TITLE SLIDE

Introduction
to
Subtitle

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CONTENT

Subtitle

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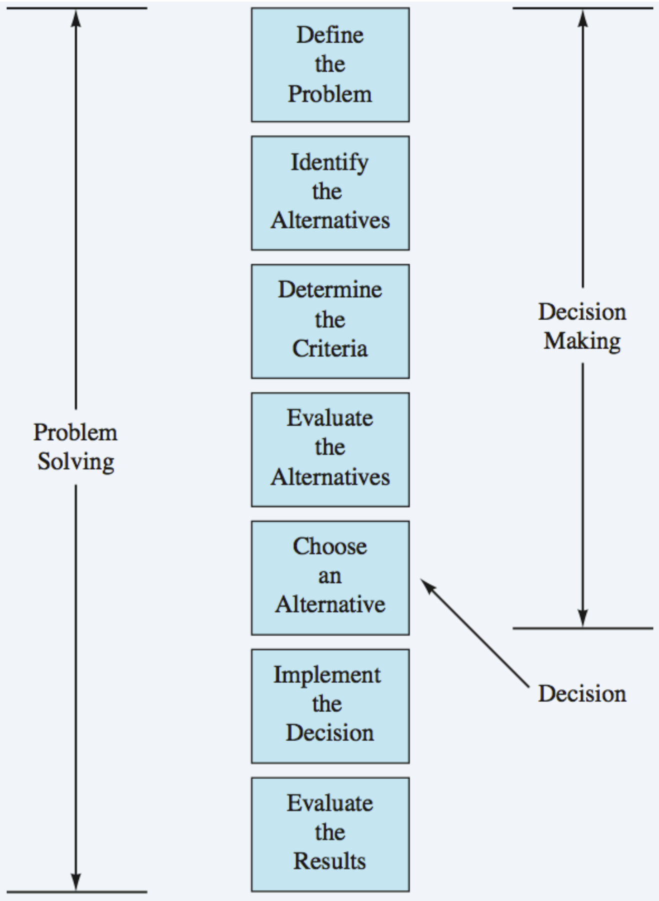

Figure: The relationship between processes of problem solving and decision making.

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Subtitle

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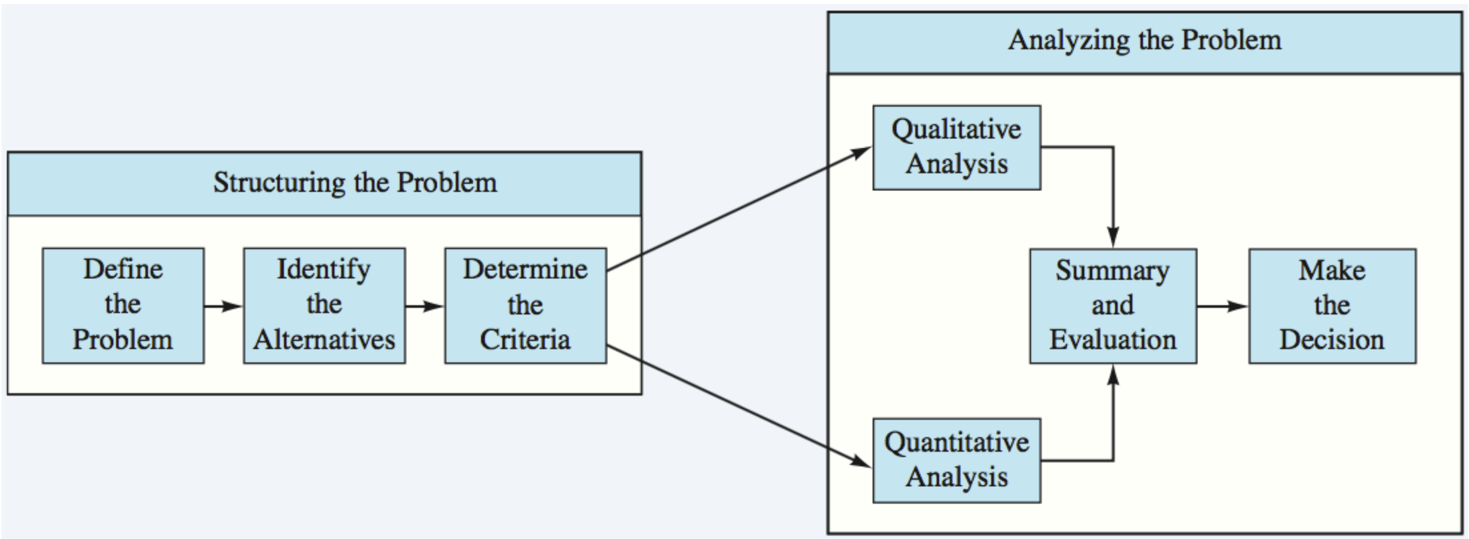

