Inventory Management

- Inventory management is an important function in controlling assets in the supply chain.
- Individuals working in the supply chain should have at least a basic understanding of the roles, costs, and benefits of inventories.
- Inventory is often obtained from suppliers in the form of raw materials and other goods and materials through the procurement department.
- Inventory also includes work in process and finished products from manufacturing operations.

Inventory Basics

Inventory Includes:

- Raw Materials
- Work in Progress (WIP)
- Finished goods
- Merchandise
- Spare parts
- Other operating supplies

Inventories may be found in:

- Factories
- Warehouses
- Retail Stores
- Other type of storage facilities

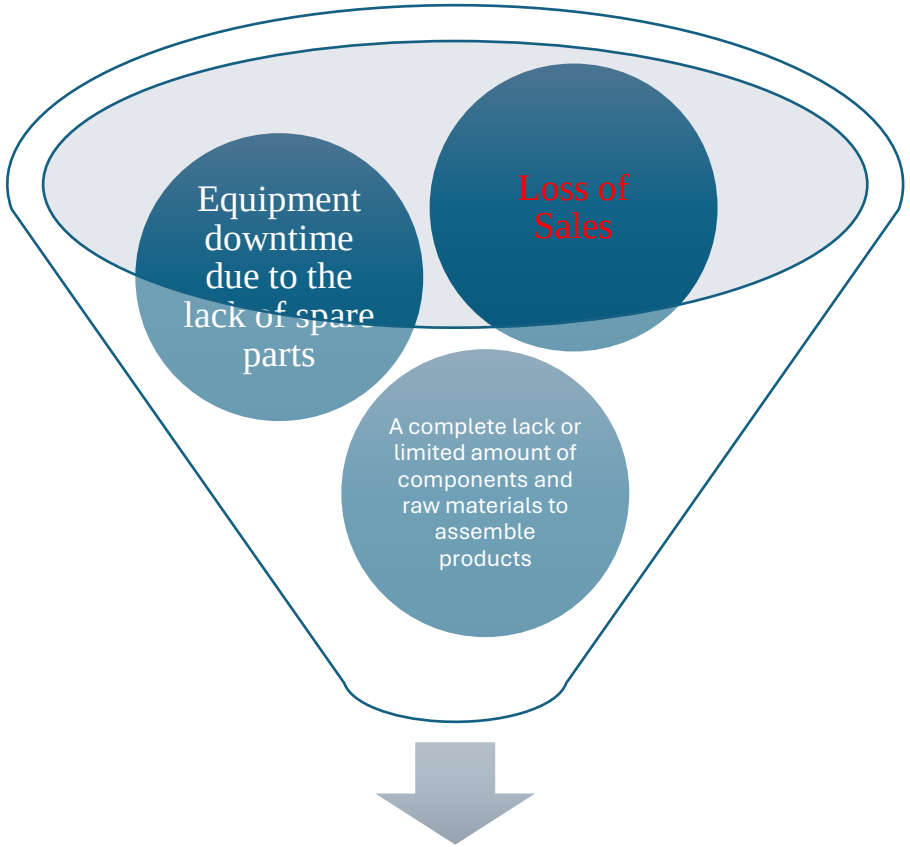
Inventory Basics

- Ideally, an organization would have sufficient inventory to satisfy customer demands for products without losing any revenue due to insufficient stock.
- An organization does not want to have too much inventory on hand, because it costs too much money to both acquire and hold inventory.

