Introduction to Management Science 16th edition Camm Solutions Manual

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Solution and Answer Guide

Jeffrey D. Camm, An Introduction to Management Science 2023, 9780357715468; Chapter 1: Introduction

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Problems

1. **Vocabulary.** Define the terms *management science* and *operations research*. **LO 1**

   Solutions:
   Management science and operations research, terms used almost interchangeably, are broad disciplines that employ scientific methodology in managerial decision making or problem solving. Drawing upon a variety of disciplines (behavioral, mathematical, etc.), management science and operations research combine quantitative and qualitative considerations in order to establish policies and decisions that are in the best interest of the organization.

2. **The Decision-Making Process.** List and discuss the steps of the decision-making process. **LO 2**

   Solutions:
   a. Define the problem.
   b. Identify the alternatives.
   c. Determine the criteria.
   d. Evaluate the alternatives.
   e. Choose an alternative.
   f. For further discussion, see Section 1.3.

3. **Roles of Qualitative and Quantitative Approaches to Decision Making.** Discuss the different roles played by the qualitative and quantitative approaches to managerial decision making. Why is it important for a manager or decision maker to have a good understanding of both of these approaches to decision making? **LO 2**

   Solutions:
   See Section 1.2.

4. **Production Scheduling.** A firm just completed a new plant that will produce more than 500 different products, using more than 50 different production lines and machines. The production scheduling decisions are critical in that sales will be lost if customer demands are not met on time. If no individual in the firm has experience with this production operation and if new production schedules must be generated each week, why should the firm consider a quantitative approach to the production scheduling problem? **LO 2**

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Solutions:
A quantitative approach should be considered because the problem is large, complex, important, new, and repetitive.

5. **Advantages of Modeling.** List the advantages of analyzing and experimenting with a model as opposed to a real object or situation. **LO 3**

Solutions:
Models usually have time, cost, and risk advantages over experimenting with actual situations.

6. **Choosing Between Models.** Suppose that a manager has a choice between the following two mathematical models of a given situation: (a) a relatively simple model that is a reasonable approximation of the real situation, and (b) a thorough and complex model that is the most accurate mathematical representation of the real situation possible. Why might the model described in part (a) be preferred by the manager? **LO 3**

Solutions:
Model (a) may be quicker to formulate, easier to solve, and/or more easy to understand.

7. **Modeling Fuel Cost.** Suppose you are going on a weekend trip to a city that is d miles away. Develop a model that determines your round-trip gasoline costs. What assumptions or approximations are necessary to treat this model as a deterministic model? Are these assumptions or approximations acceptable to you? **LO 3**

Solutions:
Let d = distance
m = miles per gallon
c = cost per gallon,

$$\therefore \text{Total Cost} = \left(\frac{2d}{m}\right)c$$

We must be willing to treat m and c as known and not subject to variation.

8. **Adding a Second Product to a Production Model.** Recall the production model from Section 1.3:

$$\begin{aligned} \text{Max} \quad & 10x \\ \text{s.t.} \quad & \\ & 5x \le 40 \\ & x \ge 0 \end{aligned}$$

Suppose the firm in this example considers a second product that has a unit profit of \$5 and requires 2 hours of production time for each unit produced. Use y as the number of units of product 2 produced. **LO 4**

a. Show the mathematical model when both products are considered simultaneously.

b. Identify the controllable and uncontrollable inputs for this model.

c. Draw the flowchart of the input–output process for this model (see Figure 1.5).

d. What are the optimal solution values of x and y?

e. Is the model developed in part (a) a deterministic or a stochastic model? Explain.

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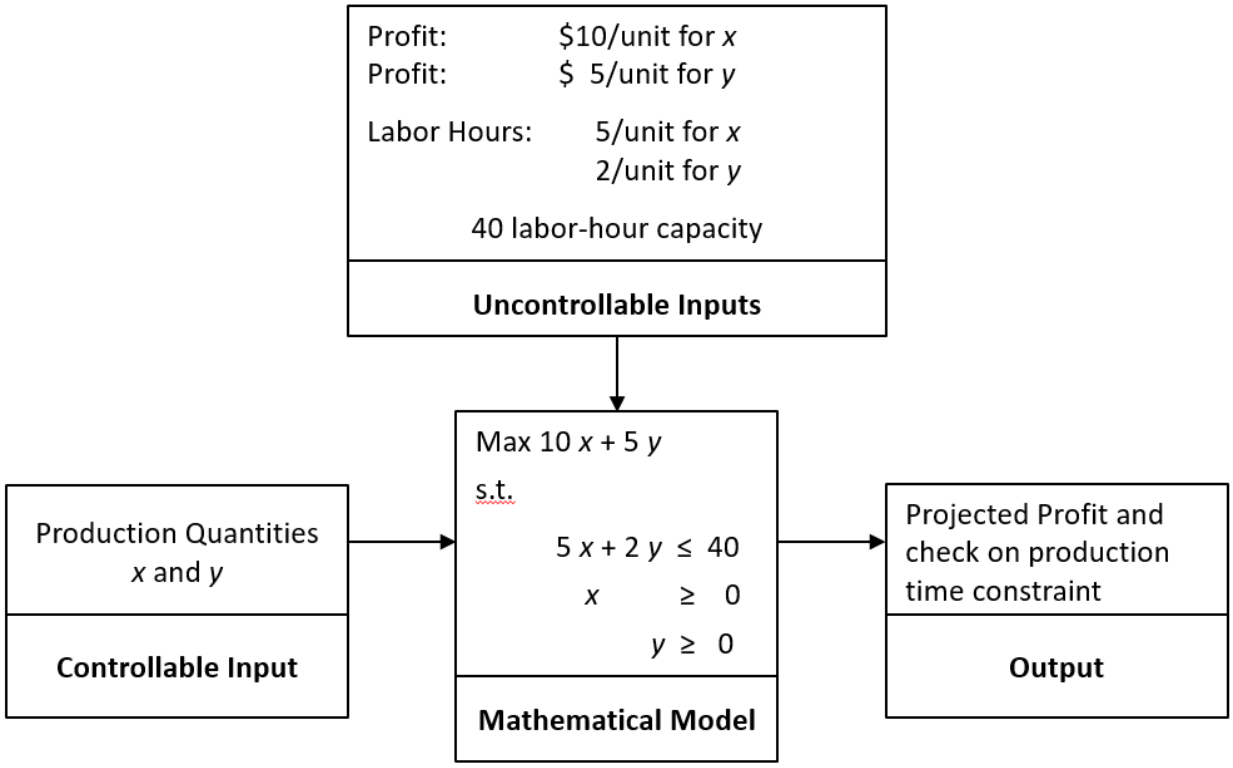
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Solutions:

