PREFERENCE MATRIX

Decisions often must be made in situations where multiple criteria cannot be na urally merged into a single measure (such as dollars). For example, a manager d ciding in which of two cities to locate a new plant would have to consider suc unquantifiable factors as quality of life, worker attitudes toward work, and com munity reception in the two cities. These important factors cannot be ignored. **preference matrix** is a table that allows the manager to rate an alternative accor ing to several performance criteria. The criteria can be scored on any scale, suc as from 1 (worst possible) to 10 (best possible) or from 0 to 1, as long as th same scale is applied to all the alternatives being compared. Each score is weight ed according to its perceived importance, with the total of these weights typicall equaling 100. The total score is the sum of the weighted scores (weight time score) for all the criteria. The manager can compare the scores for alternative against one another or against a predetermined threshold.

EXAMPLE A.4

Evaluating an Alternative with a Preference Matrix

The following table shows the performance criteria, weights, and score (1 = worst, 10 = best) for a new product: a thermal storage air conditioner. I management wants to introduce just one new product and the highest total score of any of the other product ideas is 800, should the firm pursue making the ai conditioner?

Performance Criterion	Weight (*A*)	Score (*B*)	Weighted Score (*A* × *B*)
Market potential	30	8	240
Unit profit margin	20	10	200
Operations compatibility	20	6	120
Competitive advantage	15	10	150
Investment requirement	10	2	20
Project risk	5	4	20
		Weighted score =	750

Solution Because the sum of the weighted scores is 750, it falls short of the 800 threshold, so management would not pursue the thermal storage air conditioner idea at this time.

Not all managers are comfortable with the preference matrix technique. It requires the manager to state criterion weights before examining the alternatives, although the proper weights may not be readily apparent. Perhaps only after seeing the scores for several alternatives can the manager decide what is important and what is not. Because a low score on one criterion can be compensated for or overridden by high scores on others, the preference matrix method also may cause managers to ignore important signals. In Example A.4, the investment required for the thermal storage air conditioner might exceed the firm's financial capability. In that case the manager should not even be considering the alternative, no matter how high its score.

DECISION THEORY

Decision theory is a general approach to decision making when the outcomes associated with alternatives are often in doubt. It helps operations managers with decisions on process, capacity, location, and inventory, because such decisions are about an uncertain future. Decision theory can also be used by managers in other functional areas. With decision theory, a manager makes choices using the following process.

1. List the feasible *alternatives*. One alternative that should always be considered as a basis for reference is to do nothing. A basic assumption is that the number of alternatives is finite. For example, in deciding where to locate a new retail store in a certain part of the city, a manager could theoretically consider every grid coordinate on the city's map. Realistically, however, the manager must narrow the number of choices to a reasonable number.
2. List the *events* (sometimes called *chance events* or *states of nature*) that have an impact on the outcome of the choice but are not under the manager's control. For example, the demand experienced by the new facility could be low or high, depending not only on whether the location is convenient to many customers, but also on what the competition does and general retail trends. Then group events into reasonable categories. For example, suppose that the average number of sales per day could be anywhere from 1 to 500. Rather than have 500 events, the manager could represent demand with just 3 events: 100 sales/day, 300 sales/day, or 500 sales/day. The events must be mutually exclusive and exhaustive, meaning that they do not overlap and that they cover all eventualities.
3. Calculate the *payoff* for each alternative in each event. Typically the payoff is total profit or total cost. These payoffs can be entered into a **payoff table,** which shows the amount for each alternative if each event occurs. For 3 alternatives and 4 events, the table would have 12 payoffs (3×4). If significant distortions will occur if the time value of money is not recognized, the payoffs should be expressed as present values or internal rates of return (see Appendix 1). For multiple criteria with important qualitative factors, use the weighted scores of a preference matrix approach as the payoffs.
4. Estimate the likelihood of each event, using past data, executive opinion, or other forecasting methods. Express it as a *probability,* making sure that the probabilities sum to 1.0. Develop probability estimates from past data if the past is considered a good indicator of the future.
5. Select a *decision rule* to evaluate the alternatives, such as choosing the alternative with the lowest expected cost. The rule chosen depends on the amount of information the manager has on the event probabilities and the manager's attitudes toward risk.

Using this process, we examine decisions under three different situations: certainty, uncertainty, and risk.

Decision Making Under Certainty

The simplest situation is when the manager knows which event will occur. Here the decision rule is to pick the alternative with the best payoff for the known event. The best alternative is the highest payoff if the payoffs are expressed as profits. If the payoffs are expressed as costs, the best alternative is the lowest payoff.

EXAMPLE A.5

Decisions Under Certainty

A manager is deciding whether to build a small or a large facility. Much depends on the future demand that the facility must serve, and demand may be small or large. The manager knows with certainty the payoffs that will result under each alternative, shown in the following payoff table. The payoffs (in $000) are the present values (see Appendix 1) of future revenues minus costs for each alternative in each event.

	Possible Future Demand	
Alternative	**Low**	**High**
Small facility	200	270
Large facility	160	800
Do nothing	0	0

What is the best choice if future demand will be low?

Solution In this example, the best choice is the one with the highest payoff. If the manager knows that future demand will be low, the company should build a small facility and enjoy a payoff of $200,000. The larger facility has a payoff of only $160,000. The "do nothing" alternative is dominated by the other alternatives; that is, the outcome of one alternative is no better than the outcome of another alternative for each event. Because the "do nothing" alternative is dominated, the manager doesn't consider it further.

