Inventory Management

12

PowerPoint presentation to accompany
Heizer, Render, Munson / Global Edition
Operations Management, Twelfth Edition
Principles of Operations Management, Tenth Edition

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Outline

- **Global Company Profile:** Amazon.com
- The Importance of Inventory
- Managing Inventory
- Inventory Models
- Inventory Models for Independent Demand

Inventory Management at Amazon.com

- Amazon.com started as a "virtual" retailer – no inventory, no warehouses, no overhead – just computers taking orders to be filled by others
- Growth has forced Amazon.com to become a world leader in warehousing and inventory management

Inventory Management at Amazon.com

1. Each order is assigned by computer to the closest distribution center that has the product(s)
2. A “flow meister” at each distribution center assigns work crews
3. Technology helps workers pick the correct items from the shelves with almost no errors
4. Items are placed in crates on a conveyor, bar code scanners scan each item 15 times to virtually eliminate errors

Inventory Management at Amazon.com

5. Crates arrive at central point where items are boxed and labeled with new bar code
6. Gift wrapping is done by hand at 30 packages per hour
7. Completed boxes are packed, taped, weighed and labeled before leaving warehouse in a truck
8. Order arrives at customer within 1 - 2 days

Learning Objectives

When you complete this chapter you should be able to:

12.1 ***Conduct*** an ABC analysis

12.2 ***Explain*** and use cycle counting

12.3 ***Explain*** and use the basic EOQ model for independent inventory demand

12.4 ***Compute*** a reorder point

Learning Objectives

When you complete this chapter you should be able to:

12.5 ***Explain*** and use the production order quantity model

12.6 ***Explain*** and use the quantity discount model

Inventory Management

The objective of inventory management is to strike a balance between inventory investment and customer service

Importance of Inventory

- One of the most expensive assets of many companies representing as much as 50% of total invested capital
- Less inventory lowers costs but increases chances of running out
- More inventory raises costs but always keeps customers happy

Functions of Inventory

1. *To provide a selection of goods for anticipated demand and to separate the firm from fluctuations in demand*
2. *To decouple or separate various parts of the production process*
3. *To take advantage of quantity discounts*
4. *To hedge against inflation*

Types of Inventory

- **Raw material**
  - Purchased but not processed
- **Work-in-process (WIP)**
  - Undergone some change but not completed
  - A function of cycle time for a product
- **Maintenance/repair/operating (MRO)**
  - Necessary to keep machinery and processes productive
- **Finished goods**
  - Completed product awaiting shipment