a. Maximize $10x + 5y$
s.t.
$$5x + 2y \le 40$$
$$x \ge 0, y \ge 0$$

b. Controllable inputs: x and y
Uncontrollable inputs: profit (10,5), labor hours (5,2), and labor-hour availability (40)

c.



d. $x = 0, y = 20$ Profit = $100
(Solution by trial-and-error)

e. Deterministic—all uncontrollable inputs are fixed and known.

9. **Stochastic Production Models.** Suppose we modify the production model in Section 1.3 to obtain the following mathematical model:

$$\begin{aligned} \text{Max} \quad & 10x \\ \text{s.t.} \quad & \\ & ax \le 40 \\ & x \ge 0 \end{aligned}$$

where a is the number of hours of production time required for each unit produced. With $a = 5$, the optimal solution is $x = 8$. If we have a stochastic model with $a = 3$, $a = 4$, $a = 5$, or $a = 6$ as the possible values for the number of hours required per unit, what is the optimal value for x? What problems does this stochastic model cause? **LO 4**

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Solutions:
If $a = 3$, $x = 13\ 1/3$, and profit = 133.
If $a = 4$, $x = 10$, and profit = 100.
If $a = 5$, $x = 8$, and profit = 80.
If $a = 6$, $x = 6\ 2/3$, and profit = 67.

Since a is unknown, the actual values of x and profit are not known with certainty.

10. **Modeling Shipments.** A retail store in Des Moines, Iowa, receives shipments of a particular product from Kansas City and Minneapolis. Define x and y as follows. **LO 4**

x = number of units of the product received from Kansas City
y = number of units of the product received from Minneapolis

a. Write an expression for the total number of units of the product received by the retail store in Des Moines.

b. Shipments from Kansas City cost $0.20 per unit, and shipments from Minneapolis cost $0.25 per unit. Develop an objective function representing the total cost of shipments to Des Moines.

c. Assuming the monthly demand at the retail store is 5000 units, develop a constraint that requires 5000 units to be shipped to Des Moines.

d. No more than 4000 units can be shipped from Kansas City, and no more than 3000 units can be shipped from Minneapolis in a month. Develop constraints to model this situation.

e. Of course, negative amounts cannot be shipped. Combine the objective function and constraints developed to state a mathematical model for satisfying the demand at the Des Moines retail store at minimum cost.

Solutions:
a. Total Units Received = y x +

b. Total Cost = $0.20x + 0.25y$

c. $x + y = 5000$

d. $x \le 4000$ Kansas City Constraint
$y \le 3000$ Minneapolis Constraint

e. Min $0.20x + 0.25y$
s.t.
$x + y = 5000$
$x \le 4000$
$y \le 3000$
$x, y \ge 0$

11. **Modeling Demand as a Function of Price.** For most products, higher prices result in a decreased demand, whereas lower prices result in an increased demand. Let

d = annual demand for a product in units
p = price per unit

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Assume that a firm accepts the following price–demand relationship as being realistic:

$$d = 800 - 10p$$

where p must be between \$20 and \$70. **LO 4**

a. How many units can the firm sell at the \$20 per-unit price? At the \$70 per-unit price?

b. What happens to annual units demanded for the product if the firm increases the per-unit price from \$26 to \$27? From \$42 to \$43? From \$68 to \$69? What is the suggested relationship between the per-unit price and annual demand for the product in units?

c. Show the mathematical model for the total revenue (TR), which is the annual demand multiplied by the unit price.

d. Based on other considerations, the firm's management will only consider price alternatives of \$30, \$40, and \$50. Use your model from part (b) to determine the price alternative that will maximize the total revenue.

e. What are the expected annual demand and the total revenue corresponding to your recommended price?

Solutions:

a. At \$20 $d = 800 - 10(20) = 600$
At \$70 $d = 800 - 10(70) = 100$

b. At \$26 $d = 800 - 10(26) = 540$
At \$27 $d = 800 - 10(27) = 530$
If the firm increases the per unit price from \$26 to \$27, the number of units the firm can sell falls by 10.

At \$42 $d = 800 - 10(42) = 380$
At \$43 $d = 800 - 10(43) = 370$
If the firm increases the per unit price from \$426 to \$43, the number of units the firm can sell falls by 10.

This suggests that the relationship between the per-unit price and annual demand for the product in units is linear between \$20 and \$70 and that annual demand for the product decreases by 10 units when the price is increased by \$1.

c. $TR = dp = (800 - 10p)p = 800p - 10p^2$

d. At \$30 $TR = 800(30) - 10(30)^2 = 15{,}000$
At \$40 $TR = 800(40) - 10(40)^2 = 16{,}000$
At \$50 $TR = 800(50) - 10(50)^2 = 15{,}000$
Total Revenue is maximized at the \$40 price.

e. $d = 800 - 10(40) = 400$ units
$TR = \$16{,}000$

12. **Modeling a Special Order Decision.** The O'Neill Shoe Manufacturing Company will produce a special-style shoe if the order size is large enough to provide a reasonable profit. For each special-style order, the company incurs a fixed cost of \$2000 for the production setup. The variable cost is \$60 per pair, and each pair sells for \$80. **LO 4**

a. Let x indicate the number of pairs of shoes produced. Develop a mathematical model for the total cost of producing x pairs of shoes.

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b. Let P indicate the total profit. Develop a mathematical model for the total profit realized from an order for x pairs of shoes.

c. How large must the shoe order be before O'Neill will break even?