Decision Making Under Uncertainty

Here we assume that the manager can list the possible events but cannot estimate their probabilities. Perhaps a lack of prior experience makes it difficult for the firm to estimate probabilities. In such a situation, the manager can use one of four decision rules.

1. *Maximin*—Choose the alternative that is the "best of the worst." This rule is for the *pessimist,* who anticipates the "worst case" for each alternative.
2. *Maximax*—Choose the alternative that is the "best of the best." This rule is for the *optimist,* who has high expectations and prefers to "go for broke."
3. *Laplace*—Choose the alternative with the best *weighted payoff.* To find the weighted payoff, give equal importance (or, alternatively, equal probability) to each event. If there are n events, the importance (or probability) of each is $1/n$, so they add up to 1.0. This rule is for the *realist.*
4. *Minimax Regret*—Choose the alternative with the best "worst regret." Calculate a table of regrets (or opportunity losses), where the rows represent the alternatives and the columns represent the events. A regret is the difference between a given payoff and the best payoff in the same column. For an event it shows how much is lost by picking a given alternative instead of the one that is best for this event. The regret can be lost profit or increased cost, depending on the situation.

EXAMPLE A.6
Decisions Under Uncertainty

Reconsider the payoff matrix in Example A.5. What is the best alternative for each decision rule?

Solution

a. *Maximin:* An alternative's worst payoff is the *lowest* number in its row of the payoff matrix, because the payoffs are profits. The worst payoffs ($000) are

Alternative	Worst Payoff
Small facility	200
Large facility	160

The best of these worst numbers is $200,000, so the pessimist would build a small facility.

b. *Maximax:* An alternative's best payoff ($000) is the *highest* number in its row of the payoff matrix, or

Alternative	Best Payoff
Small facility	270
Large facility	800

The best of these best numbers is $800,000, so the optimist would build a large facility.

c. *Laplace:* With two events, we assign each a probability of 0.5. Thus the weighted payoffs ($000) are

Alternative	Weighted Payoff
Small facility	0.5(200) + 0.5(270) = **235**
Large facility	0.5(160) + 0.5(800) = **480**

The best of these weighted payoffs is $480,000, so the realist would build a large facility.

d. *Minimax Regret:* If demand turns out to be low, the best alternative is a small facility and its regret is 0 (or 200 − 200). If a large facility is built when demand turns out to be low, the regret is 40 (or 200 − 160).

	Regret		
Alternative	Low Demand	High Demand	Maximum Regret
Small facility	200 − 200 = **0**	800 − 270 = **530**	**530**
Large facility	200 − 160 = **40**	800 − 800 = **0**	**40**

The column on the right shows the worst regret for each alternative. To minimize the maximum regret, pick a large facility. The biggest regret is associated with having only a small facility and high demand.

Decision Making Under Risk

Here we assume that the manager can list the events and estimate their probabilities. The manager has less information than with decision making under certainty but more information than with decision making under uncertainty. For this intermediate situation, the *expected value* decision rule is widely used. The expected value for an alternative is found by weighting each payoff with its associated probability and then adding the weighted payoff scores. The alternative with the best expected value (highest for profits and lowest for costs) is chosen.

This rule is much like the Laplace decision rule, except that the events are no longer assumed to be equally likely (or equally important). The expected value is what the *average* payoff would be if the decision could be repeated time after time. Of course, the expected value decision rule can result in a bad outcome if the wrong event occurs. However, it gives the best results if applied consistently over a long period of time. The rule should not be used if the manager is inclined to avoid risk.

EXAMPLE A.7
Decisions Under Risk

Reconsider the payoff matrix in Example A.5. For the expected value decision rule, which is the best alternative if the probability of small demand is estimated to be 0.4 and the probability of large demand is estimated to be 0.6?

Solution The expected value for each alternative is

Alternative	Expected Value
Small facility	0.4(200) + 0.6(270) = **242**
Large facility	0.4(160) + 0.6(800) = **544**

Choose a large facility, because its expected value is the highest at $544,000.

Value of Perfect Information

Suppose that a manager has a way of improving the forecasts—say, through more expensive market research or studying past trends. Assume that the manager, although unable to affect the probabilities of the events, can predict the future without error. The **value of perfect information** is the amount by which the expected payoff will improve if the manager knows which event will occur. It can be found with the following procedure.

1. Identify the best payoff for each event.
2. Calculate the expected value of these best payoffs by multiplying the best payoff for each event by the probability that it will occur.
3. Subtract the expected value of the payoff without perfect information from the expected value of the payoff with perfect information. This difference is the value of perfect information.

EXAMPLE A.8

Value of Perfect Information

What is the value of perfect information to the manager in Example A.7?

Solution The best payoff for each event is the highest number in its column of the payoff matrix, or

Event	Best Payoff
Low demand	200
High demand	800

The expected values, with and without perfect information, are

$$EV_{perfect} = 200(0.4) + 800(0.6) = 560$$

$$EV_{imperfect} = 160(0.4) + 800(0.6) = 544$$

Therefore the value of perfect information is \$560,000 − \$544,000 = \$16,000.