The Material Flow Cycle

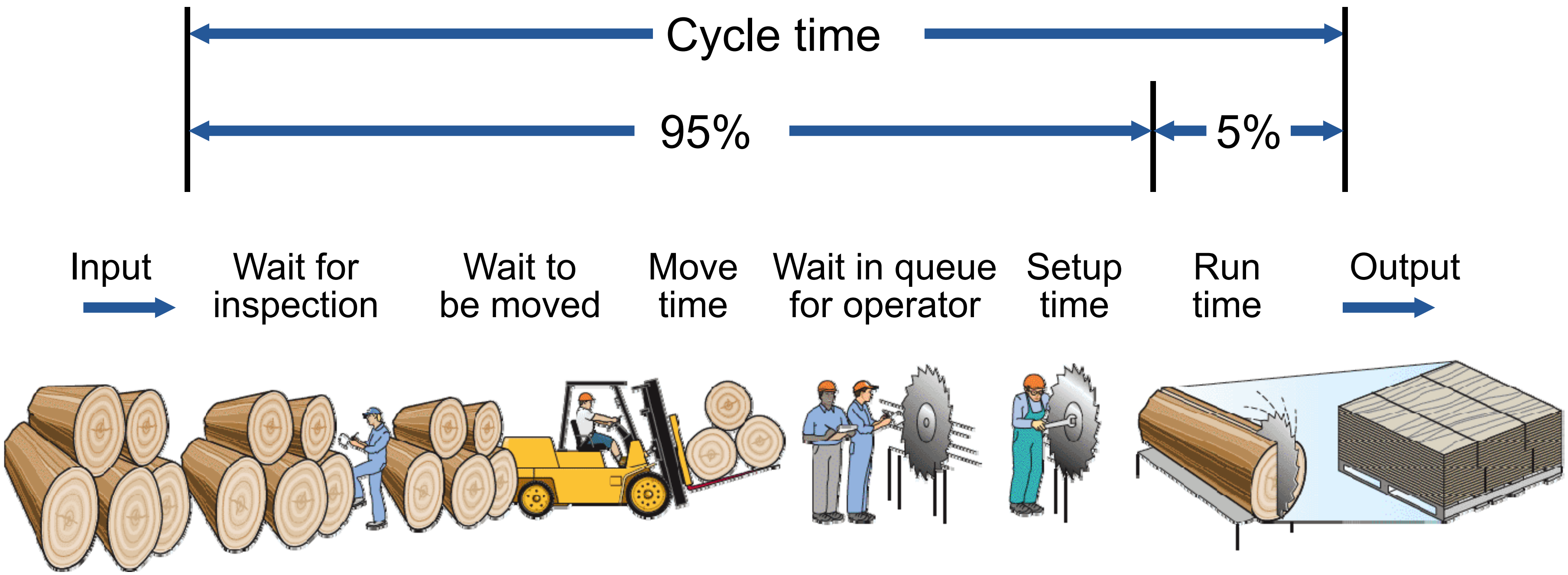


Figure 12.1

Managing Inventory

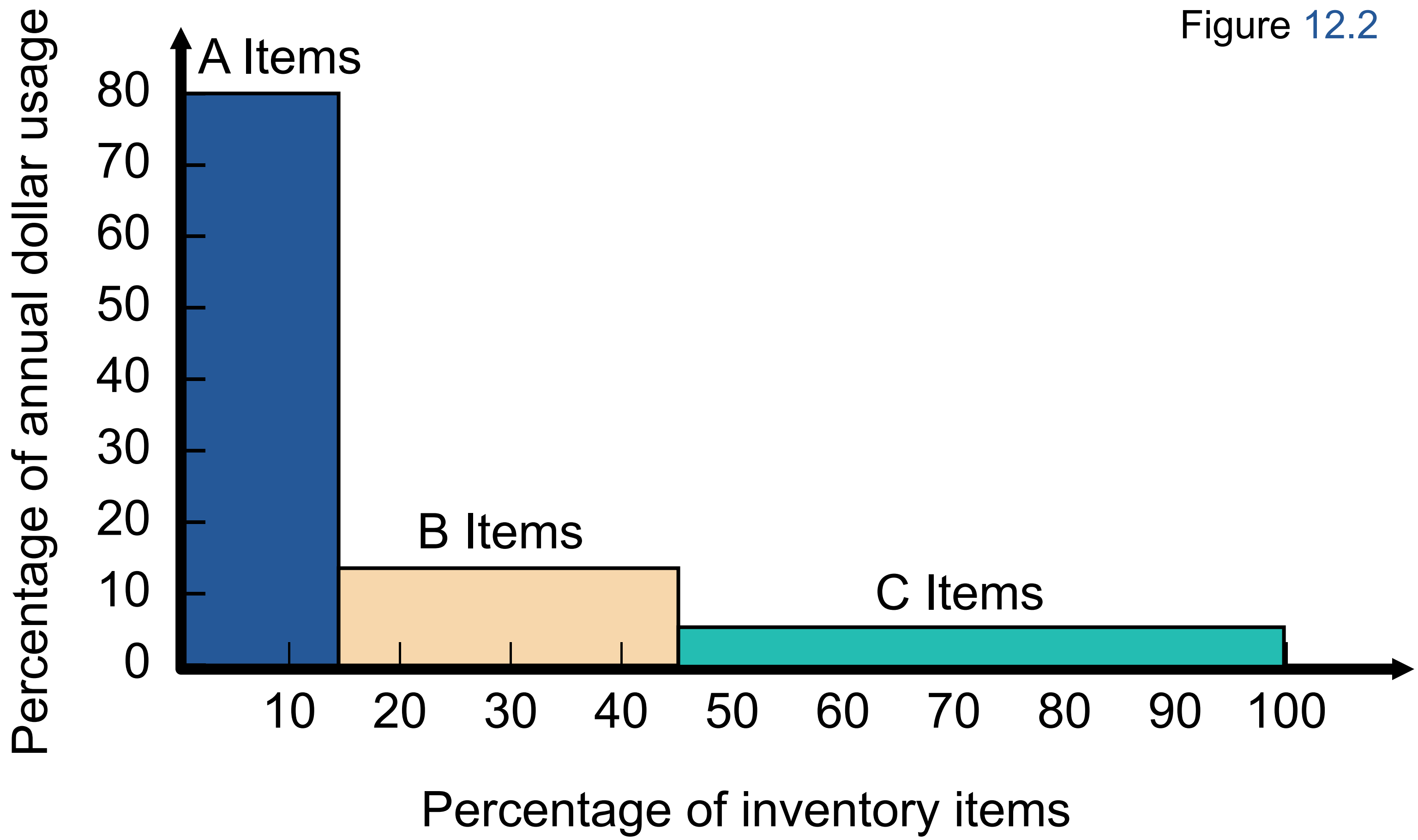
1) How inventory items can be classified (*ABC analysis*)
2) How accurate inventory records can be maintained

ABC Analysis

- Divides inventory into three classes based on annual dollar volume
  - Class A - high annual dollar volume
  - Class B - medium annual dollar volume
  - Class C - low annual dollar volume
- Used to establish policies that focus on the few critical parts and not the many trivial ones

ABC Analysis

Figure 12.2



ABC Analysis

ABC Calculation

(1) ITEM STOCK NUMBER	(2) PERCENT OF NUMBER OF ITEMS STOCKED	(3) ANNUAL VOLUME (UNITS)	x	(4) UNIT COST	=	(5) ANNUAL DOLLAR VOLUME	(6) PERCENT OF ANNUAL DOLLAR VOLUME		(7) CLASS
#10286	20%	1,000		$ 90.00		$ 90,000	38.8%	72%	A
#11526		500		154.00		77,000	33.2%		A
#12760		1,550		17.00		26,350	11.3%		B
#10867	30%	350		42.86		15,001	6.4%	23%	B
#10500		1,000		12.50		12,500	5.4%		B
#12572		600		14.17		8,502	3.7%		C
#14075		2,000		.60		1,200	.5%		C
#01036	50%	100		8.50		850	.4%	5%	C
#01307		1,200		.42		504	.2%		C
#10572		250		.60		150	.1%		C
		8,550				$232,057	100.0%		

ABC Analysis

- Other criteria than annual dollar volume may be used
  - High shortage or holding cost
  - Anticipated engineering changes
  - Delivery problems
  - Quality problems

ABC Analysis

- Policies employed may include
  1. More emphasis on supplier development for A items
  2. Tighter physical inventory control for A items
  3. More care in forecasting A items

Record Accuracy

- Accurate records are a critical ingredient in production and inventory systems
  - *Periodic systems* require regular checks of inventory
    - *Two-bin system*
  - *Perpetual inventory* tracks receipts and subtractions on a continuing basis
    - May be semi-automated

Record Accuracy

- Incoming and outgoing record keeping must be accurate
- Stockrooms should be secure
- Necessary to make precise decisions about ordering, scheduling, and shipping