Solutions:

a. $TC = 2000 + 60x$

b. $P = 80x - (2000 + 60x) = 20x - 2000$

c. Breakeven point is the value of x when $P = 0$.
Thus, $20x - 2000 = 0$
$20x = 2000$
$x = 100$

13. **Breakeven Point for a Training Seminar.** Micromedia offers computer training seminars on a variety of topics. In the seminars each student works at a personal computer, practicing the particular activity that the instructor is presenting. Micromedia is currently planning a two-day seminar on the use of Microsoft Excel in statistical analysis. The projected fee for the seminar is $600 per student. The cost for the conference room, instructor compensation, lab assistants, and promotion is $9600. Micromedia rents computers for its seminars at a cost of $120 per computer per day. **LO 4**

a. Develop a model for the total cost to put on the seminar. Let x represent the number of students who enroll in the seminar.

b. Develop a model for the total profit if x students enroll in the seminar.

c. Micromedia has forecasted an enrollment of 30 students for the seminar. How much profit will be earned if their forecast is accurate?

d. Compute the breakeven point.

Solutions:

a. Total cost = $9600 + (2 \times 120)x = 9600 + 240x$

b. Total profit = total revenue − total cost
$= 600x - (9600 + 240x)$
$= 360x - 9600$

c. Total profit = $360(30) - 9600 = 1200$

d. $360x - 9600 = 0$
$x = 9600/360 = 26.67$

The breakeven point is between 26 and 27 students.

14. **Breakeven Point for a Textbook.** Eastman Publishing Company is considering publishing a paperback textbook on spreadsheet applications for business. The fixed cost of manuscript preparation, textbook design, and production setup is estimated to be $160,000. Variable production and material costs are estimated to be $6 per book. The publisher plans to sell the text to college and university bookstores for $46 each. **LO 4**

a. What is the breakeven point?

b. What profit or loss can be anticipated with a demand of 3800 copies?

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c. With a demand of 3800 copies, what is the minimum price per copy that the publisher must charge to break even?

d. If the publisher believes that the price per copy could be increased to $50.95 and not affect the anticipated demand of 3800 copies, what action would you recommend? What profit or loss can be anticipated?

Solutions:

a. Profit = Revenue − Cost
$= 46x - (160{,}000 + 6x)$
$= 40x - 160{,}000$
$40x - 160{,}000 = 0$
$40x = 160{,}000$
$x = 4000$

Breakeven point = 4000

b. Profit = 40(3800) − 16,000 = −8000

Thus, a loss of $8000 is anticipated.

c. Profit = $px - (160{,}000 + 6x)$
$= 3800p - (160{,}000 + 6(3800)) = 0$
$3800p = 182{,}800$
$P = 48.105$ or $48.11

d. Profit = $50.95 (3800) − (160,000 + 6 (3800))
= $10,810

Probably go ahead with the project, although the $10,810 is only a 5.98% return on the total cost of $182,800.

15. **Breakeven Point for Stadium Luxury Boxes.** Preliminary plans are under way for the construction of a new stadium for a major league baseball team. City officials have questioned the number and profitability of the luxury corporate boxes planned for the upper deck of the stadium. Corporations and selected individuals may buy the boxes for $300,000 each. The fixed construction cost for the upper-deck area is estimated to be $4,500,000, with a variable cost of $150,000 for each box constructed. **LO 4**

a. What is the breakeven point for the number of luxury boxes in the new stadium?

b. Preliminary drawings for the stadium show that space is available for the construction of up to 50 luxury boxes. Promoters indicate that buyers are available and that all 50 could be sold if constructed. What is your recommendation concerning the construction of luxury boxes? What profit is anticipated?

Solutions:

a. Profit = $300{,}000x - (4{,}500{,}000 + 150{,}000x) = 0$
$150{,}000x = 4{,}500{,}000$
$x = 30$

b. Build the luxury boxes.
Profit = 300,000 (50) − (4,500,000 + 150,000 (50))
= $3,000,000

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16. **Modeling Investment Strategies.** Financial Analysts, Inc., is an investment firm that manages stock portfolios for a number of clients. A new client is requesting that the firm handle an $800,000 portfolio. As an initial investment strategy, the client would like to restrict the portfolio to a mix of the following two stocks:

Stock	Price/Share	Maximum Estimated Annual Return/Share	Possible Investment
Oil Alaska	$50	$6	$500,000
Southwest Petroleum	$30	$4	$450,000

Define *x* and *y* as follows. **LO 4**

x = number of shares of Oil Alaska
y = number of shares of Southwest Petroleum

a. Develop the objective function, assuming that the client desires to maximize the total annual return.

b. Show the mathematical expression for each of the following three constraints:
(1) Total investment funds available are $800,000.
(2) Maximum Oil Alaska investment is $500,000.
(3) Maximum Southwest Petroleum investment is $500,000.

Note: Adding the *x* $ 0 and *y* $ 0 constraints provides a linear programming model for the investment problem. A solution procedure for this model will be discussed in Chapter 2.

Solutions:

a. Max $6x + 4y$

b.
$$\begin{aligned} 50x + 30y &\le 800{,}000 \\ 50x &\le 500{,}000 \\ 30y &\le 450{,}000 \\ x, y &\ge 0 \end{aligned}$$

17. **Modeling an Inventory System.** Models of inventory systems frequently consider the relationships among a beginning inventory, a production quantity, a demand or sales, and an ending inventory. For a given production period *j*, define *s, x,* and *d* as follows. **LO 4**

s_{j-1} = ending inventory from the previous period (beginning inventory for period *j*)
x_j = production quantity in period *j*
d_j = demand in period *j*
s_j = ending inventory for period *j*

a. Write the mathematical relationship or model that describes how these four variables are related.

b. What constraint should be added if production capacity for period *j* is given by *Cj*?

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c. What constraint should be added if inventory requirements for period *j* mandate an ending inventory of at least l_j?