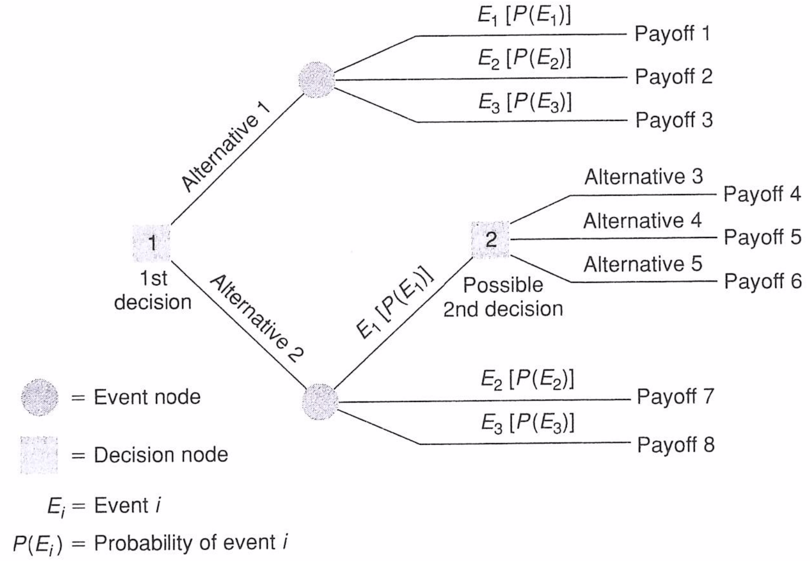
DECISION TREES

A decision tree is a general approach to a wide range of OM decisions, such as product planning, process management, capacity, and location. It is particularly valuable for evaluating different capacity expansion alternatives when demand is uncertain and sequential decisions are involved. For example, a company may expand a facility in 1996 only to discover in 1998 that demand is much higher than forecasted. In that case, a second decision may be necessary to determine whether to expand once again or build a second facility.

A **decision tree** is a schematic model of alternatives available to the decision maker, along with their possible consequences. The name derives from the tree-like appearance of the model. It consists of a number of square *nodes,* representing decision points, that are left by *branches* (which should be read from left to right), representing the alternatives. Branches leaving circular, or chance, nodes represent the events. The probability of each chance event, *P(E),* is shown above each branch. The probabilities for all branches leaving a chance node must sum to 1.0. The conditional payoff, which is the payoff for each possible alternative–event combination, is shown at the end of each combination. Payoffs are given only at the outset, before the analysis begins, for the end points of each alternative–event combination. In Fig. A.2 on the next page, for example, payoff 1 is the financial outcome the manager expects if alternative 1 is chosen and then chance event 1 occurs. No payoff can be associated yet with any branches farther to the left, such as alternative 1 as a whole, because it is followed by a chance event and is not an end point. Payoffs often are expressed as the present value (see Appendix 1) of net profits. If revenues are not affected by the decision, the payoff is expressed as net costs.

After drawing a decision tree, we solve it by working from right to left, calculating the *expected payoff* for each node as follows.

FIGURE A.2
A Decision Tree Model



1. For an event node, multiply the payoff of each event branch by the event's probability. Add these products to get the event node's expected payoff.
2. For a decision node, pick the alternative that has the best expected payoff. If an alternative leads to an event node, its payoff is equal to that node's expected payoff (already calculated). "Saw off," or "prune," the other branches not chosen by marking two short lines through them. The decision node's expected payoff is the one associated with the single remaining unpruned branch.

We continue this process until the leftmost decision node is reached. The unpruned branch extending from it is the best alternative to pursue. If multistage decisions are involved, the manager must await subsequent events before deciding what to do next. If new probability or payoff estimates are obtained, the manager should repeat the process.

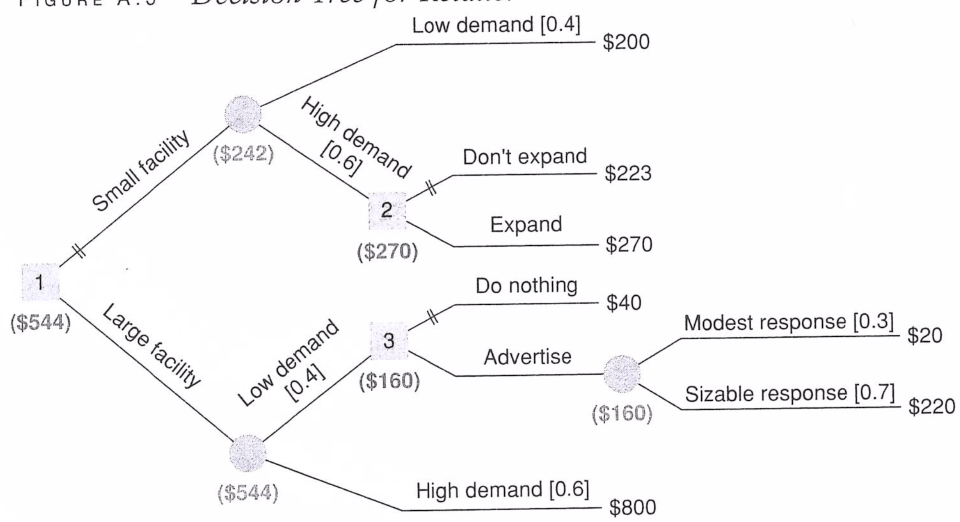
EXAMPLE A.9
Analyzing a Decision Tree

A retailer must decide whether to build a small or a large facility at a new location. Demand at the location can be either small or large, with probabilities estimated to be 0.4 and 0.6, respectively. If a small facility is built and demand proves to be high, the manager may choose not to expand (payoff = \$223,000) or to expand (payoff = \$270,000). If a small facility is built and demand is low, there is no reason to expand and the payoff is \$200,000. If a large facility is built and demand proves to be low, the choice is to do nothing (\$40,000) or to stimulate demand through local advertising. The response to advertising may be either modest or sizable, with their probabilities estimated to be 0.3 and 0.7, respectively. If it is modest, the payoff is estimated to be only \$20,000; the payoff grows to \$220,000 if the response is sizable. Finally, if a large facility is built and demand turns out to be high, the payoff is \$800,000.