Cycle Counting

- Items are counted and records updated on a periodic basis
- Often used with ABC analysis
- Has several advantages
  1. Eliminates shutdowns and interruptions
  2. Eliminates annual inventory adjustment
  3. Trained personnel audit inventory accuracy
  4. Allows causes of errors to be identified and corrected
  5. Maintains accurate inventory records

Cycle Counting Example

5,000 items in inventory, 500 A items, 1,750 B items, 2,750 C items

Policy is to count A items every month (20 working days), B items every quarter (60 days), and C items every six months (120 days)

ITEM CLASS	QUANTITY	CYCLE COUNTING POLICY	NUMBER OF ITEMS COUNTED PER DAY	
A	500	Each month	500/20 =	25/day
B	1,750	Each quarter	1,750/60 =	29/day
C	2,750	Every 6 months	2,750/120 =	23/day
				77/day

Control of Service Inventories

- Can be a critical component of profitability
- Losses may come from shrinkage or pilferage
- Applicable techniques include
  1. *Good personnel selection, training, and discipline*
  2. *Tight control of incoming shipments*
  3. *Effective control of all goods leaving facility*

Inventory Models

- **Independent demand** - the demand for item is independent of the demand for any other item in inventory
- **Dependent demand** - the demand for item is dependent upon the demand for some other item in the inventory

Inventory Models

- **Holding costs** - the costs of holding or "carrying" inventory over time
- **Ordering cost** - the costs of placing an order and receiving goods
- **Setup cost** - cost to prepare a machine or process for manufacturing an order
  - May be highly correlated with **setup time**

Holding Costs

TABLE 12.1	Determining Inventory Holding Costs
CATEGORY	**COST (AND RANGE) AS A PERCENT OF INVENTORY VALUE**
Housing costs (building rent or depreciation, operating costs, taxes, insurance)	6% (3 - 10%)
Material handling costs (equipment lease or depreciation, power, operating cost)	3% (1 - 3.5%)
Labor cost (receiving, warehousing, security)	3% (3 - 5%)
Investment costs (borrowing costs, taxes, and insurance on inventory)	11% (6 - 24%)
Pilferage, space, and obsolescence (much higher in industries undergoing rapid change like tablets and smart phones)	3% (2 - 5%)
Overall carrying cost	26%

Holding Costs

TABLE 12.1 Determining Inventory Holding Costs

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L	
In … costs, taxes, and insurance on inventory)	11% (6 - 24%)
Pilferage, space, and obsolescence (much higher in industries undergoing rapid change like PCs and cell phones)	3% (2 - 5%)
Overall carrying cost	26%

Holding costs vary considerably depending on the business, location, and interest rates. Generally greater than 15%, some high tech and fashion items have holding costs greater than 40%.