Figure: An alternate classification of the decision making process.

EXAMPLES

From a Real Presentation

Why a quantitative approach might be used in the decision-making process:

1. The problem is complex, and the manager cannot develop a good solution without the aid of quantitative analysis.
2. The problem is especially important (e.g., a great deal of money is involved), and the manager desires a thorough analysis before attempting to make a decision.
3. The problem is new, and the manager has no previous experience from which to draw.
4. The problem is repetitive, and the manager saves time and effort by relying on quantitative procedures to make routine decision recommendations.

MODELS

Model Development

Models are representations of real objects or situations and can be presented in various forms.

Classification

1. Iconic models, a toy is a physical replica of a real object.
2. Analog models, thermometer represents temperature.
3. Mathematical models, representations of a problem by a system of symbols and mathematical relationships or expressions.

Mathematical Modeling
A process that translates observed or desired phenomena into mathematical expressions.

An Example: Office Furniture Shop

Story

Office Furnature Shop produces three products: Desk, Chair, Molded steel. In the production facility steel as the raw material is used for producing these products. Managers don't worry about the sale process, all products will be sold. We already know two functions from previous slides;

- what the total profit of this shop can be at the end of the day, and
- how much raw material should be used (required) for production in that day.

Company has a warehouse with the capacity of two thousand kilogram and contains steel in it. On that day, managers decide to satisfy expo's contract commitments which are at least hundred desks and at most five hundred chairs.

Product	*Profit*	*Raw Steel Used*
Desk	\$50 per item	7 kg
Chair	\$20 per item	3 kg
Molded steel	\$6 per kg	1.5 kg

Table: Shop's profit for each of products produced.

Questions

- What are the amounts of products produced to maximize company's profit in that day?
- What is the maximum profit of the company at the end of the day?

MODEL DEVELOPMENT

An Example: Office Furniture Shop

Description

There are 3 products to produce: *Desk, Chair, Molded steel.* No need to think about the sale process, all products will be sold.

Model variables

D: Amount of desks (countable, number)
C: Amount of chairs (countable, number)
M: Amount of molded steel (uncountable, kg)

Question

What is the **Total Profit** of this shop at the end of the day?

Product	*Profit*
Desk	\$50 per item
Chair	\$20 per item
Molded steel	\$6 per kg

Table: Shop's profit for each of products produced.

An Example: Office Furniture Shop

Question

What is the **Total Profit** of this shop at the end of the day?

Answer

Total Profit = $Profit_{Desk} + Profit_{Chair} + Profit_{Molded-Steel}$

$P_{Total}\ (\$) = 50D + 30C + 6M$

New question

How much **raw steel required** for the daily production process?

Answer for the new question

Total Requirement = $Steel_{Desk} + Steel_{Chair} + Steel_{Molded-Steel}$

$R_{Total}\ (\text{kg}) = 7D + 3C + 1.5M$

Product	*Profit*	*Raw Steel Used*
Desk	$50 per item	7 kg
Chair	$20 per item	3 kg
Molded steel	$6 per kg	1.5 kg

Table: Shop's profit for each of products produced.

Constrained Mathematical Model

Constrained mathematical model is a model with an objective and one or more constraints.

Functional constraints are restrictions that involve expressions with one or more variables.

- $\leq$ less than or equal to
- $\geq$ greater than or equal to
- $=$ equal to

Variable constraints are constraints involving only one of the variables.