Solutions:

a. $s_j = s_{j-1} + x_j - d_j$
or $s_j - s_{j-1} - x_j + d_j = 0$

b. $x_j \le c_j$

c. $s_j \ge l_j$

18. **Blending Fuels.** Esiason Oil makes two blends of fuel by mixing oil from three wells, one each in Texas, Oklahoma, and California. The costs and daily availability of the oils are provided in the following table.

Source of Oil	Cost per Gallon	Daily Gallons Available
Texas well	0.30	12,000
Oklahoma well	0.40	20,000
California well	0.48	24,000

Because these three wells yield oils with different chemical compositions, Esiason's two blends of fuel are composed of different proportions of oil from its three wells. Blend A must be composed of at least 35% of oil from the Texas well, no more than 50% of oil from the Oklahoma well, and at least 15% of oil from the California well. Blend B must be composed of at least 20% of oil from the Texas well, at least 30% of oil from the Oklahoma well, and no more than 40% of oil from the California well.

Each gallon of Blend A can be sold for $3.10 and each gallon of Blend B can be sold for $3.20. Long-term contracts require at least 20,000 gallons of each blend to be produced.

Define *x, y,* and *i* as follows. **LO 4**

x_i = number of gallons of oil from well *i* used in production of Blend A
y_i = number of gallons of oil from well *i* used in production of Blend B
i = 1 for the Texas well, 2 for the Oklahoma well, 3 for the California well

a. Develop the objective function, assuming that the client desires to maximize the total daily profit.

b. Show the mathematical expression for each of the following three constraints:
(1) Total daily gallons of oil available from the Texas well is 12,000.
(2) Total daily gallons of oil available from the Oklahoma well is 20,000.
(3) Total daily gallons of oil available from the California well is 24,000.

c. Should this problem include any other constraints? If so, express them mathematically in terms of the decision variables.

Solutions:

a. Maximize $(3.10 - 0.30)x_1 + (3.10 - 0.40)\,x_2 + (3.10 - 0.48)x_3 + (3.20 - 0.30)y_1 + (3.20 - 0.40)y_2 + (3.20 - 0.48)y_3$
$= \text{Maximize } 2.80x_1 + 2.70\,x_2 + 2.62x_3 + 2.90y_1 + 2.80y_2 + 2.72y_3$

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b. (1) $x_1 + y_1 \le 12{,}000$
(2) $x_2 + y_2 \le 20{,}000$
(3) $x_3 + y_3 \le 24{,}000$

c.

$x_1 \ge .35(x_1 + x_2 + x_3)$ or $.65x_1 - .35x_2 - .35x_3 \ge 0$	(Blend A must be composed of at least 35% of oil from the Texas well.)
$x_2 \le .50(x_1 + x_2 + x_3)$ or $-.50x_1 + .50x_2 - .50x_3 \le 0$	(Blend A must be composed of no more than 50% of oil from the Oklahoma well.)
$x_3 \ge .15(x_1 + x_2 + x_3)$ or $-.15x_1 - .15x_2 + .85x_3 \ge 0$	(Blend A must be composed of at least 15% of oil from the California well.)
$y_1 \ge .20(y_1 + y_2 + y_3)$ or $.80y_1 - .20y_2 - .20y_3 \ge 0$	(Blend B must be composed of at least 20% of oil from the Texas well.)
$y_2 \ge .30(y_1 + y_2 + y_3)$ or $-.30y_1 + .70y_2 - .30y_3 \ge 0$	(Blend B must be composed of at least 30% of oil from the Oklahoma well.)
$y_3 \le .40(y_1 + y_2 + y_3)$ or $-.40y_1 - .40y_2 + .60y_3 \le 0$	(Blend B must be composed of no more than 40% of oil from the California well.)
$x_1 + x_2 + x_3 \ge 20{,}000$	(Long-term contracts require at least 20,000 gallons of Blend A to be produced.)
$y_1 + y_2 + y_3 \ge 20{,}000$	(Long-term contracts require at least 20,000 gallons of Blend B to be produced.)

19. **Modeling Cabinet Production.** Brooklyn Cabinets is a manufacturer of kitchen cabinets. The two cabinetry styles manufactured by Brooklyn are contemporary and farmhouse. Contemporary style cabinets sell for $90 and farmhouse style cabinets sell for $85. Each cabinet produced must go through carpentry, painting, and finishing processes. The following table summarizes how much time in each process must be devoted to each style of cabinet.

	Hours per Process		
Style	**Carpentry**	**Painting**	**Finishing**
Contemporary	2.0	1.5	1.3
Farmhouse	2.5	1.0	1.2

Carpentry costs $15 per hour, painting costs $12 per hour, and finishing costs $18 per hour; and the weekly number of hours available in the processes is 3000 in carpentry, 1500 in painting, and 1500 in finishing. Brooklyn also has a contract that requires the company to supply one of its customers with 500 contemporary cabinets and 650 farmhouse style cabinets each week.

Define x and y as follows. **LO 4**

x = the number of contemporary style cabinets produced each week
y = the number of farmhouse style cabinets produced each week

a. Develop the objective function, assuming that Brooklyn Cabinets wants to maximize the total weekly profit.

b. Show the mathematical expression for each of the constraints on the three processes.

c. Show the mathematical expression for each of Brooklyn Cabinets' contractual agreements.