Inventory Basics

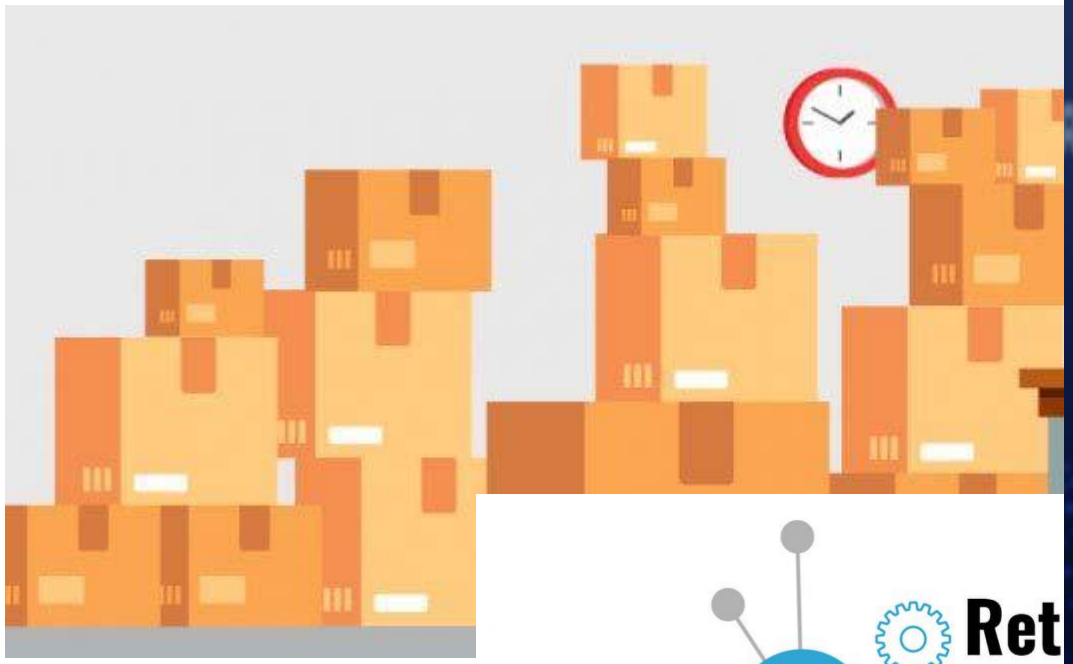
- Inventory management involves striking a balance between three classes of costs:
  - **Acquisition costs** are incurred during purchase order (PO) preparation and processing and during receiving and inspecting purchase items
  - **Carrying costs** are incurred in maintaining a stock of goods in storage
  - **Stockout costs** (also called shortage costs) are incurred when an item is out of stock

Inventory basics



Insufficient Inventory

Why inventory management



Different type of inventory

Raw materials | Components | Work-in-progress | Finished goods | Distribution inventory | Maintenance, repair & operating supplies

Inventory types

Inventory form	Inventory function	Driver of demand
Finished goods (FG) for sale (new and refurbished)	Cycle stock; safety stock; in-transit inventory; pre-build inventory to support market launches	Customer and consumer demand
Service parts (spare parts)	Service level based on criticality	Mean time between failure (MTBF)
Work in progress (WIP)	Sub-assemblies awaiting further production. Postponement; assemble to order (ATO)	FG inventory; production capacity; customer orders
Raw materials (RM)	Dependent demand items. Component parts; packaging materials	Purchased items required for production
Maintenance, repair and overhaul (MRO)	Service level based on criticality	Mean time between failure (MTBF)
Consumables	Support production. Two bin replacement system	As required based on production
General supplies	Office and technical items. Two bin replacement	As required by the enterprise

Critical analysis (VBL)

https://www.youtube.com/watch?v=tn0OCaf3O1Y

- Why is excess inventory a negative factor for companies?
- Why cut prices to move excess inventory?
- What can retailers do to prevent excess inventory?

Chapter 14/Inventory management/ p-585

- IM at Nike

Nike’s IM system uses long-term forecasts that provide retailers with significant discounts.

A mismatch between demand and production.

“on-demand "order reduces supply chain variability.

Henry Ford's famous proclamation

Customers can have any color they want, as long as it is black.

Practical challenges

- Customer do not easily forgive shortage of delivery delays
- Inventory management critical to a firm's strategic viability
- Success stores in retailing (Wal-Mart), auto (Toyota), computer (Dell) are founded on operational capabilities that among other things keep inventories lean
- Amazon.com
  - operation without huge inventory
  - innovation in inventory management enabled by technology

Need of inventory planning

- The average manufacturing company spends over one-half of its sales revenue on inventory. Because of the large investment and expenditure required for acquiring and controlling inventories and their effect on profits, successful companies devote a great deal of attention to inventory management.

How much inventory is enough?

Marketing department wants large inventory, it does not like stockouts.

Finance department likes low inventory and high turnover to minimize funds tied up in inventories; opportunity cost of capital.

Production department likes to keep production costs low. It likes uniform production and long uninterrupted runs of a small number of products.

Inventory system

Types of inventory systems

- Order point planning (OPP)
- Fixed-Quantity system
- Fixed-Interval system -
- Minimum-Maximum System, (s,S)-system
- Material requirement planning (MRP)
- Just-in-time system

- Information technology allows us to easily keep and update information
- Simple inventory system can include:
  - forecasting module
  - determination of order points and order quantities
  - monitoring of inventory levels

Costs

  - holding costs including opportunity costs
  - ordering or setup costs
  - shortage costs or service levels

Capacity Constraints

- demand distribution
- lead times

Inventory Costs type/p.589-590

- Item purchase Cost
- Ordering Cost
- Shortage Costs
- Risk costs
- Storage costs

Method for Order Quantities

Lot-for-lot	Order exactly what is needed
Fixed-order quantity	Specifies the number of units to order whenever an order is placed
Min-max system	Places a replenishment order when the on-hand inventory falls below the predetermined minimum level.