Variable Constraint	*Mathematical Expression*
Non negativity constraint	$x \geq 0$
Lower bound constraint	$x \geq L$
Upper bound constraint	$x \leq U$
Integer constraint	$x = integer$
Binary constraint	$x = 0$ or 1

Table: Variable constraints and their mathematical expressions.

1. Non negativity constraint

Amount of production cannot be negative.

$$D \geq 0$$
$$C \geq 0$$
$$M \geq 0$$

2. Raw material constraint

If the company has only 2,000 kg of raw steel available for production in its warehouse, this will be a constraint for the model.

$$\text{Requirement for production} \leq 2,000 \text{ kg raw steel}$$
$$\text{or}$$
$$7D + 3C + 1.5M \leq 2,000$$

3. Contract constraint

If there is a contract between the Office Furniture Shop and a fair company (an expo), to satisfy contract commitments;

- at least 100 desks, and
- due to the availability of seat cushions, no more than 500 chairs must be produced.

$$D \geq 100$$
$$C \leq 500$$

4. Integer constraint

Quantities of desks and chairs produced during the production must be integer values.

$$D, C, M = \textit{integer}$$

An Example: Office Furniture Shop

Model for the example;

Objective of the model is *Maximize the total profit* subject to the **constraints** (*warehouse, contract, etc.*)

Mathematical model for the example;

$$\begin{aligned} \text{Maximize Z} &= 50D + 30C + 6M \\ \text{Subject to:} & \\ & 7D + 3C + 1.5M \leq 2,000 && \text{warehouse limit for steel} \\ & D \geq 100 && \text{from contract} \\ & C \leq 500 && \text{from contract} \\ & D, C, M \geq 0 && \text{non negativity} \\ & D, C && \text{are integers} \end{aligned}$$

Best or **optimal** solution for Office Furniture Shop;

Amount of Production:

100 Desks

433 Chairs

0 Molded Steel

Total Profit:

$17,990

CLASSIFICATION OF MATHEMATICAL MODELS

Purpose and Data Certainty

Purpose of the model

Optimization Models Seek to

- maximize a quantity (*profit, efficiency, etc.*) or
- minimize a quantity (*cost, time, etc.*)

that may be restricted by a set of constraints (*limitations on the availability of capital, personnel, supplies, etc.*)

Prediction Models Describe or predict events (*sales forecasts, project completion dates, etc.*) given certain conditions.

Degree of certainty of the data in the model

Deterministic Models Data (*profit, cost, resource, etc.*) are assumed to be known with certainty.

Probabilistic or Stochastic Models One or more of the input parameters' values are determined by probability distributions.

WHEN?

Past, Present, Future

Management science is generally applied in three situations:

- Designing and implementing new operations or procedures.
- Evaluating an ongoing set of operations or procedures.
- Determining and recommending corrective action for operations and procedures that are producing unsatisfactory results.

MANAGEMENT SCIENCE PROCESS

Generalization

The process

A Problem Definition

B Mathematical Modeling

C Solution of the Model

D Post-Solution Phase

FIGURE

MANAGEMENT SCIENCE PROCESS

A. Problem Definition

How to define a problem?

1. Observe operations.
2. Ease up on complexity.
3. Recognize political realities.
4. Decide what is really wanted.
5. Identify constraints.

   Create a limiting condition in words in the following manner:
   - The amount of a resource required.
   - Has some relation to.
   - The availability of the resource.

6. Seek conditions feedback.

Homework

Define a real-life business problem. You may use below template to define the problem.

Part A

1. What are your observations on the operations of the firm in this situation?
2. Which assumptions do you want to consider in the situation for reducing complexity?
3. Which social or managerial affairs should be considered in this situation?
4. Which part of this situation is create the problem?
5. What are the conditions as identified constraints or restrictions about this problem?
6. How do these conditions affect the problem?

Part B

Write down your mathematical model to solve this specific problem.

B. Mathematical Modeling

How to build a model?

1. Identify decision variables.

   Asking a question;

   Does the decision maker have the authority to decide the numerical value (amount) of the item?

   If the answer **Yes** it is a decision variable.