Inventory Models for Independent Demand

Need to determine when and how much to order

1. Basic economic order quantity (EOQ) model
2. Production order quantity model
3. Quantity discount model

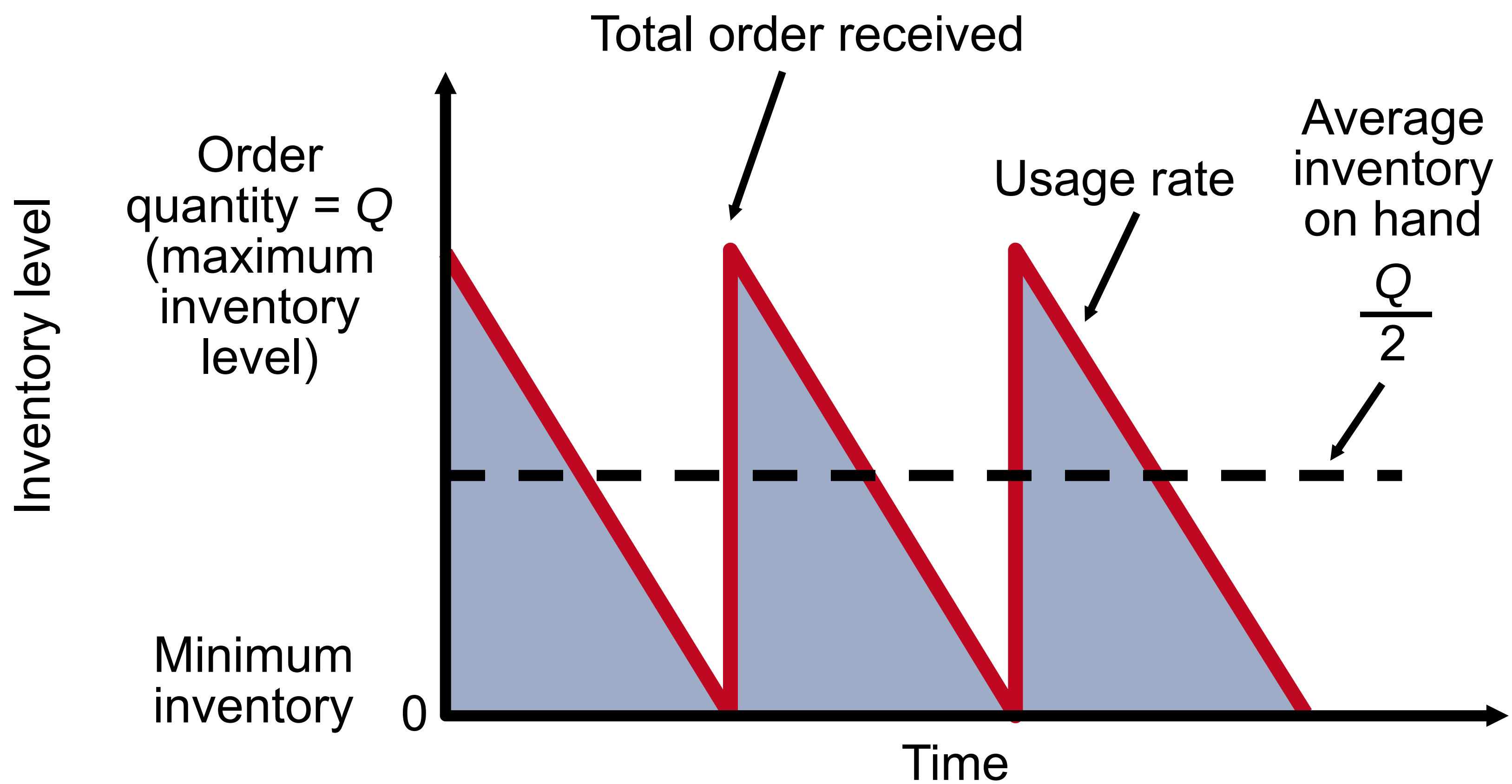
Basic EOQ Model

Important assumptions

1. Demand is known, constant, and independent
2. Lead time is known and constant
3. Receipt of inventory is instantaneous and complete
4. Quantity discounts are not possible
5. Only variable costs are setup (or ordering) and holding
6. Stockouts can be completely avoided

Inventory Usage Over Time

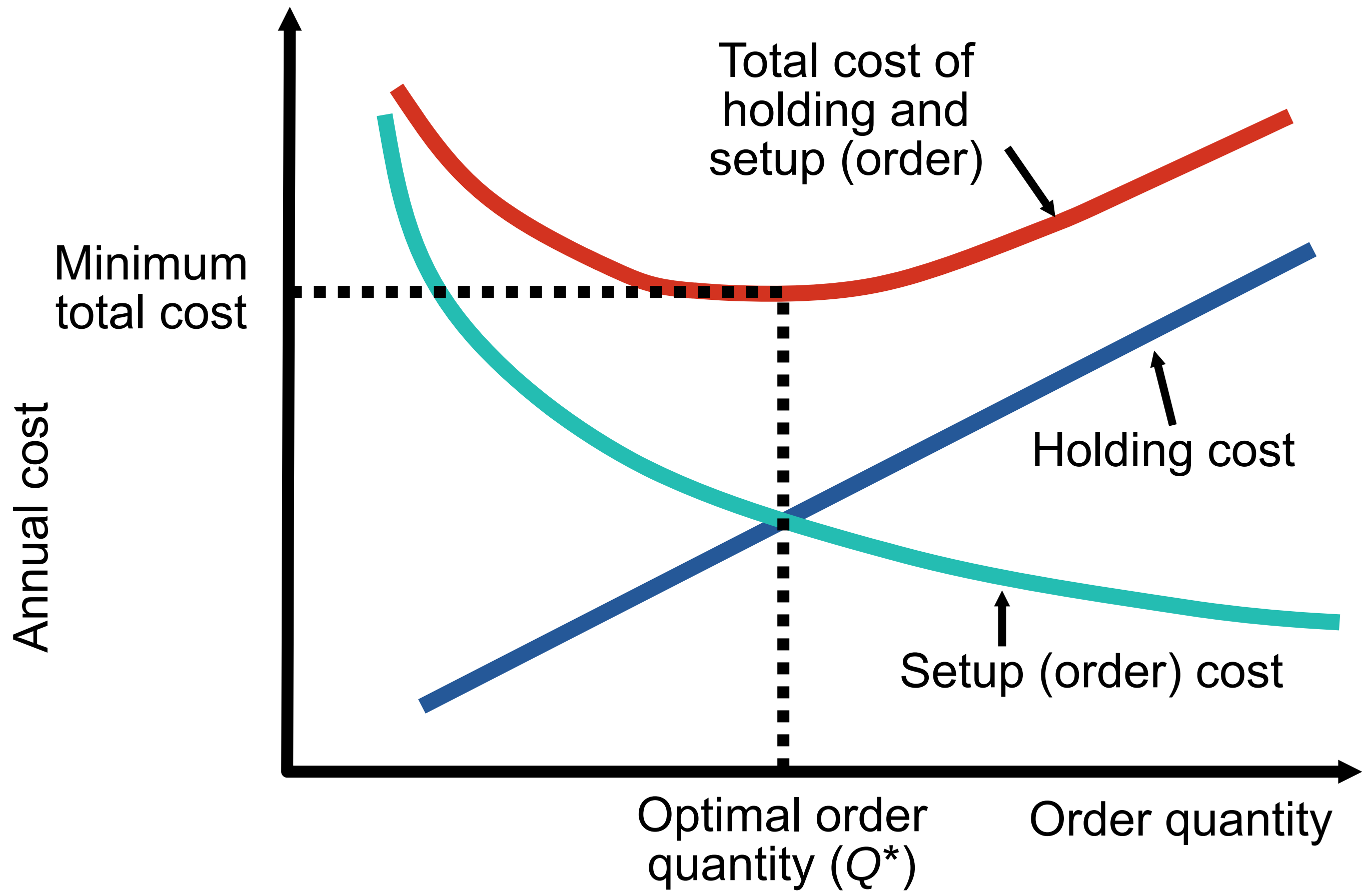
Figure 12.3



Minimizing Costs

Objective is to minimize total costs

Table 12.4(c)



Minimizing Costs

- By minimizing the sum of setup (or ordering) and holding costs, total costs are minimized
- Optimal order size Q^* will minimize total cost
- A reduction in either cost reduces the total cost
- Optimal order quantity occurs when holding cost and setup cost are equal

Minimizing Costs

Q = Number of units per order
Q^* = Optimal number of units per order (EOQ)
D = Annual demand in units for the inventory item
S = Setup or ordering cost for each order
H = Holding or carrying cost per unit per year