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Solutions:

a. Profit per contemporary cabinet is \$90 − [2.0(\$15) + 1.5(\$12) + 1.3(\$18)] = \$18.60.
Profit per farmhouse cabinet is \$85 − [2.5(\$15) + 1.0(\$12) + 1.2(\$18)] = \$13.90.
So the objective function is maximize $18.6x + 13.9y$.

b. $2.0x_1 + 2.5y_1 \le 3000$ hours available in carpentry
$1.5x_2 + 1.0y_2 \le 1500$ hours available in painting
$1.3x_3 + 1.2y_3 \le 1500$ hours available in finishing

c. $x \ge 500$
$y \ge 650$

20. **Modeling the Promotion Mix for a Movie.** PromoTime, a local advertising agency, has been hired to promote the new adventure film *Tomb Raiders* starring Angie Harrison and Joe Lee Ford. The agency has been given a \$100,000 budget to spend on advertising for the movie in the week prior to its release, and the movie's producers have dictated that only local television ads and locally targeted Internet ads will be used. Each television ad costs \$500 and reaches an estimated 7000 people, and each Internet ad costs \$250 and reaches an estimated 4000 people. The movie's producers have also dictated that, in order to avoid saturation, no more than 20 television ads will be placed. The producers have also stipulated that, in order to reach a critical mass, at least 50 Internet ads will be placed. Finally, the producers want at least one-third of all ads to be placed on television.
Define x and y as follows. **LO 4**

x = the number of television ads purchased
y = the number of Internet ads purchased

a. Develop the objective function, assuming that the movie's producers want to reach the maximum number of people possible.

b. Show the mathematical expression for the budget constraint.

c. Show the mathematical expression for the maximum number of 20 television ads to be used.

d. Show the mathematical expression for the minimum number of Internet ads to be used.

e. Show the mathematical expression for the stipulated ratio of television ads to Internet ads.

f. Carefully review the constraints you created in part (b), part (c), and part (d). Does any aspect of these constraints concern you? If so, why?

Solutions:

a. Maximize $7000x + 4000y$

b. $500x + 250y \le 100{,}000$

c. $x \le 20$

d. $y \ge 50$

e. $\frac{x}{x+y} \ge \frac{1}{3}$, or $2x - y \ge 0$

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f. If the constraints for the maximum number of television ads to be used from part(c) and the minimum number of Internet ads to be used from part (d) are both satisfied, then television ads can be at most $\frac{20}{20+50} = 0.285 \leq 0.333$. That is, the constraint for the stipulated ratio of television ads to Internet ads cannot be satisfied. Therefore, the problem as stated is infeasible.

Case Problem: Scheduling a Youth Soccer League

Caridad Suárez, head of the Boone County Recreational Department, must develop a schedule of games for a youth soccer league that begins its season at 4:00 P.M. tomorrow. Eighteen teams signed up for the league, and each team must play every other team over the course of the 17-week season (each team plays one game per week). Caridad thought it would be fairly easy to develop a schedule, but after working on it for a couple of hours, she has been unable to come up with a schedule. Because Caridad must have a schedule ready by tomorrow afternoon, she asked you to help her. A possible complication is that one of the teams told Caridad that it may have to cancel for the season. This team told Caridad it will let her know by 1:00 P.M. tomorrow whether it will be able to play this season. **LO 4**

Managerial Report

Prepare a report for Caridad Suárez. Your report should include, at a minimum, the following items:

1. A schedule that will enable each of the 18 teams to play every other team over the 17-week season.
2. A contingency schedule that can be used if the team that contacted Caridad decides to cancel for the season.

Solutions:

Note to Instructor: This case problem illustrates the value of the rational management science approach. The problem is easy to understand and, at first glance, appears simple. But, most students will have trouble finding a solution. The solution procedure suggested involves decomposing a larger problem into a series of smaller problems that are easier to solve. The case provides students with a good first look at the kinds of problems where management science is applied in practice.

Solution: Scheduling problems such as this occur frequently, and are often difficult to solve. The typical approach is to use trial and error. An alternative approach involves breaking the larger problem into a series of smaller problems. We show how this can be done here using what we call the Red, White, and Blue algorithm.

Suppose we break the 18 teams up into three divisions, referred to as the Red, White, and Blue divisions. The six teams in the Red division can then be identified as R1, R2, R3, R4, R5, R6; the six teams in the White division can be identified as W1, W2, ..., W6; and the six teams in the Blue division can be identified as B1, B2, ..., B6. We begin by developing a schedule for the first 5 weeks of the season so that each team plays every other team in its own division. This can be done fairly easily by trial and error. Shown below is the first 5-week schedule for the Red division.

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Week 1	Week 2	Week 3	Week 4	Week 5
R1 vs. R2	R1 vs. R3	R1 vs. R4	R1 vs. R5	R1 vs. R6
R3 vs. R4	R2 vs. R5	R2 vs. R6	R2 vs. R4	R2 vs. R3
R5 vs. R6	R4 vs. R6	R3 vs. R5	R3 vs. R6	R4 vs. R5

Similar five-week schedules can be developed for the White and Blue divisions by replacing the R in the above table with a W or a B.

To develop the schedule for the next three weeks, we create three new six-team divisions by pairing three of the teams in each division with three of the teams in another division; for example, (R1, R2, R3, W1, W2, W3), (B1, B2, B3, R4, R5, R6), and (W4, W5, W6, B4, B5, B6). Within each of these new divisions, games can be scheduled for three weeks without any teams playing a team they have played before. For instance, a three-week schedule for the first of these divisions is shown below:

Week 6	Week 7	Week 8
R1 vs. W1	R1 vs. W2	R1 vs. W3
R2 vs. W2	R2 vs. W3	R2 vs. W1
R3 vs. W3	R3 vs. W1	R3 vs. W2

A similar three-week schedule can be easily set up for the other two new divisions. This will provide us with a schedule for the first 8 weeks of the season.

For the final nine weeks, we continue to create new divisions by pairing three teams from the original Red, White, and Blue divisions with three teams from the other divisions that they have not yet been paired with. Then a three-week schedule is developed as above. Shown below is a set of divisions for the next nine weeks.

Weeks 9 to 11
(R1, R2, R3, W4, W5, W6) (W1, W2, W3, B1, B2, B3) (R4, R5, R6, B4, B5, B6)

Weeks 12 to 14
(R1, R2, R3, B1, B2, B3) (W1, W2, W3, B4, B5, B6) (W4, W5, W6, R4, R5, R6)

Weeks 15 to 17
(R1, R2, R3, B4, B5, B6) (W1, W2, W3, R4, R5, R6) (W4, W5, W6, B1, B2, B3)

This Red, White, and Blue scheduling procedure provides a schedule with every team playing every other team over the 17-week season. If one of the teams should cancel, the schedule can be modified easily. Designate the team that cancels, say R4, as the Bye team. Then whichever team is scheduled to play team R4 will receive a Bye in that week. With only 17 teams a Bye must be scheduled for one team each week.