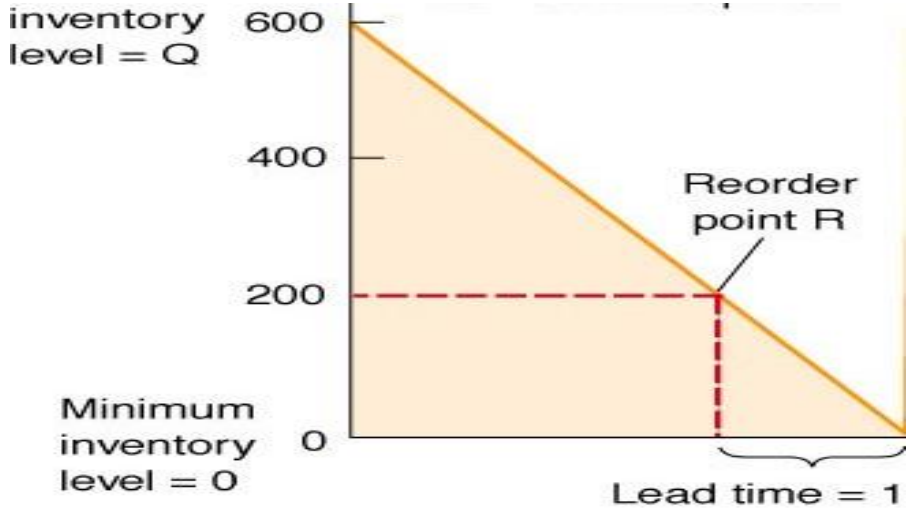
Mathematical Models for Determining Order Quantity/ inventory control system-p 590-591

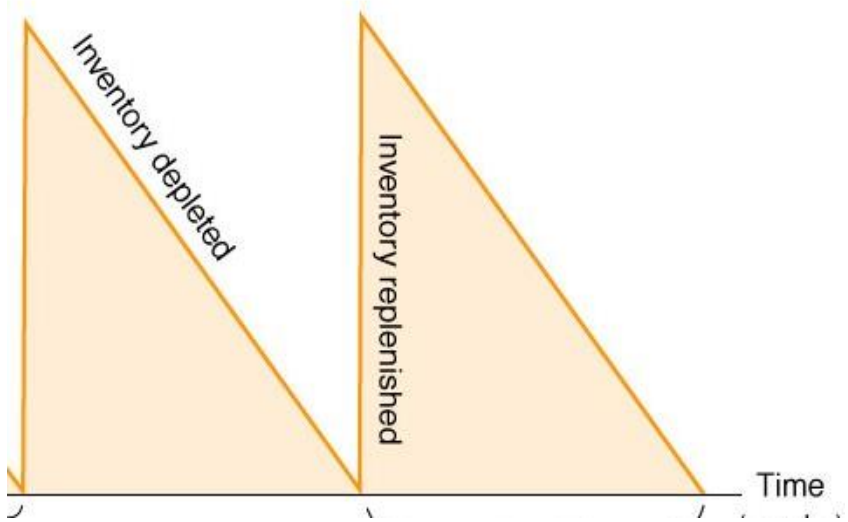
- Economic Order Quantity (EOQ or Q System)
  - An optimizing method used for determining order quantity and reorder points
  - Part of continuous review system which tracks on-hand inventory each time a withdrawal is made
  - Periodic review system is also called as fixed time system
- Economic Production Quantity (EPQ)
  - A model that allows for incremental product delivery
- Quantity Discount Model
  - Modifies the EOQ process to consider cases where quantity discounts are available

Economic Order Quantity p.594

Assumptions:

- Demand is known & constant - no safety stock is required
- Lead time is known & constant
- No quantity discounts are available
- Ordering (or setup) costs are constant
- All demand is satisfied (no shortages)
- The order quantity arrives in a single shipment