Annual setup cost = (Number of orders placed per year) x (Setup or order cost per order)

$$= \left(\frac{\text{Annual demand}}{\text{Number of units in each order}}\right)\left(\begin{array}{c}\text{Setup or order}\\ \text{cost per order}\end{array}\right)$$

$$= \left(\frac{D}{Q}\right)S$$

Minimizing C

Annual setup cost = $\frac{D}{Q}S$

Q = Number of pieces per order

Q^* = Optimal number of pieces per order (EOQ)

D = Annual demand in units for the inventory item

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Annual setup cost = (Number of orders placed per year) x (Setup or order cost per order)

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$$= \left(\frac{D}{Q}\right)S$$

Minimizing C

Annual setup cost = $\frac{D}{Q}S$

Annual holding cost = $\frac{Q}{2}H$

Q = Number of pieces per order

Q^* = Optimal number of pieces per order (EOQ)

D = Annual demand in units for the inventory item

S = Setup or ordering cost for each order

H = Holding or carrying cost per unit per year

Annual holding cost = (Average inventory level)
x (Holding cost per unit per year)

$$= \left(\frac{\text{Order quantity}}{2}\right)(\text{Holding cost per unit per year})$$

$$= \left(\frac{Q}{2}\right)H$$

Minimizing C

Annual setup cost = $\frac{D}{Q}S$

Annual holding cost = $\frac{Q}{2}H$

Q = Number of pieces per order

Q^* = Optimal number of pieces per order (EOQ)

D = Annual demand in units for the inventory item

S = Setup or ordering cost for each order

H = Holding or carrying cost per unit per year

Optimal order quantity is found when annual setup cost equals annual holding cost

$$\left(\frac{D}{Q}\right)S = \left(\frac{Q}{2}\right)H$$

Solving for Q^*

$$2DS = Q^2H$$

$$Q^2 = \frac{2DS}{H}$$

$$Q^* = \sqrt{\frac{2DS}{H}}$$

An EOQ Example

Determine **optimal number of needles to order**

D = 1,000 units

S = $10 per order

H = $.50 per unit per year

$$Q^* = \sqrt{\frac{2DS}{H}}$$

$$Q^* = \sqrt{\frac{2(1{,}000)(10)}{0.50}} = \sqrt{40{,}000} = 200 \text{ units}$$

An EOQ Example

Determine **expected number of orders**

D = 1,000 units Q^* = 200 units

S = $10 per order

H = $.50 per unit per year

$$\text{Expected number of orders} = N = \frac{\text{Demand}}{\text{Order quantity}} = \frac{D}{Q^*}$$

$$N = \frac{1{,}000}{200} = 5 \text{ orders per year}$$

An EOQ Example

Determine **optimal time between orders**

D = 1,000 units

S = $10 per order

H = $.50 per unit per year

Q^* = 200 units

N = 5 orders/year

$$\text{Expected time between orders} = T = \frac{\text{Number of working days per year}}{\text{Expected number of orders}}$$

$$T = \frac{250}{5} = 50 \text{ days between orders}$$

An EOQ Example

Determine the **total annual cost**

D = 1,000 units
S = $10 per order
H = $.50 per unit per year

Q^* = 200 units
N = 5 orders/year
T = 50 days

Total annual cost = Setup cost + Holding cost

$$TC = \frac{D}{Q}S + \frac{Q}{2}H$$

$$= \frac{1{,}000}{200}(\$10) + \frac{200}{2}(\$.50)$$

$$= (5)(\$10) + (100)(\$.50)$$

$$= \$50 + \$50 = \$100$$

The EOQ Model

When including actual cost of material P

Total annual cost = Setup cost + Holding cost + Product cost

$$TC = \frac{D}{Q}S + \frac{Q}{2}H + PD$$

Robust Model

- The EOQ model is **robust**
- It works even if all parameters and assumptions are not met
- The total cost curve is relatively flat in the area of the EOQ

An EOQ Example

Determine optimal number of needles to order

D = ~~1,000 units~~ 1,500 units

S = \$10 per order

H = \$.50 per unit per year

N= 5 orders/year

$Q^*_{1,000}$ = 200 units

T = 50 days

$Q^*_{1,500}$ = 244.9 units

Ordering old Q^*

$$TC = \frac{D}{Q}S + \frac{Q}{2}H$$

$$= \frac{1{,}500}{200}(\$10) + \frac{200}{2}(\$.50)$$

$$= \$75 + \$50 = \$125$$

Ordering new Q^*

$$= \frac{1{,}500}{244.9}(\$10) + \frac{244.9}{2}(\$.50)$$

$$= 6.125(\$10) + 122.45(\$.50)$$

$$= \$61.25 + \$61.22 = \$122.47$$

An EOQ Example

Determine optimal number of

D = ~~1,000 units~~ 1,500 units

S = $10 per order

H = $.50 per unit per year

N= 5 orders/year

Only 2% less than the total cost of $125 when the order quantity was 200

Ordering old Q^*

$$TC = \frac{D}{Q}S + \frac{Q}{2}H$$

$$= \frac{1{,}500}{200}(\$10) + \frac{200}{2}(\$.50)$$

$$= \$75 + \$50 = \$125$$

Or

$$= \frac{1{,}500}{244.9}(\$10) + \frac{244.9}{2}(\$.50)$$

$$= 6.125(\$10) + 122.45(\$.50)$$

$$= \$61.25 + \$61.22 = \$122.47$$

Reorder Points

- EOQ answers the "how much" question
- The reorder point (ROP) tells "when" to order
- Lead time (L) is the time between placing and receiving an order