Draw a decision tree. Then analyze it to determine the expected payoff for each decision and event node. Which alternative—building a small facility or building a large facility—has the higher expected payoff?

Solution The decision tree in Fig. A.3 shows the event probability and the payoff for each of the seven alternative–event combinations. The first decision is whether to build a small or a large facility. Its node is shown first, to the left, because it is the decision the retailer must make now. The second decision node—whether to expand at a later date—is reached only if a small facility is built and demand turns out to be high. Finally the third decision point—whether to advertise—is reached only if the retailer builds a large facility and demand turns out to be low.

FIGURE A.3 *Decision Tree for Retailer*



Now we can begin the analysis of the decision tree, calculating the expected payoffs from right to left, shown on Fig. A.3 beneath the appropriate event and decision nodes.

1. For the event node dealing with advertising, the expected payoff is 160, or the sum of each event's payoff weighted by its probability [0.3(20) + 0.7(220)].
2. The expected payoff for decision node 3 is 160 because *Advertise* (160) is better than *Do nothing* (40). Prune the *Do nothing* alternative.
3. The payoff for decision node 2 is 270 because *Expand* (270) is better than *Don't expand* (223). Prune *Don't expand*.
4. The expected payoff for the event node dealing with demand, assuming that a small facility is built, is 242 [or 0.4(200) + 0.6(270)].
5. The expected payoff for the event node dealing with demand, assuming that a large facility is built, is 544 [or 0.4(160) + 0.6(800)].
6. The expected payoff for decision node 1 is 544 because the large facility's expected payoff is largest. Prune *Small facility*.

The best alternative is to build the large facility. This initial decision is the only one the retailer makes now. Subsequent decisions are made after learning whether demand actually is low or high.

Problem 2

Binford Tool Company is screening three new product ideas, A, B, and C. Resource constraints allow only one of them to be commercialized. The performance criteria and ratings, on a scale of 1 (worst) to 10 (best), are shown in the following table. The Binford managers give equal weights to the performance criteria. Which is the best alternative, as indicated by the preference matrix method?

	Rating		
Performance Criterion	**Product A**	**Product B**	**Product C**
1. Demand uncertainty and project risk	3	9	2
2. Similarity to present products	7	8	6
3. Expected return on investment (ROI)	10	4	8
4. Compatibility with current manufacturing process	4	7	6
5. Competitive advantage	4	6	5

Solution Each of the five criteria receives a weight of ⅕ or 0.20.

Product	Calculation	Total Score
A	$(0.20 \times 3) + (0.20 \times 7) + (0.20 \times 10) + (0.20 \times 4) + (0.20 \times 4)$	= 5.6
B	$(0.20 \times 9) + (0.20 \times 8) + (0.20 \times 4) + (0.20 \times 7) + (0.20 \times 6)$	= 6.8
C	$(0.20 \times 2) + (0.20 \times 6) + (0.20 \times 8) + (0.20 \times 6) + (0.20 \times 5)$	= 5.4

The best choice is product B. Products A and C are well behind in terms of total weighted score.

Problem 3

Adele Weiss manages the campus flower shop. Flowers must be ordered three days in advance from her supplier in Mexico. Although Valentine's Day is fast approaching, sales are almost entirely last-minute, impulse purchases. Advance sales are so small that Weiss has no way to estimate the probability of low (25 dozen), medium (60 dozen), or high (130 dozen) demand for red roses on the big day. She buys roses for $15 per dozen and sells them for $40 per dozen. Construct a payoff table. Which decision is indicated by each of the following decision criteria?

a. Maximin
b. Maximax
c. Laplace
d. Minimax regret

Solution The payoff table for this problem is

	Demand for Red Roses		
Alternative	**Low (25 dozen)**	**Medium (60 dozen)**	**High (130 dozen)**
Order 25 dozen	$625	$625	$625
Order 60 dozen	$100	$1500	$1500
Order 130 dozen	($950)	$450	$3250
Do nothing	$0	$0	$0

a. Under the maximin criteria, Weiss should order 25 dozen, because if demand is low, Weiss's profits are \$625.
b. Under the maximax criteria, Weiss should order 130 dozen. The greatest possible payoff, \$3250, is associated with the largest order.
c. Under the Laplace criteria, Weiss should order 60 dozen. Equally weighted payoffs for ordering 25, 60, and 130 dozen are about \$625, \$1033, and \$917, respectively.
d. Under the minimax regret criteria, Weiss should order 130 dozen. The maximum regret of ordering 25 dozen occurs if demand is high: \$3250 − \$625 = \$2625. The maximum regret of ordering 60 dozen occurs if demand is high: \$3250 − \$1500 = \$1750. The maximum regret of ordering 130 dozen occurs if demand is low: 625 − (−\$950) = \$1575.