This same scheduling procedure can obviously be used for scheduling any types of teams or any other kinds of matches involving 17 or 18 teams. Modifications of the Red, White, and Blue algorithm can be employed for 15 or 16 team leagues and other numbers of teams.

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Chapter 1 – Introduction

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Purpose and Perspective of the Chapter

The body of knowledge involving quantitative approaches to decision making is referred to as management science, operations research, and decision science. It had its early roots in World War II and is flourishing in business and industry due, in part, to numerous methodological developments (e.g. simplex method for solving linear programming problems) and a virtual explosion in computing power.

Cengage Supplements

Additional instructor and student resources for this product are available online at www.cengage.com.

List of Instructor Downloads

The following product-level supplements provide additional information that may help you prepare for your course. They are available in the Instructor Resource Center.

- Solutions and Answers Guide.
- Educator's Guide.
- PowerPoint slides
- Test bank powered by Cognero.

List of Student Downloads

Students should download the following items from the Student Companion Center to complete the activities and assignments:

- Excel datasets.
- Excel workbooks.

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Chapter Objectives

This chapter addresses the following objectives:

LO 1.1 Define the terms management science and operations research.

LO 1.2 List the steps in the decision-making process and explain the roles of qualitative and quantitative approaches to managerial decision making.

LO 1.3 Explain the modelling process and its benefits to analyzing real situations.

LO 1.4 Formulate basic mathematical models of cost, revenue, and profit and compute the breakeven point.

Complete List of Chapter Activities and Assessments

For additional guidance, refer to the Teaching Online Guide.

Chapter Objective	PPT slide	Activity/Assessment	Duration
1.1	4	Activity in PPT	10 minutes
1.2	5-8	Activity in PPT	40 minutes
1.3	9-17	Activity in PPT	1.5 hours
1.4	18-21	Activity in PPT	40 minutes
1.1-1.4		Chapter 1 Problems	50 minutes

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Key Terms

Analog model Although physical in form, an analog model does not have a physical appearance similar to the real object or situation it represents.

Breakeven point The volume at which total revenue equals total cost.

Constraints Restrictions or limitations imposed on a problem.

Controllable inputs The inputs that are controlled or determined by the decision maker.

Decision The alternative selected.

Decision making The process of defining the problem, identifying the alternatives, determining the criteria, evaluating the alternatives, and choosing an alternative.

Decision variable Another term for controllable input.

Deterministic model A model in which all uncontrollable inputs are known and cannot vary.

Feasible solution A decision alternative or solution that satisfies all constraints.

Fixed cost The portion of the total cost that does not depend on the volume; this cost remains the same no matter how much is produced.

Iconic model A physical replica, or representation, of a real object.

Marginal cost The rate of change of the total cost with respect to volume.

Marginal revenue The rate of change of total revenue with respect to volume.

Mathematical model Mathematical symbols and expressions used to represent a real situation.

Model A representation of a real object or situation.

Multicriteria decision problem A problem that involves more than one criterion; the objective is to find the "best" solution, taking into account all the criteria.

Objective function A mathematical expression that describes the problem's objective.

Optimal solution The specific decision-variable value or values that provide the "best" output for the model.

Problem solving The process of identifying a difference between the actual and the desired state of affairs and then taking action to resolve the difference.

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Single-criterion decision problem A problem in which the objective is to find the "best" solution with respect to just one criterion.

Stochastic (probabilistic) model A model in which at least one uncontrollable input is uncertain and subject to variation; stochastic models are also referred to as probabilistic models

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Chapter Outline

I. Introduction (PPT slide 4)

1. The body of knowledge involving quantitative approaches to decision making is referred to as
   (1) management science
   (2) operations research
   (3) decision science
2. It had its early roots in World War II and is flourishing in business and industry due, in part, to:
   (1) numerous methodological developments (e.g. simplex method for solving linear programming problems)
   (2) a virtual explosion in computing power

II. 1-1 Problem Solving and Decision Making (PPT slides 5-8)

a. 1-1 Problem Solving

1. Problem solving is the process of identifying a difference between the actual and the desired state of affairs and then taking action to resolve the difference.
2. The problem-solving process involves the following seven steps:
   (1) Define the problem.
   (2) Determine the set of alternative solutions.
   (3) Determine the criteria for evaluating alternatives.
   (4) Evaluate the alternatives.
   (5) Choose an alternative (make a decision).
   (6) Implement the selected alternative.
   (7) Evaluate the results.

b. 1-1 The Decision-Making Process

1. Decision making is the term associated with the first five steps of the problem-solving process.
2. Problems in which the objective is to find the best solution with respect to one criterion are referred to as single-criterion decision problems.
3. Problems that involve more than one criterion are referred to as multicriteria decision problems.
4. The decision is the choice of the best alternative.

c. 1-2 Quantitative Analysis and Decision Making

1. An Alternate Classification of the Decision-Making Process

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2. The flowchart combines the first three steps of the decision-making process under the heading "Structuring the Problem" and the latter two steps under the heading "Analyzing the Problem".

d. 1-2 Analysis Phase of the Decision-Making Process
   1. The Role of Qualitative and Quantitative Analysis
   2. Qualitative analysis:
      (1) Based largely on the manager's judgment and experience
      (2) Includes the manager's intuitive "feel" for the problem
      (3) Is more of an art than a science
   3. Quantitative analysis:
      (1) Based on the quantitative facts or data associated with the problem
      (2) Uses mathematical expressions to describe objectives, constraints, and other relationships existing in the problem
      (3) One or more quantitative methods may be used to make a recommendation

III. 1-3 Quantitative Analysis and Decision Making (PPT slides 9-17)

a. 1-3 Quantitative Analysis
   1. Reasons for a Quantitative Analysis Approach to Decision Making
      (1) The problem is complex.
      (2) The problem is very important.
      (3) The problem is new.
      (4) The problem is repetitive.
   2. The Four Steps of the Quantitative Analysis Process
      (1) Model Development.
      (2) Data Preparation.
      (3) Model Solution.
      (4) Report Generation.

b. 1-3 Step 1: Model Development
   1. Models are representations of real objects or situations.
   2. The three main model forms are:
      (1) Iconic models - physical replicas (scalar representations) of real objects.
      (2) Analog models - do not physically resemble the object being modeled.

