilities, additional costs and additional revenues forecast for each option are given in **Table 2**. The costs and revenues are projected over a five-year period.

Table 2. Forecast additional costs, additional revenues and probabilities of each option for CS over five years.

Option	**Forecast additional costs ($)**	**Forecast additional revenue if successful ($) (Probability 0.50)**	**Forecast additional revenue if not successful ($) (Probability 0.50)**
Option 1 Establish fair trade relationships with coffee farmers.	18 000	32 000	20 000
Option 2a Buy the same type of coffee machine requiring manual operation.	4000	120 000	50 000
Option 2b Buy a new type of coffee machine that grinds and makes coffee automatically.	11 000	140 000	50 000

Questions

1. Construct a fully labelled decision tree. [4 marks]
2. Calculate the expected value (EV) of the three options and recommend an option to follow based on this information. [2 marks]

Evaluation of the decision tree tool

Table 3 outlines some of the advantages and disadvantages of using the decision tree tool for making business decisions.

Table 3. Advantages and disadvantages of the decision tree tool.

Advantages	Disadvantages
Visual representation. Provides a clear representation of complex problems, making the alternatives easier to understand and communicate.	**No qualitative factors**. Does not take qualitative factors into account.
Risk consideration. Allows for the integration of uncertainty (risk) into the analysis.	**Estimated values**. Probabilities used are only estimates, as are the projected revenues, and could lead to false results.
All options. Considers all available options, even the ‘don’t change’ option, which is often ignored.	**Prone to bias**. The probabilities and the estimated figures for profit and loss might be prone to bias from the decision-maker, who may favour one option over another. This could lead to inaccurate results.