Solved Problem 4

White Valley Ski Resort is planning the ski lift operation for its new ski resort. Management is trying to determine whether one or two lifts will be necessary; each lift can accommodate 250 people per day. Skiing normally occurs in the 14-week period from December to April, during which the lift will operate seven days per week. The first lift will operate at 90 percent capacity if economic conditions are bad, the probability of which is believed to be about a 0.3. During normal times the first lift will be utilized at 100 percent capacity, and the excess crowd will provide 50 percent utilization of the second lift. The probability of normal times is 0.5. Finally, if times are really good, the probability of which is 0.2, the utilization of the second lift will increase to 90 percent. The equivalent annual cost of installing a new lift, recognizing the time value of money and the lift's economic life, is \$50,000. The annual cost of installing two lifts is only \$90,000 if both are purchased at the same time. If used at all, each lift costs \$200,000 to operate, no matter how low or high its utilization rate. Lift tickets cost \$20 per customer per day.

a. Should the resort purchase one lift or two?
b. What is the value of perfect information?

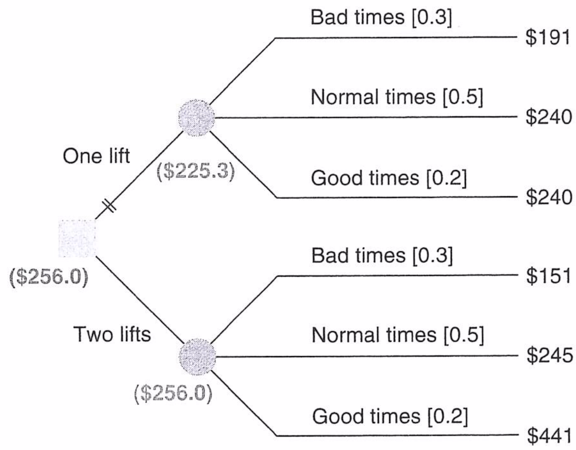
Solution a. The decision tree is shown in Fig. A.5. The payoff (\$000) for each alternative–event branch is shown in the following table. The total revenues from one lift operating at 100 percent capacity are \$490,000 (or 250 customers × 98 days × \$20/customer-day).

Alternative	Economic Condition	Payoff Calculation (Revenue − Cost)
One lift	Bad times	0.9(490) − (50 + 200) = 191
	Normal times	1.0(490) − (50 + 200) = 240
	Good times	1.0(490) − (50 + 200) = 240
Two lifts	Bad times	0.9(490) − (90 + 200) = 151
	Normal times	1.5(490) − (90 + 400) = 245
	Good times	1.9(490) − (90 + 400) = 441

b. The value of perfect information is

Economic Condition	Best Payoff	Probability	Weighted Payoff
Bad times	\$191,000	0.3	\$ 57,300
Normal times	\$245,000	0.5	\$122,500
Good times	\$441,000	0.2	\$ 88,200
	Expected value with perfect information		\$268,000
	Without perfect information, part (a)		\$256,000
	The value of perfect information is		\$ 12,000

FIGURE A.5



Formula Review

1. Break-even volume: $Q = \dfrac{F}{p - c}$

2. Evaluating processes, make-or-buy indifference quantity: $Q = \dfrac{F_m - F_b}{c_b - c_m}$

Supplement Highlights

- Break-even analysis can be used to evaluate the profit potential of products and services. It can also be used to compare alternative production methods. Sensitivity analysis can be used to predict the effect of changing forecasts, costs, or prices.
- At times, decision alternatives cannot be evaluated in light of a single performance measure such as profit or cost. The preference matrix is a method of rating alternatives according to several objectives. The technique calls for important objectives to receive more weight in the decision, but determining in advance which objectives are important may be difficult.
- Applications of decision theory in operations management include decisions on process, capacity, location, and inventory. Decision theory is a general approach to decision making under conditions of certainty, uncertainty, or risk.

Key Terms

break-even analysis *72*
break-even point *72*
decision theory *77*
decision tree *81*
fixed cost *73*
payoff table *77*
preference matrix *76*
sensitivity analysis *74*
value of perfect information *80*
variable cost *73*

Study Questions

1. Explain how break-even analysis can be used to
   a. screen product ideas.
   b. compare alternative processes or alternative facility locations.
2. A newlywed couple used the preference matrix to decide among several apartments. They scored available apartments against weighted performance criteria. The criteria included rent, proximity to work and recreational opportunities, security, and other neighborhood characteristics associated with the couple's values and life-style. Upon completing the analysis, they found that the best apartment indicated by the technique happened to be next door to the bride's parents!

   Evaluate the application of the preference matrix in this decision situation.

3. Explain why the accuracy of demand forecasts and cost estimates becomes important in break-even analysis when the margin between price and cost is small.
4. When we cannot estimate the probability of alternative future events, decisions are made under uncertainty. In such cases do you tend to the maximin, maximax, Laplace, or minimax regret method of making decisions? Does your decision-making style match your pessimistic, optimistic, or realist character? Does your approach to decisions vary in some situations? What situations encourage you to take risks (maximax)? Which cause you to favor minimax regret?
5. The expected value criterion gives good results if ap plied consistently over the long run. Congratulations You've been promoted to Director of the Metropoli tan Major League Baseball Stadium District. Your cit is building a new stadium and you must decide amon alternative designs calling for 30,000, 42,000, an 50,000 seats. What might cause difficulty if you use decision tree and the expected value criterion to evalu ate these alternatives?
6. You have calculated the value of perfect informatior An expert in forecasting offers to provide you wit consulting services for 90 percent of the value of per fect information. Should you accept the offer?