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(3) Mathematical models - represent real situations through mathematical expressions/formulas using assumptions, estimates, or statistical analyses.

3. Compared to experimenting with the real situation, experimenting with models
   (1) requires less time
   (2) is less expensive
   (3) involves less risk.
4. The more closely the model represents the real situation, the accurate the conclusions and predictions will be.

c. 1-3 Example: a Simple Production Problem
   1. A mathematical model consists of an objective function described by a controllable input (called a decision variable) and subject to a set of restrictions (called constraints) under the influence of environmental factors (called uncontrollable inputs.)
   2. As an example, consider the following simple production problem:
      (1) We want to find out the optimal number of units to be produced and sold each week to maximize the total weekly profit, with a unit profit of $10 per unit.
      (2) We know it takes 5 hours to produce each unit and only 40 hours are available per week.

d. 1-3 A Mathematical Model
   1. Decision variable: x is the number of units being produced.
   2. Objective function: with a profit of $10 per unit, the objective function is $10x$.
   3. Uncontrollable inputs: the profit per unit ($10), the production time per unit (5 hours), and the production capacity (40 hours) are environmental factors.
   4. Constraints: because it takes 5 hours to produce each units, and there are 40 hours available per week, the production capacity constraint is $5x \le 40$.
   5. A complete mathematical model for our simple production problem is:
      (1) Maximize: $10x$ (objective function)
      (2) subject to: $5x \le 40$ (production constraint)
      (3) $x \ge 0$ (the number of produced units cannot be negative)

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e. 1-3 Types of Mathematical Models
    1. There are two main types of mathematical models:
        (1) Deterministic model – when all uncontrollable inputs to the model are known and cannot vary.
        (2) Stochastic (or probabilistic) model – when any uncontrollable input is uncertain and subject to variation.
    2. Stochastic models are often more difficult to analyze.
    3. In our simple production example, if the number of hours of production time per unit could vary from 3 to 6 hours depending on the quality of the raw material, the model would be stochastic.

f. 1-3 Step 2: Data Preparation
    1. All uncontrollable inputs or data must be specified before we can analyze the model and recommend a decision or solution for the problem.
    2. Data preparation is not a trivial step, due to the time required and the possibility of data collection errors.
        (1) A model with 50 decision variables and 25 constraints could have over 1300 data elements!
        (2) Often, a fairly large data base is needed.
        (3) Information systems specialists might be needed.

g. 1-3 Step 3: Model Solution
    1. Trial-and-Error Solution for the Production Problem
    2. The analyst attempts to identify the alternative (the set of decision variable values) that provides the "best" output for the model, a.k.a., the optimal solution.
    3. If the alternative does not satisfy all the model constraints, it is rejected as being infeasible, regardless of the objective function value.
    4. If the alternative satisfies all the model constraints, it is feasible and a candidate for the "best" solution.
    5. $x = 8$ is the optimal solution.

h. 1-3 A Flowchart of the Simple Production Model

i. 1-3 After the Solution
    1. Model Testing and Validation
        (1) Often, goodness/accuracy of a model cannot be assessed until solutions are generated.
            (a) Small test problems having known, or at least expected, solutions can be used for model testing and validation.

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(b) If the model generates expected solutions, use the model on the full-scale problem.

(c) If inaccuracies or potential shortcomings inherent in the model are identified, take corrective action such as:

(i) Collection of more-accurate input data

(ii) Modification of the model

2. 1-3 Report Generation

(1) A managerial report, based on the results of the model, should be prepared.

(a) The report should be easily understood by the decision maker.

(b) The report should include:

(i) the recommended decision

(ii) other pertinent information about the results (for example, how sensitive the model solution is to the assumptions and data used in the model)

IV. 1-4 Models of Cost, Revenue, and Profit (PPT slides 18-21)

1. Some of the most basic quantitative models arising in business and economic applications are those involving the relationship between a suitable decision variable and objective function.

(1) Typical decision variables in business and economics can be production or sales volume.

(2) Whereas common objective functions are cost, revenue, or profit.

2. Through the use of these models, a manager can determine the projected cost, revenue, and/or profit associated with an established production quantity or a forecasted sales volume.

b. 1-4 Cost-Volume Model

1. Example: Nowlin Plastics

(1) The Viper, a slim but very durable black and gray plastic cover, is Nowlin Plastics' best-selling cell phone cover.

(2) Several products are produced on the same manufacturing line, and a setup cost of $3,000 is incurred each time a changeover is made for a new product.

(3) This setup cost is a fixed cost that is incurred regardless of the number of produced units.

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(4) In addition, suppose that there is a $2 variable cost, due to the cost of labor and material for each unit produced.

2. The Mathematical Model
   (1) The cost–volume model for producing *x* units of the Viper can be written as
   (2) $C(x) = 3{,}000 + 2x$
   (3) Where $C(x)$ is the total cost of producing a volume of *x* units.
   (4) The marginal cost is defined as the cost increase associated with a one-unit increase in the production volume.
   (5) In the cost-volume equation above, we see that the total cost will increase by $2 for each unit increase in the production volume.
   (6) Thus, the marginal cost is $2

c. 1-4 Revenue and Profit-Cost Models
   1. Revenue-Volume Model
      (1) Suppose that each Viper cover sells for $5. The model for total revenue can be written as
         (a) $R(x) = 5x$
      (2) Where $R(x)$ is the total revenue associated with the sale of *x* units.
      (3) The marginal revenue is defined as the increase in total revenue resulting from a one-unit increase in sales volume.
      (4) In the cost-revenue equation above, we see that the total revenue will increase by $5 for each additional unit sold.
      (5) Thus, the marginal revenue is $5.
   2. Profit-Volume Model
      (1) The total profit, $P(x)$, is total revenue minus total cost that is associated with producing and selling *x* units.
      (2) Thus, the profit-volume model can be derived from the revenue-volume and cost-volume models.
         (a) $P(x) = R(x) - C(x)$
         (b) $P(x) = 5x - (3{,}000 + 2x) = -3{,}000 + 3x$
      (3) Using this equation, we can now determine the total profit associated with any production volume *x*.

d. 1-4 Breakeven Analysis
   1. The volume that results in total revenue equaling total cost, $R(x) = C(x)$, is called the breakeven point.