2. Quantify the objective function.

   The objective of all optimization models, is to figure out how to do the best you can with what you've got. **The best you can** implies maximizing something (*profit, efficiency, etc.*) or minimizing something (*cost, time, etc.*).

3. Write constraints.

   - Make sure the units on the left side of the relation are the same as those on the right side.
   - Translate the words into mathematical notation using known or estimated values for the parameters and the previously defined symbols for the decision variables.
   - Rewrite the constraint, if necessary, so that all terms involving the decision variables are on the left side of the relationship, with only a constant value on the right side.

4. Construct a model shell.

   In the formative stage of model building, generic symbols can be used for the parameters until the actual data are determined.

5. Gather data.

   - The time and cost of collecting, organizing, and sorting relevant data.
   - The time and cost of generating a solution approach;

     - Make some assumptions, so that a standard solution technique may be used,
     - Develop a new technique, or modify an existing one.

   - The time and cost of using a model.

MANAGEMENT SCIENCE PROCESS

C. Solution of the Model

How to solve the model?

1. Choose an appropriate solution technique.
2. Generate model solutions.
3. Test/validate model results.
4. Return to modelling step if results are unacceptable.
5. Perform **what-if** analyses (i.e. sensitivity analysis).

MANAGEMENT SCIENCE PROCESS

D. Post-Solution Phase

How to follow?

1. Prepare a business report or presentation.
2. Monitor the progress of the implementation.

Story

Delta Hardware Stores is a regional retailer with warehouses in three cities in California:

- San Jose,
- Fresno, and
- Azusa.

Each month, Delta restocks its warehouses with its own brand of paint. Delta has its own paint manufacturing plant in Phoenix, Arizona.

Although the plant's production capacity is sometime inefficient to meet monthly demand, a recent feasibility study commissioned by Delta found that it was not cost effective to expand production capacity at this time.

To meet demand, Delta subcontracts with a national paint manufacturer to produce paint under the Delta label and deliver it (at a higher cost) to any of its three California warehouses. There is to be no expansion of plant capacity.

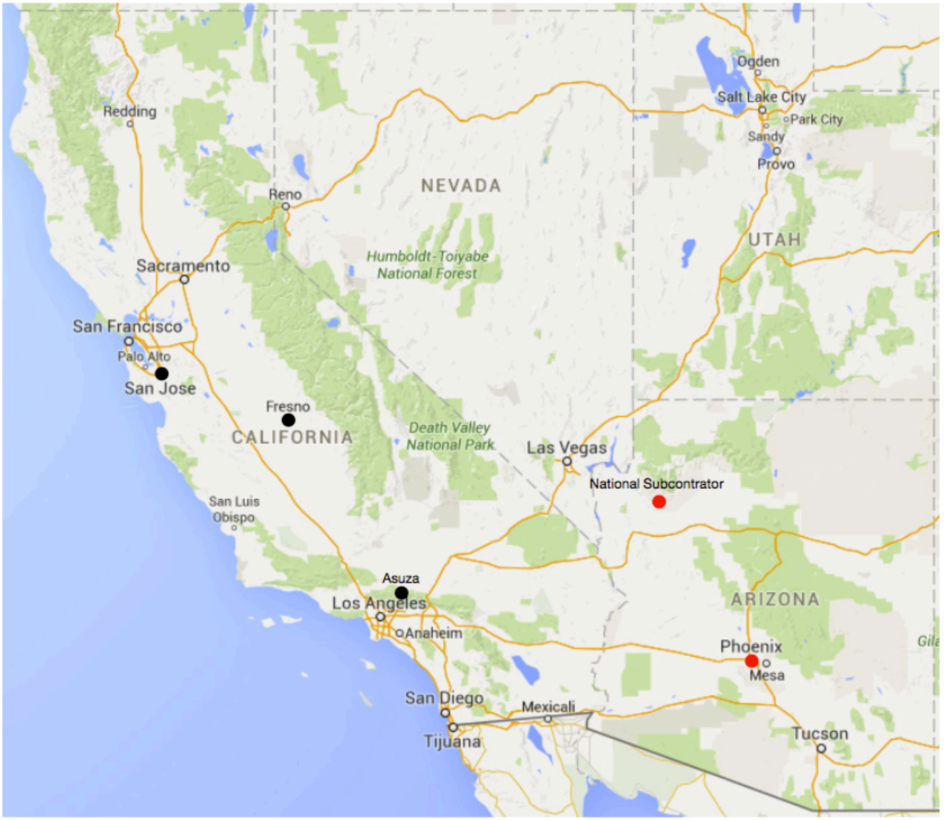

Figure: Map for the problem which indicates warehouses (black dots) and production facilities (red dots).