Problems

Problems 1–11 show a variety of applications for break-even analysis. Problems 1–4 apply break-even analysis to product or service planning decisions (Chapter 2). Problems 12 and 13 demonstrate use of the preference matrix for product or service planning, and problem 14 applies the preference matrix to location decisions. Decision theory problems 15, 16, and 19–22 apply to capacity decisions (discussed in Chapter 7). Problems 17 and 18 use decision trees to evaluate fairly complex product or service planning decisions.

Break-Even Analysis

1. Mary Williams, owner of Williams Products, is evaluating whether to introduce a new product line. After thinking through the production process and the costs of raw materials and new equipment, Williams estimates the variable costs of each unit produced and sold at $5 and the fixed costs per year at $46,500.
   a. If the selling price is set at $17 each, how many units must be produced and sold to break even? Use both graphic and algebraic approaches to get your answer.
   b. Williams forecasts sales of 8000 units for the first year if the selling price is set at $12.50 each. What would be the total contribution to profits from this new product during the first year?
   c. If the selling price is set at $11.50, Williams forecasts that first-year sales would increase to 10,000 units. Which pricing strategy ($12.50 or $11.50) would result in the greater total contribution to profits?
   d. What other considerations would be crucial to the final decision about making and marketing the new product?
2. A product at the Jennings Company has enjoyed reasonable sales volumes, but its contributions to profits have been disappointing. Last year, 17,500 units were produced and sold. The selling price is $22 per unit, c is $18, and F is $80,000.
   a. What is the break-even quantity for this product Use both graphic and algebraic approaches to ge your answer.
   b. Jennings is considering ways to either stimulat sales volumes or decrease variable costs. Manage ment believes that sales can be increased by 30 pe cent or that c can be reduced to 85 percent of i current level. Which alternative leads to highe contributions to profits, assuming that each equally costly to implement? (*Hint*: Calculate pro its for both alternatives and identify the one havin the greatest profits.)
   c. What is the percentage change in the per unit prof contribution generated by each alternative i part b?
3. An interactive television service that costs $7 p month to provide can be sold on the informatio highway for $12 per client per month. If a service are includes a potential of 10,000 customers, what is th most a company could spend on annual fixed costs t acquire and maintain the equipment?
4. A restaurant is considering adding fresh brook tro to its menu. Customers would have the choice catching their own trout from a simulated mounta stream or simply asking the waiter to net the trout f them. Operating the stream would require $10,600 fixed costs per year. Variable costs are estimated to b $6.70 per trout. The firm wants to break even if 8C trout dinners are sold per year. What should be th price of the new item?
5. Goliath Manufacturing must implement a manufa turing process that reduces the amount of toxic b products. Two processes have been identified th provide the same level of toxic by-product reductio The first process would incur $205,000 of fixed cos and $650 per unit of variable costs. The secor process has fixed costs of $145,000 and variable cos of $800 per unit.

What is the break-even quantity beyond which the first process is more attractive?

. What is the difference in total cost if the quantity produced is 500 units?

news clipping service is considering modernization. ather than manually clipping and photocopying arti- les of interest and mailing them to its clients, employ- es electronically input stories from most widely irculated publications into a database. Each new ssue is searched for key words, such as a client's com- pany name, competitors' names, type of business, and he company's products, services, and officers. When natches occur, affected clients are instantly notified ia an on-line network. If the story is of interest, it is lectronically transmitted, so the client often has the tory and can prepare comments for follow-up inter- iews before the publication hits the street. The manu- al process has fixed costs of $400,000 per year and variable costs of $6.20 per clipping mailed. The price charged the client is $8.00 per clipping. The comput- erized process has fixed costs of $1,300,000 per year and variable costs of $2.25 per story electronically transmitted to the client.

a. If the same price is charged for either process, what is the annual volume beyond which the automated process is more attractive?

b. The present volume of business is 225,000 clip- pings per year. Many of the clippings sent with the current process are not of interest to the client or are multiple copies of the same story appearing in several publications. The news clipping service be- lieves that by improving service and by lowering the price to $4.00 per story, modernization will in- crease volume to 900,000 stories transmitted per year. Should the clipping service modernize?

c. If the forecasted increase in business is too optimistic, at what volume will the new process break even?

Hahn Manufacturing has been purchasing a key com- ponent of one of its products from a local supplier. The current purchase price is $1500 per unit. Efforts to standardize parts have succeeded to the point that this same component can now be used in five different products. Annual component usage should increase from 150 to 750 units. Management wonders whether it is time to make the component in-house, rather than to continue buying it from the supplier. Fixed costs would increase by about $40,000 per year for the new equipment and tooling needed. The cost of raw mate- rials and variable overhead would be about $1100 per unit, and labor costs would go up by another $300 per unit produced.

a. Should Hahn make rather than buy?

b. What is the break-even quantity?

c. What other considerations might be important?

8. A construction company is trying to decide whether to continue renting or to buy a concrete pump for its foundation and slab construction. The fixed annual cost for buying a new pump with hose and all other accessories is $8800, and annual maintenance costs would be another $2000 per year. One of the compa- ny's current employees would operate the pump, at a wage rate of $35 per hour. If the company doesn't buy the pump, it will continue to rent one for $125 per hour, including operator labor cost. The pump is nor- mally needed for eight hours per pour.
   a. What is the break-even quantity in number of pours?
   b. If the company expects to have 40 pours per year, should it buy or continue to rent? What is the dif- ference in annual costs at this volume?