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2. We can find the breakeven point by setting the total profit equal to zero and solving for x.
   (1) $-3{,}000 + 3x = 0$
   (2) $x = 1{,}000$ units
3. Thus, production and sales of the product must be greater than 1,000 units to obtain a profit.

V. 1-5 Management Science Techniques (PPT slides 22-23)

a. 1-5 (Most Frequent) Management Science Techniques

1. Linear programming is a problem-solving approach developed for situations involving maximizing or minimizing a linear function subject to linear constraints that limit the degree to which the objective can be pursued.
2. Integer linear programming is an approach used for problems that can be set up as linear programs with the additional requirement that some or all of the decision recommendations be integer values.
3. Distribution and network models are specialized solution procedures for problems in transportation system design, information system design, and project scheduling.
4. Simulation is a technique that employs a computer program to perform simulation computations and model the operation of a system.

b. 1-5 (Other) Management Science Techniques

1. Nonlinear programming is a technique that allows for maximizing or minimizing a nonlinear function subject to nonlinear constraints.
2. Inventory models help maintain inventories to meet demand for goods while minimizing inventory holding costs.
3. Waiting line (or queuing) models help managers understand and make better decisions concerning the operation of systems involving waiting lines.
4. Forecasting methods are techniques used to predict the future aspects of a business operation.
5. Goal programming is a technique for solving multi-criteria decision problems, usually within the framework of linear programming.
6. PERT (Program Evaluation and Review Technique) and CPM (Critical Path Method) help managers responsible for planning, scheduling, and controlling projects consisting of numerous tasks.

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7. Decision analysis determines optimal strategies in situations involving several decision alternatives and an uncertain pattern of future events.
8. Analytic hierarchy process is a multi-criteria decision-making technique that permits the inclusion of subjective factors in arriving at a recommended decision.
9. Markov-process models study the evolution of systems over repeated trials (such as describing the probability that a machine, functioning in a period, will break down in another one.

VI. Summary (PPT slides 24)

1. This text is about how management science may be used to help managers make better decisions.
2. The focus of this text is on the decision-making process and on the role of management science in that process.
3. Mathematical models are abstractions of real-world situations and, as such, cannot capture all the aspects of the real situation but just the major relevant aspects of the problem and provide a solution recommendation.
4. One of the characteristics of management science is the search for the “best” or optimal solution to the problem.

VII. Problems.

a. #1 (LO 1.1, PPT slide 4) Vocabulary
b. #3 (LO 1.2, PPT slides 5-8) Roles of Qualitative and Quantitative Approaches to Decision Making
c. #7 (LO 1.3, PPT slide 9-17) Modeling Fuel Cost
d. #13 (LO 1.4, PPT slide 18-21) Breakeven Point for a Training Seminar
e. #18 (LO 1.4, PPT slide 18-21) Blending Fuels

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Appendix

Generic Rubrics

Providing students with rubrics helps them understand expectations and components of assignments. Rubrics help students become more aware of their learning process and progress, and they improve students' work through timely and detailed feedback. Customize these rubrics as you wish. The writing rubric indicates 40 points, and the discussion rubric indicates 30 points.

Standard Writing Rubric

Criteria	Meets Requirements	Needs Improvement	Incomplete
Content	The assignment clearly and comprehensively addresses all questions in the assignment. 15 points	The assignment partially addresses some or all questions in the assignment. 8 points	The assignment does not address the questions in the assignment. 0 points
Organization and Clarity	The assignment presents ideas in a clear manner and with a strong organizational structure. The assignment includes an appropriate introduction, content, and conclusion. The coverage of facts, arguments, and conclusions is logically related and consistent. 10 points	The assignment presents ideas in a mostly clear manner and with a mostly strong organizational structure. The assignment includes an appropriate introduction, content, and conclusion. The coverage of facts, arguments, and conclusions are most logically related and consistent. 7 points	The assignment does not present ideas in a clear manner and with a strong organizational structure. The assignment includes an introduction, content, and conclusion, but coverage of facts, arguments, and conclusions are not logically related and consistent. 0 points
Research	The assignment is based upon appropriate and adequate academic literature, including peer-reviewed journals and other scholarly work. 5 points	The assignment is based upon adequate academic literature but does not include peer-reviewed journals and other scholarly work. 3 points	The assignment is not based upon appropriate and adequate academic literature and does not include peer-reviewed journals and other scholarly work. 0 points
Research	The assignment follows the required citation guidelines. 5 points	The assignment follows some of the required citation guidelines. 3 points	The assignment does not follow the required citation guidelines. 0 points
Grammar and Spelling	The assignment has two or fewer grammatical and spelling errors. 5 points	The assignment has three to five grammatical and spelling errors. 3 points	The assignment is incomplete or unintelligible. 0 points

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Standard Discussion Rubric

Criteria	Meets Requirements	Needs Improvement	Incomplete
Participation	Submits or participates in the discussion by the posted deadlines. Follows all the assignment's instructions for the initial post and responses. 5 points	Does not participate or submit discussion by the posted deadlines. Does not follow instructions for initial post and responses. 3 points	Does not participate in the discussion. 0 points
Contribution Quality	Comments stay on task. Comments add value to the discussion topic. Comments motivate other students to respond. 20 points	Comments may not stay on task. Comments may not add value to the discussion topic. Comments may not motivate other students to respond. 10 points	Does not participate in the discussion. 0 points
Etiquette	Maintains appropriate language. Constructively offers criticism. Provides both positive and negative feedback. 5 points	Does not always maintain the appropriate language. Offers criticism offensively. Provides only negative feedback. 3 points	Does not participate in the discussion. 0 points

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