An Example: Delta Hardware Stores

Question

The problem is to determine a **least cost distribution scheme** of paint produced at its manufacturing plant and shipments from the subcontractor to meet the demands of its California warehouses.

The decision maker is simply being asked;

1. How much paint should be shipped this month from the plant in Phoenix to San Jose, Fresno, and Asuza?
2. How much extra should be purchased from the subcontractor and sent to each of the three cities to satisfy their orders?

Building the model

1. Identify decision variables.
2. Quantify the objective function.
3. Write constraints.
4. Construct a model shell.
5. Gather data.

An Example: Delta Hardware Stores

Decision Variables

Amount of paint **shipped** this month;

x_1 From Phoenix to San Jose

x_2 From Phoenix to Fresno

x_3 From Phoenix to Azusa

Amount of paint **subcontracted** this month;

x_4 For San Jose

x_5 For Fresno

x_6 For Azusa

Objective Function and Constraints

The objective is to **minimize the total overall monthly costs** of manufacturing, transporting and subcontracting paint, **subject to**:

1. The Phoenix plant cannot operate beyond its capacity.
2. The amount ordered from subcontractor cannot exceed a maximum limit.
3. The orders for paint at each warehouse will be fulfilled.

Parameters

To determine the overall costs;

- m The manufacturing cost per 10,000 liters of paint at the plant in Phoenix.
- c The procurement cost per 10,000 liters of paint from National Subcontractor
- t_1, t_2, t_3 The respective truckload shipping costs form Phoenix to San Jose, Fresno, and Azusa.
- s_1, s_2, s_3 The fixed purchase cost per 10,000 liters from the subcontractor to San Jose, Fresno, and Azusa.

To write to constraints, we need to know;

- q_1 The capacity of the Phoenix plant.
- q_2 The maximum number of gallons available from the subcontractor.
- r_1, r_2, r_3 The respective orders for paint at the warehouses in San Jose, Fresno, and Azusa.

An Example: Delta Hardware Stores

Objective Function

$$
\begin{aligned}
\text{Minimize Z} = {} & \text{Total Cost} \\
\textit{or} & \\
\text{Minimize Z} = {} & \text{Manufacturing Cost} \\
& +\text{Transportation Cost} \\
& +\text{Purchasing Cost} \\
& +\text{Subcontracting Cost} \\
\textit{or} & \\
\text{Minimize Z} = {} & mx_1 + mx_2 + mx_3 \\
& +t_1x_1 + t_2x_2 + t_3x_3 \\
& +cx_4 + cx_5 + cx_6 \\
& +s_1x_4 + s_2x_5 + s_3x_6 \\
\textit{or} & \\
\text{Minimize Z} = {} & (m+t_1)x_1 + (m+t_2)x_2 + (m+t_3)x_3 \\
& +(c+s_1)x_4 + (c+s_2)x_5 + (c+s_3)x_6
\end{aligned}
$$

Constraints

The number of truckloads shipped out from Phoenix cannot exceed the plant capacity:

$$x_1 + x_2 + x_3 \leq q_1$$

The number of thousands of gallons ordered from the subcontrator cannot exceed the order limit:

$$x_4 + x_5 + x_6 \leq q_2$$

The number of thousands of gallons received at each warehouse equals the total orders of the warehouse:

$$
\begin{aligned}
x_1 + x_4 &= r_1 \\
x_2 + x_5 &= r_2 \\
x_3 + x_6 &= r_3
\end{aligned}
$$