9. The Tri-County Generation and Transmission Associ- ation is a nonprofit cooperative organization that pro- vides electrical service to rural customers. Based on a faulty long-range demand forecast, Tri-County overbuilt its generation and distribution system. Tri- County now has much more capacity than it needs to serve its customers. Fixed costs, mostly debt service on investment in plant and equipment, are $82.5 million per year. Variable costs, mostly fossil fuel costs, are $25 per megawatt-hour (MWh, or million watts of power used for one hour). The new person in charge of demand forecasting prepared a short-range forecast for use in next year's budgeting process. That forecast calls for Tri-County customers to consume 1 million MWh of energy next year.
   a. How much will Tri-County need to charge its cus- tomers per MWh to break even next year?
   b. The Tri-County customers balk at that price and conserve electrical energy. Only 95 percent of fore- casted demand materializes. What is the resulting surplus or loss for this nonprofit organization?

10. Earthquake, drought, fire, economic famine, flood, and a pestilence of TV court reporters have caused an exodus from the City of Angels to Boulder, Colorado. The sudden increase in demand is straining the capaci- ty of Boulder's electrical system. Boulder's alternatives have been reduced to buying 150,000 MWh of electric power from Tri-County G&T at a price of $75 per MWh, or refurbishing and recommissioning the aban- doned Pearl Street Power Station in downtown Boul- der. Fixed costs of that project are $10 million per year, and variable costs would be $35 per MWh. Should Boulder build or buy?

11. Tri-County G&T sells 150,000 MWh per year of elec- trical power to Boulder at $75 per MWh, has fixed costs of $82.5 million per year, and has variable costs of $25 per MWh. If Tri-County has 1,000,000 MWh of demand from its customers (other than Boulder) what will Tri-County have to charge to break even?

Preference Matrix

12. The Forsite Company is screening three ideas for new services. Resource constraints allow only one idea to be commercialized at the present time. The following estimates have been made for the five performance criteria that management believes to be most important.

	Rating		
Performance Criterion	**Service A**	**Service B**	**Service C**
Capital equipment investment required	0.6	0.8	0.3
Expected return on investment (ROI)	0.7	0.3	0.9
Compatibility with current work-force skills	0.4	0.7	0.5
Competitive advantage	1.0	0.4	0.6
Compatibility with EPA requirements	0.2	1.0	0.5

a. Calculate a total weighted score for each alternative. Use a preference matrix and assume equal weights for each performance criterion. Which alternative is best? Worst?

b. Suppose that the expected ROI is given twice the weight assigned to each of the remaining criteria. (Sum of weights should remain the same as in part a.) Does this modification affect the ranking of the three potential services?

13. You are in charge of analyzing five new product ideas and have been given the information shown in Table A.1 (1 = worst, 10 = best). Management has decided that criteria 2 and 3 are equally important, criterion 1 is five times as important as criterion 2, and criterion 4 is three times as important as criterion 2. Only two new products can be introduced, and a product can be introduced only if its score exceeds 70 percent of the maximum possible total points. Which product ideas do you recommend?

14. Schlemiel, Schlimazel, Hasenpfeffer, Inc. collected the following information on where to locate a brewery (1 = poor, 10 = excellent).

		Location Score	
Location Factor	**Factor Weight**	**Milwaukee**	**Boulder**
Construction costs	10	8	5
Utilities available	10	7	7
Business services	20	4	7
Real estate cost	30	7	4
Quality of life	10	4	8
Transportation	20	7	6

a. Which location, A or B, should be chosen on the basis of the total weighted score?

b. If the factors were weighted equally, would the choice change?

Decision Theory

15. B&K Construction has received favorable publicity from guest appearances on a public TV home improvement program. Public TV programming decisions seem to be unpredictable, so B&K can't estimate the probability of continued benefits from its relationship with the show. Demand for home improvements next year may be either low or high. But B&K must decide now whether to hire more employees, do nothing, or develop subcontracts with other home improvement contractors. B&K has developed the following payoff table (top of next page). Which alternative is best, according to each of the following decision criteria?

a. Maximin
b. Maximax
c. Laplace
d. Minimax regret

Table A.1 *Analysis of New Product Ideas*

	Rating				
Performance Criterion	**Product A**	**Product B**	**Product C**	**Product D**	**Product E**
Compatibility with current manufacturing	8	7	3	6	8
Expected return on investment (ROI)	3	8	4	7	7
Compatibility with current work-force skills	7	5	7	6	2
Unit profit margin	7	6	9	1	6

	Demand for Home Improvements	
Alternative	Low	High
Hire	($250,000)	$625,000
Subcontract	$100,000	$415,000
Do nothing	$250,000	$300,000

16. Once upon a time in the old West, Fletcher, Cooper, and Wainwright (the Firm) was deciding whether to make arrows, barrels, or Conestoga wagons. The Firm understood that demand for products would vary, depending on U.S. government policies concerning the development of travel routes to California. If land routes were chosen and treaties with Native Americans could not be negotiated, the demand for arrows would be great. Success in those negotiations would favor demand for Conestoga wagons. If the water route was chosen, the success of negotiations would be irrelevant. Instead, many barrels would be needed to contain goods during the long sea voyage around Cape Horn. Although the Firm was expert at forecasting the effect of policy on its business, it couldn't estimate the probability of the U.S. government favoring one policy over another. Based on the Firm's forecasted demand, which alternative is best, according to each of the following decision criteria?
    a. Maximin
    b. Maximax
    c. Laplace