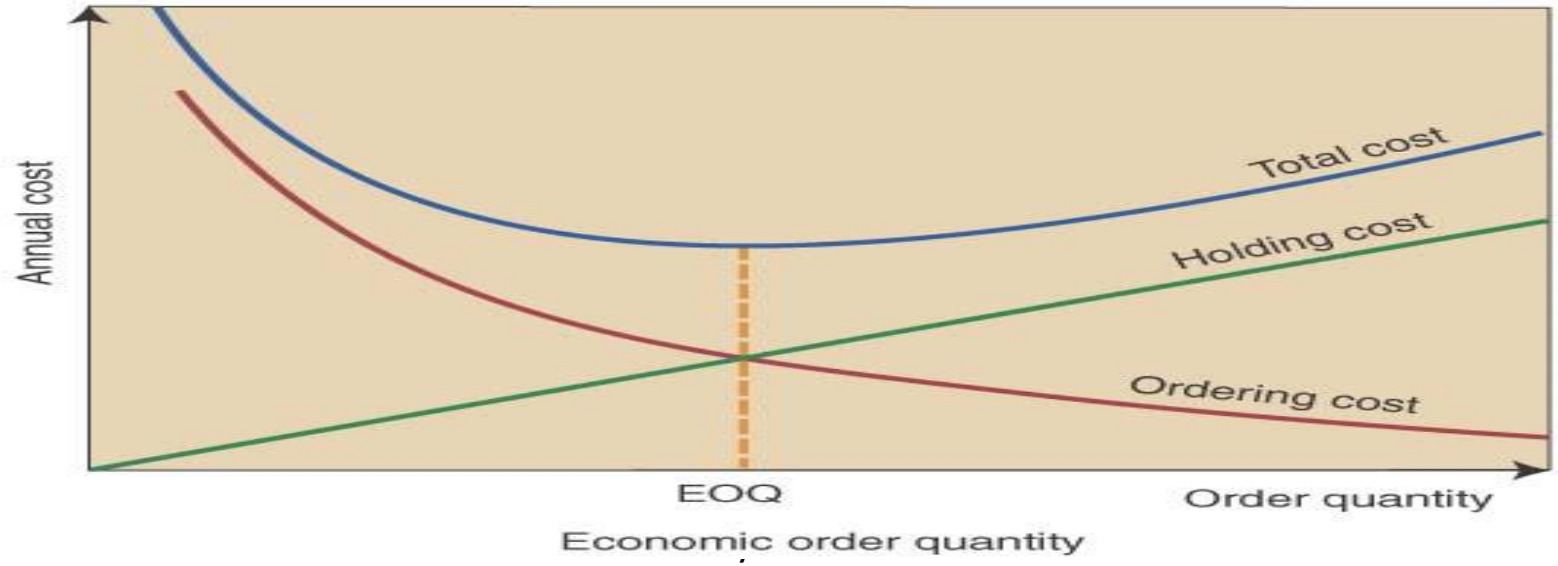




Total AIC with EOQ Model

- **Total annual cost= annual ordering cost + annual holding costs**

$$TC_Q = \left(\frac{D}{Q}\right)S + \left(\frac{Q}{2}\right)H; \quad \text{and} \quad Q = \sqrt{\frac{2DS}{H}}$$



Continuous (Q) Review System Example: A computer company has annual demand of 10,000. They want to determine EOQ for circuit boards which have an annual holding cost (H) of $6 per unit, and an ordering cost (S) of $75. They want to calculate TC and the reorder point (R) if the purchasing lead time is 5 days.

- **EOQ (Q)**

$$Q = \sqrt{\frac{2DS}{H}} = \sqrt{\frac{2 * 10{,}000 * \$75}{\$6}} = 500 \text{ units}$$

- **Reorder Point (R)**

$$R = \text{Daily Demand x Lead Time} = \frac{10{,}000}{250 \text{ days}} * 5 \text{ days} = 200 \text{ units}$$

- **Total Inventory Cost (TC)**

$$TC = \left(\frac{10{,}000}{500}\right)\$75 + \left(\frac{500}{2}\right)\$6 = \$1500 + \$1500 = \$3000$$

Reorder point computation 604

- EOQ models answer the question of how much to order, but not the question of when to order.
- The reorder point occurs when the quantity on hand drops to a predetermined amount.
- That amount generally includes expected demand during lead time and perhaps an extra cushion of stock, which serves to reduce the probability of experiencing a stockout during lead time.
- There are four determinants of the reorder point quantity:

1. The rate of demand (usually based on a forecast)
2. The lead time
3. The extent of demand and/or lead time variability
4. The degree of stockout risk acceptable to management

- If demand and lead time are both constant, the reorder point is simply

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

d=daily demand

Class exercise/Ex.14.2

The epaint store stocks paint in its warehouse ans sells it online on its website. The store stocks several brands of paint; however, its biggest seller is Sherman-Wilson iron coat paint. The company wants yo determine the optimal order size and total inventory cost for ironcoat paint given an estimated annual demand of 10000 gallons of paint, an annual carrying cost of $ 0.75 per gallon, and an ordering cost of $150 per order. It would also like to know the number of orders that will be made annually and the time between orders. Assume company operates 300 days annually.