All shipments must be nonnegative and integer:

$$
\begin{gathered}
x_1, x_2, x_3, x_4, x_5, x_6 \geq 0 \\
x_1, x_2, x_3, x_4, x_5, x_6 : \text{integer}
\end{gathered}
$$

Model Shell

$$
\begin{aligned}
\text{Minimize } Z = \; & (m+t_1)x_1 + (m+t_2)x_2 + (m+t_3)x_3 \\
& +(c+s_1)x_4 + (c+s_2)x_5 + (c+s_3)x_6
\end{aligned}
$$

Subject to:

$$
\begin{aligned}
& x_1 + x_2 + x_3 \leq q_1 \\
& x_4 + x_5 + x_6 \leq q_2 \\
& x_1 + x_4 = r_1 \\
& x_2 + x_5 = r_2 \\
& x_3 + x_6 = r_3 \\
& x_1, x_2, x_3, x_4, x_5, x_6 \geq 0 \\
& x_1, x_2, x_3, x_4, x_5, x_6 : \text{integer}
\end{aligned}
$$

Data Gathering

Respective orders
r_1 = 4,000 liters, r_2 = 2,000 liters, r_3 = 5,000 liters

Capacity
q_1 = 8,000 liters, q_2 = 5,000 liters

Subcontractor price
c = \$5,000 per 1,000 liters

Cost of production
m = \$3,000 per 1,000 liters

Transportation costs
Subcontractor
s_1 = \$1,200, s_2 = \$1,400, s_3 = \$1,100
Phoenix Plant
t_1 = \$1,050, t_2 = \$750, t_3 = \$650

An Example: Delta Hardware Stores

Mathematical Model

$$\begin{aligned}
\text{Minimize Z} = \;& 4,050x_1 + 3,750x_2 + 3,650x_3 \\
& +6,200x_4 + 6,400x_5 + 6,100x_6 \\
\text{Subject to:} \;& \\
& x_1 + x_2 + x_3 \leq 8,000 \\
& x_4 + x_5 + x_6 \leq 5,000 \\
& x_1 + x_4 = 4,000 \\
& x_2 + x_5 = 2,000 \\
& x_3 + x_6 = 5,000 \\
& x_1, x_2, x_3, x_4, x_5, x_6 \geq 0 \\
& x_1, x_2, x_3, x_4, x_5, x_6 : \text{integer}
\end{aligned}$$

Solution Result

$$\begin{aligned}
x_1 &= 1,000 \text{ liters} \\
x_2 &= 2,000 \text{ liters} \\
x_3 &= 5,000 \text{ liters} \\
x_4 &= 3,000 \text{ liters} \\
x_5 &= 0 \\
x_6 &= 0
\end{aligned}$$

Total Cost

$44,800

Profit = Income - Outcome

Income = Selling Price per Unit x Number of Units

Outcome = Fixed Cost + (Variable Cost per Unit x Number of Units)