	Forecasted Demand		
Policy	Arrows	Barrels	Conestoga Wagons
Land, no treaty	9,000,000	300,000	5,000
Land, with treaty	5,000,000	200,000	50,000
Sea	2,500,000	500,000	3,000

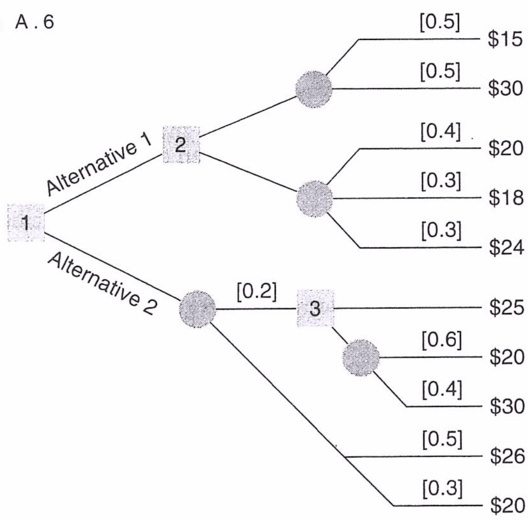
	Product		
Price and Costs	Arrows	Barrels	Conestoga Wagons
Fixed costs	$60,000	$80,000	$100,000
Variable costs per unit	$0.05	$1.50	$50
Price per unit	$0.15	$3.00	$75

17. Returning to Problem 16, assume that Fletcher, Cooper, and Wainwright has contributed to the reelection campaign and legal defense fund for the Chair of the House Ways and Means Committee. In return the Firm learns that the probability of choosing the sea route is 0.2, the probability of developing the land route and successful treaty negotiations is 0.3, and the probability of developing the land route and unsuccessful negotiations is 0.5.
    a. Draw a decision tree to analyze the problem. Calculate the expected value of each product alternative.
    b. The Chair informs Fletcher, Cooper and Wainwright that a more accurate forecast of events is available "for a price." What is the value of perfect information?

Decision Tree

18. Analyze the decision tree in Fig. A.6. What is the expected payoff for the best alternative?

FIGURE A.6



19. A manager is trying to decide whether to buy one machine or two. If only one is purchased and demand proves to be excessive, the second machine can be purchased later. Some sales will be lost, however, because the lead time for producing this type of machine is six months. In addition, the cost per machine will be lower if both are purchased at the same time. The probability of low demand is estimated to be 0.25, and of high demand, 0.75. The after-tax net present value of the benefits from purchasing the two machines together is $94,000 if demand is low and $165,000 if demand is high.

    If one machine is purchased and demand is low, the net present value is $115,000. If demand is high, the manager has three options. Doing nothing has a net present value of $115,000; subcontracting, $140,000; and buying the second machine, $126,000.
    a. Draw a decision tree for this problem.
    b. How many machines should the company buy initially? What is the expected payoff for this alternative?

20. A manager is trying to decide whether to build a small, medium, or large facility. Demand can be low, average, or high, with the estimated probabilities being 0.25, 0.40, and 0.35, respectively.

A small facility is expected to earn an after-tax net present value of just \$18,000 if demand is low. If demand is average, the small facility is expected to earn \$75,000; it can be increased to average size to earn a net present value of \$60,000. If demand is high, the small facility is expected to earn \$75,000 and can be expanded to average size to earn \$60,000 or to large size to earn \$125,000.

A medium-sized facility is expected to lose an estimated \$25,000 if demand is low and earn \$140,000 if demand is average. If demand is high, the medium-sized facility is expected to earn a net present value of \$150,000; it can be expanded to a large size for a net payoff of \$145,000.

If a large facility is built and demand is high, earnings are expected to be \$220,000. If demand is average for the large facility, the present value is expected to be \$125,000; if demand is low, the facility is expected to lose \$60,000.

a. Draw a decision tree for this problem.
b. What should management do to achieve the highest expected payoff?

21. A manufacturing plant has reached full capacity. The company must build a second plant—either small or large—at a nearby location. The probabilities are 0.40 for low demand and 0.60 for high demand.

If demand is low, the large plant has a present value of \$5 million and the small plant, \$8 million. If demand is high, the large plant pays off with a present value of \$17 million and the small plant with a present value of only \$10 million. However, the small plant can be expanded later if demand proves to be high, for a present value of \$15 million.

a. Draw a decision tree for this problem.
b. What should management do to achieve the highest expected payoff?

22. A firm is adding a new product line and must build a new plant. Demand will be either favorable or unfavorable, with probabilities of 0.60 and 0.40, respectively. If a large plant is built and demand is favorable, the after-tax net present value of benefits is estimated at \$1,520,000. If demand is unfavorable, the loss with the large plant will be \$20,000.

If a small plant is built and demand is unfavorable, the net present value is \$760,000, after deducting the costs to build and equip the plant. If demand proves to be favorable, the firm can maintain the small facility or expand it. Maintaining the small facility has a present value of \$950,000; expanding, it has a present value of \$570,000.

a. Draw a decision tree for this problem.
b. What should management do to achieve the highest expected payoff?

Selected References

Bierman, Harold, Jr., Charles P. Bonini, and Warren H. Hausman. *Quantitative Analysis for Business Decisions.* Homewood, Ill.: Irwin, 1986.

Clemen, Robert T. *Making Hard Decisions: An Introduction to Decision Analysis.* Boston: PWS-Kent, 1991.

Taylor, Bernard W. III. *Introduction to Management Science.* Needham Heights, Mass.: Allyn & Bacon, 1990.