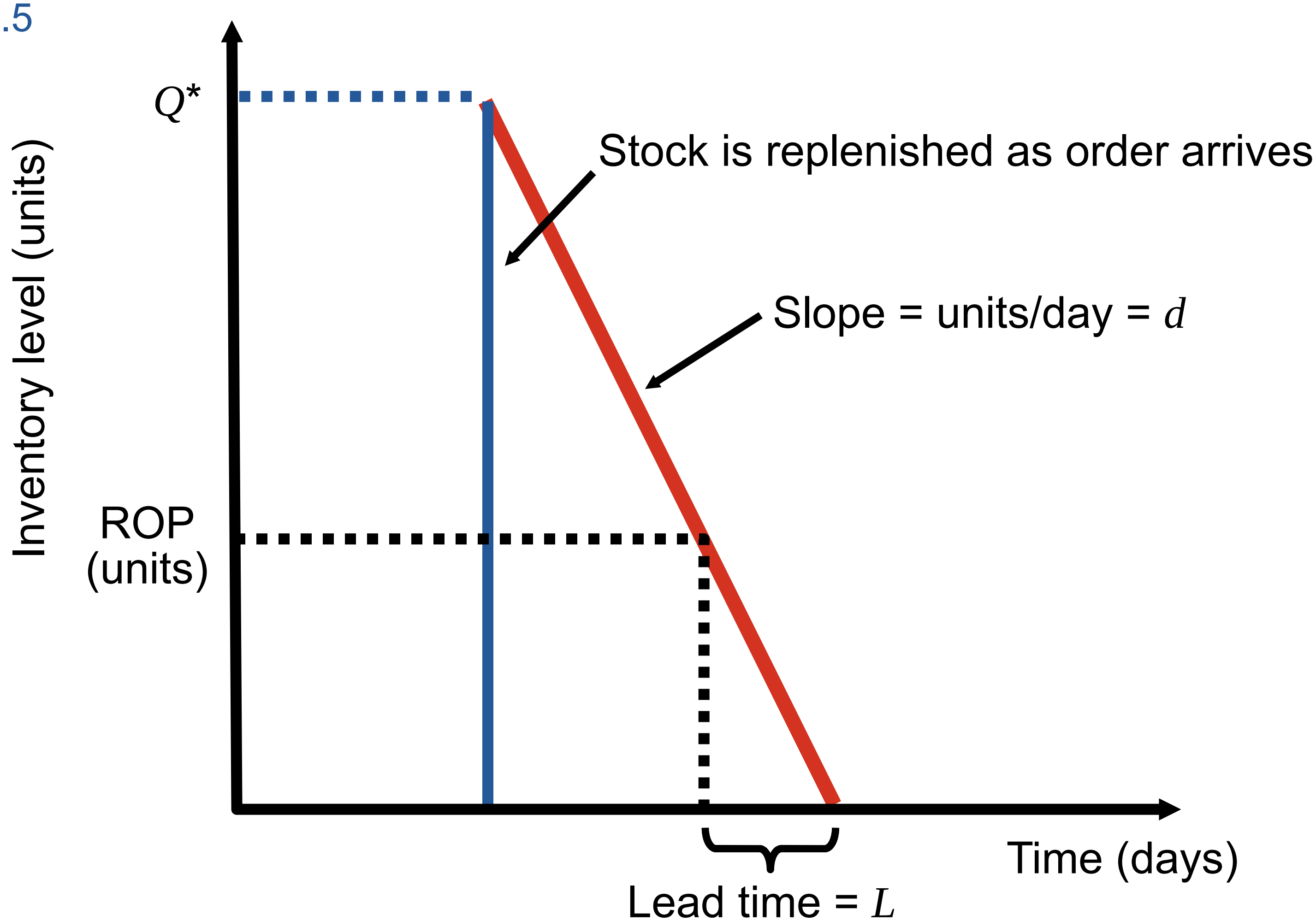
$$\text{ROP} = \begin{pmatrix}\text{Demand}\\ \text{per day}\end{pmatrix}\begin{pmatrix}\text{Lead time for a new}\\ \text{order in days}\end{pmatrix}$$

$$\text{ROP} = d \times L$$

$$d = \frac{D}{\text{Number of working days in a year}}$$

Reorder Point Curve

Figure 12.5



Reorder Point Example

Demand = 8,000 iPhones per year
250 working day year
Lead time for orders is 3 working days, may take 4