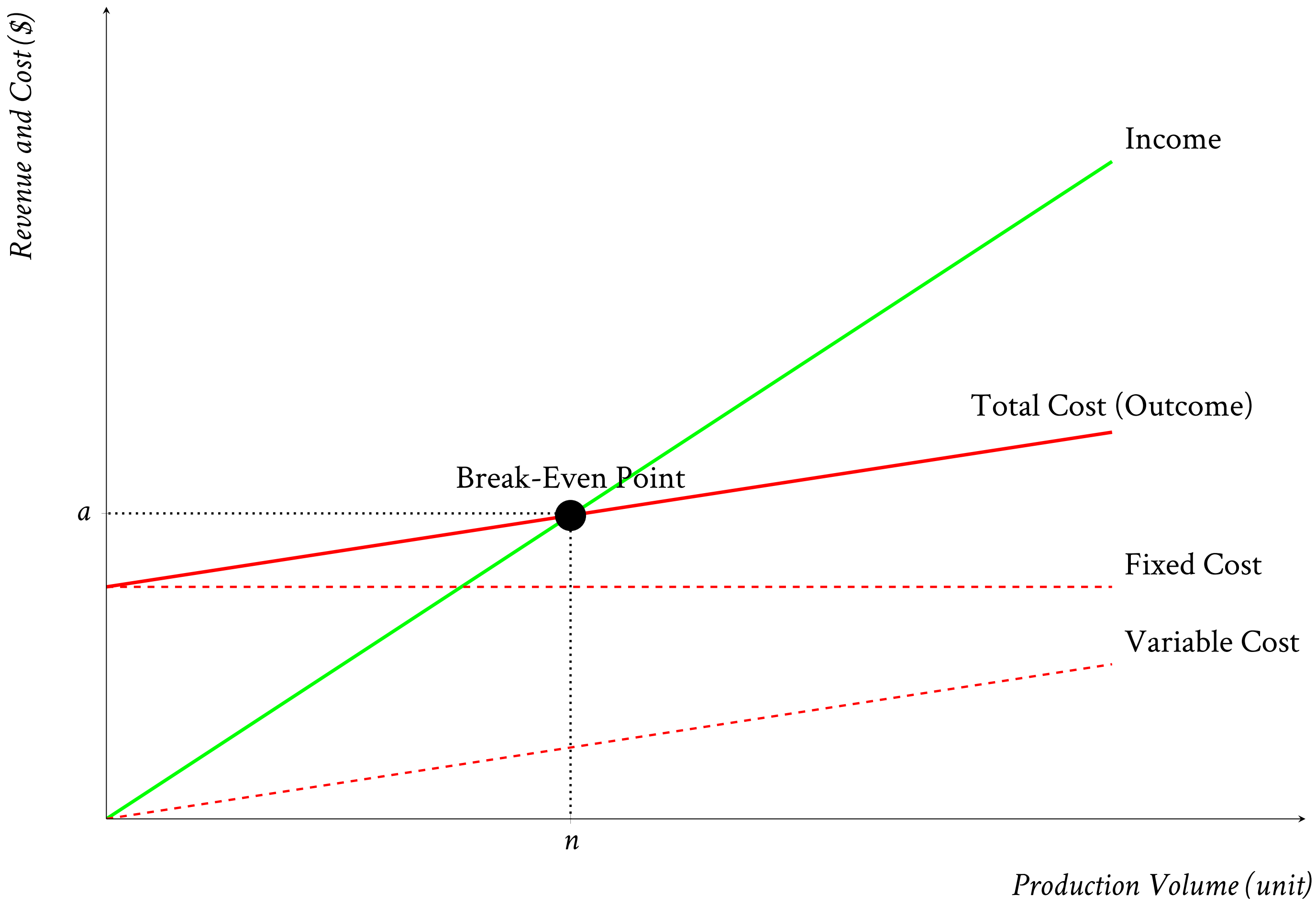

TABLE TALK PROBLEMS FROM TEXTBOOK

Introduction to Management Science

Problem – Break-Even Analysis

Three types of manufacturing equipment for engine gaskets are under consideration. Their fixed costs and resulting variable costs per unit are shown in the table below.

	Fixed Cost ($)	*Variable Cost ($/unit)*
Equipment A	4,000	1.90
Equipment B	7,000	1.40
Equipment C	12,000	1.00

1. At what volume of production would Equipment A and Equipment B cost the same?
2. Establish this breakeven point for equipments B and C.
3. Suppose the volume anticipated was 8,000 units. Which equipment should be purchased?
4. Suppose the volume anticipated was 12,900 units. Which equipment should then be purchased?

Problem – Break-Even Analysis

Two brothers want to open a small neighborhood bakery, where they will specialize in loaves of bread. They have carefully estimated their fixed costs to be $110,000 per year. This includes a salary of $35,000 for each brother.

The facility they will use is a former pizza kitchen. One problem is that there is limited capacity, so there will be an upper limit on the number of loaves of bread they can produce.

Baking 6 days a week, the brothers believe they can produce 150 loaves per day. The cost to them for each loaf is $0.55. They believe they will be able to sell all the bread they can bake. They plan to bake 312 days during the year.

1. Given these projections, how much will the brothers have to charge per loaf to stay in business?
2. Suppose they are willing to take a much lower salary to get their business started. If they each agreed to take only $25,000 per year, how much would they have to charge for their bread?