$$d = \frac{D}{\text{Number of working days in a year}}$$

$= 8{,}000/250 = 32$ units

ROP = $d \times L$

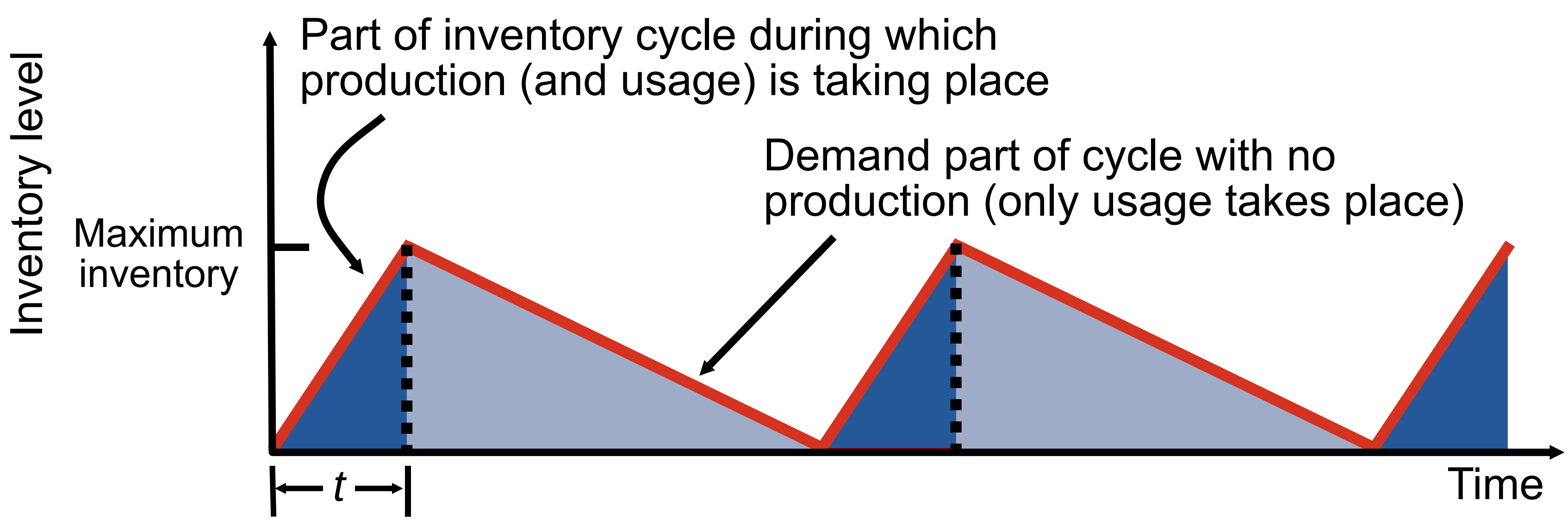
= 32 units per day x 3 days = 96 units

= 32 units per day x 4 days = 128 units

Production Order Quantity Model

1. Used when inventory builds up over a period of time after an order is placed
2. Used when units are produced and sold simultaneously

Figure 12.6



Production Order Quantity Model

Q = Number of units per order
H = Holding cost per unit per year
t = Length of the production run in days
p = Daily production rate
d = Daily demand/usage rate

$$\begin{pmatrix}\text{Annual inventory} \\ \text{holding cost}\end{pmatrix} = (\text{Average inventory level}) \times \begin{pmatrix}\text{Holding cost} \\ \text{per unit per year}\end{pmatrix}$$

$$\begin{pmatrix}\text{Annual inventory} \\ \text{level}\end{pmatrix} = (\text{Maximum inventory level})/2$$

$$\begin{pmatrix}\text{Maximum} \\ \text{inventory level}\end{pmatrix} = \begin{pmatrix}\text{Total produced during} \\ \text{the production run}\end{pmatrix} - \begin{pmatrix}\text{Total used during} \\ \text{the production run}\end{pmatrix}$$

$$= pt - dt$$

Production Order Quantity Model

Q = Number of units per order
H = Holding cost per unit per year
t = Length of the production run in days
p = Daily production rate
d = Daily demand/usage rate

$$\begin{pmatrix}\text{Maximum}\\ \text{inventory level}\end{pmatrix} = \begin{pmatrix}\text{Total produced during}\\ \text{the production run}\end{pmatrix} - \begin{pmatrix}\text{Total used during}\\ \text{the production run}\end{pmatrix}$$

$$= pt - dt$$

However, Q = total produced = pt ; thus $t = Q/p$

$$\begin{pmatrix}\text{Maximum}\\ \text{inventory level}\end{pmatrix} = p\left(\frac{Q}{p}\right) - d\left(\frac{Q}{p}\right) = Q\left(1 - \frac{d}{p}\right)$$

$$\text{Holding cost} = \frac{\text{Maximum inventory level}}{2}(H) = \frac{Q}{2}\left[1 - \left(\frac{d}{p}\right)H\right]$$

Production Order Quantity Model

Q = Number of units per order
H = Holding cost per unit per year
t = Length of the production run in days
p = Daily production rate
d = Daily demand/usage rate

$$\text{Setup cost} = (D/Q)S$$

$$\text{Holding cost} = \tfrac{1}{2}HQ\left[1-(d/p)\right]$$

$$\frac{D}{Q}S = \tfrac{1}{2}HQ\left[1-(d/p)\right]$$

$$Q^2 = \frac{2DS}{H\left[1-(d/p)\right]}$$

$$Q_p^* = \sqrt{\frac{2DS}{H\left[1-(d/p)\right]}}$$

Production Order Quantity Example

D = 1,000 units
S = $10
H = $0.50 per unit per year

p = 8 units per day
d = 4 units per day

$$Q_p^* = \sqrt{\frac{2DS}{H\left[1-\left(d/p\right)\right]}}$$

$$Q_p^* = \sqrt{\frac{2(1{,}000)(10)}{0.50\left[1-(4/8)\right]}}$$

$$= \sqrt{\frac{20{,}000}{0.50(1/2)}} = \sqrt{80{,}000}$$

$$= 282.8 \text{ hubcaps, or } 283 \text{ hubcaps}$$

Production Order Quantity Model

Note:

$$d = 4 = \frac{D}{\text{Number of days the plant is in operation}} = \frac{1{,}000}{250}$$

When annual data are used the equation becomes:

$$Q_p^* = \sqrt{\frac{2DS}{H\left(1 - \frac{\text{Annual demand rate}}{\text{Annual production rate}}\right)}}$$

Quantity Discount Models

- Reduced prices are often available when larger quantities are purchased
- Trade-off is between reduced product cost and increased holding cost

TABLE 12.2	A Quantity Discount Schedule	
PRICE RANGE	**QUANTITY ORDERED**	**PRICE PER UNIT *P***
Initial price	0 to 119	$100
Discount price 1	200 to 1,499	$ 98
Discount price 2	1,500 and over	$ 96

Quantity Discount Models

Total annual cost = Setup cost + Holding cost + Product cost

$$TC = \frac{D}{Q}S + \frac{Q}{2}IP + PD$$

where
Q = Quantity ordered
D = Annual demand in units
S = Ordering or setup cost per order
P = Price per unit
I = Holding cost per unit per year expressed as a percent of price P

$$Q^* = \sqrt{\frac{2DS}{IP}}$$

Because unit price varies, holding cost is expressed as a percent (I) of unit price (P)

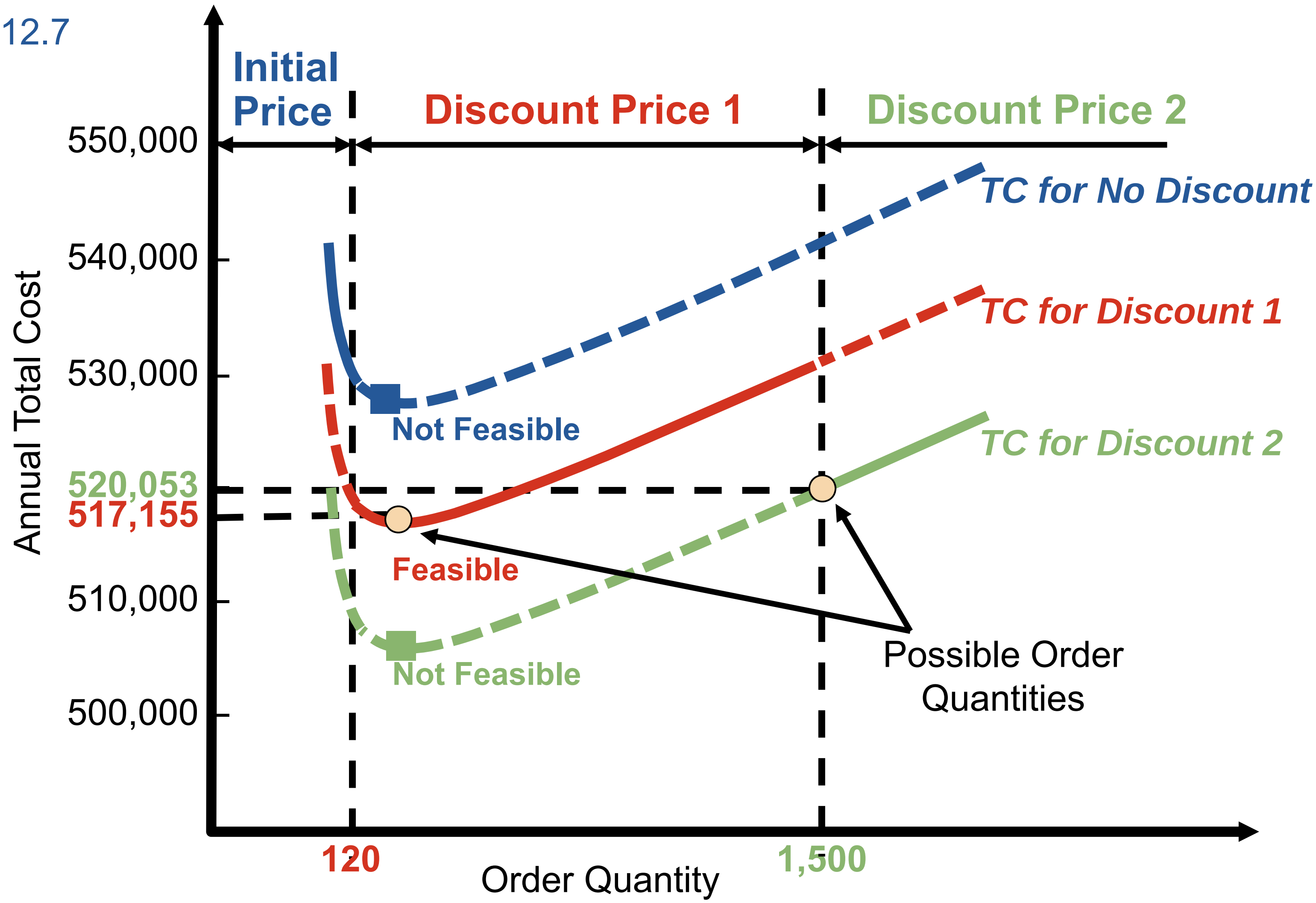
Quantity Discount Models

Steps in analyzing a quantity discount

1. Starting with the *lowest* possible purchase price, calculate Q^* until the first feasible EOQ is found. This is a possible best order quantity, along with all price-break quantities for all *lower* prices.
2. Calculate the total annual cost for each possible order quantity determined in Step 1. Select the quantity that gives the lowest total cost.

Quantity Discount Models

Figure 12.7



Quantity Discount Example

Calculate Q^* for every discount starting with the lowest price

$$Q^* = \sqrt{\frac{2DS}{IP}}$$

$$Q_{\$96}^* = \sqrt{\frac{2(5{,}200)(\$200)}{(.28)(\$96)}} = \text{~~278~~ drones/order}$$

Infeasible – calculate Q* for next-higher price

$$Q_{\$98}^* = \sqrt{\frac{2(5{,}200)(\$200)}{(.28)(\$98)}} = 275 \text{ drones/order}$$

Feasible

Quantity Discount Example

TABLE 12.3	Total Cost Computations for Chris Beehner Electronics				
ORDER QUANTITY	UNIT PRICE	ANNUAL ORDERING COST	ANNUAL HOLDING COST	ANNUAL PRODUCT COST	TOTAL ANNUAL COST
275	$98	$3,782	$3,773	$509,600	$517,155
1,500	$96	$693	$20,160	$499,200	$520,053

Choose the price and quantity that gives the lowest total cost

Buy 275 drones at $98 per unit

Quantity Discount Variations

- *All-units discount* is the most popular form
- *Incremental quantity discounts* apply only to those units purchased beyond the price break quantity
- *Fixed fees* may encourage larger purchases
- *Aggregation* over items or time
- *Truckload discounts*, *buy-one-get-one-free offers*, *one-time-only sales*