Answer

D=10000

S=$150

H=$0.75

EOQ =2000 gallons

Tcmin= ordering cost+holding cost= 750+750=1500USD

No .of orders per year= D/EOQ= 10000/2000=5 orders per year

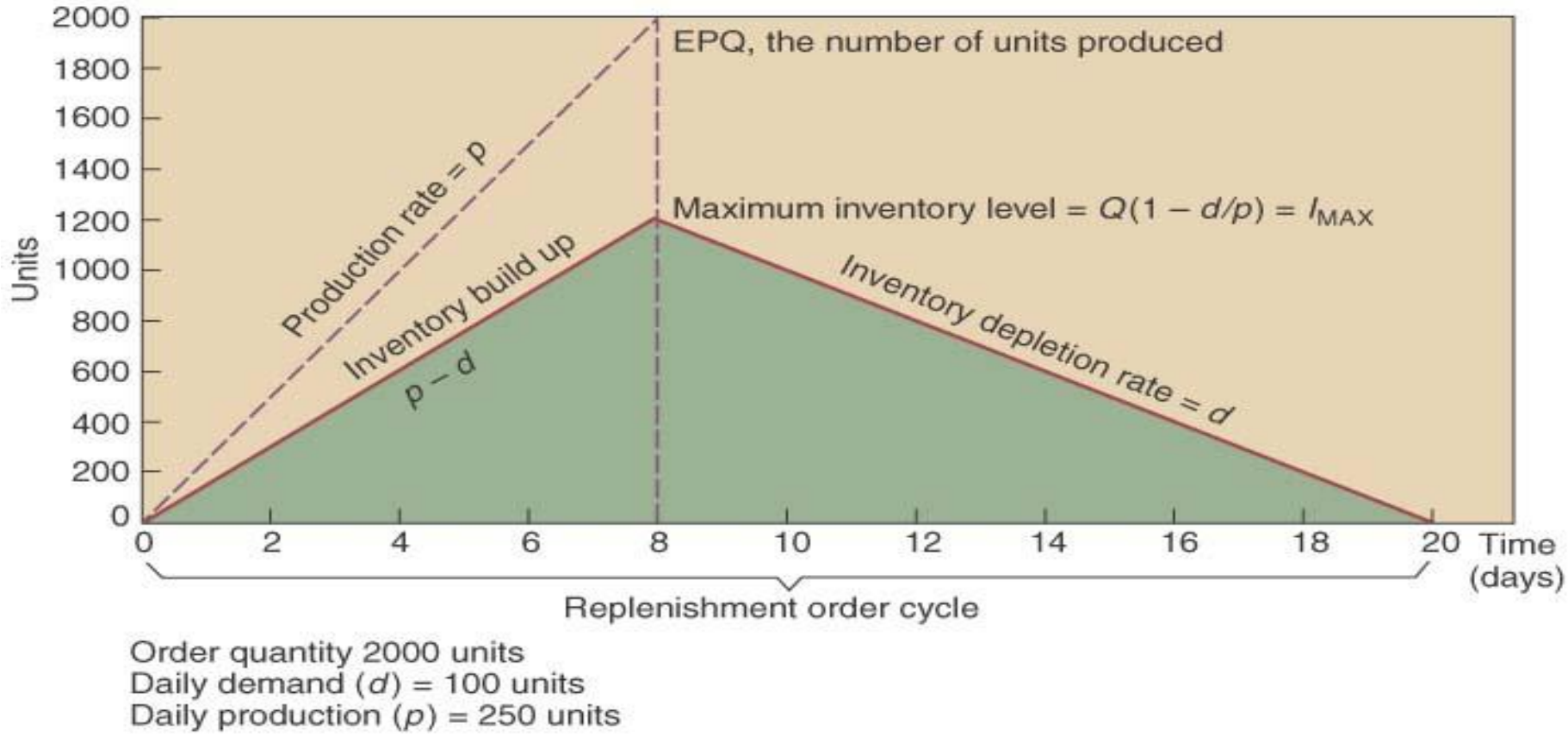
Order cycle time= working time/no .of orders =300/5= 75 days

Extension 14.5

If store open 31 days per year and demand 10000 gallons and lead time to receive orders is 10 days then reorder point = dL=(10000/311)*10 = 321.54 gallons

Economic Production Quantity (EPQ)

- Same assumptions as the EOQ except: inventory arrives in increments & is drawn down as it arrives



Model formulation

- **Total cost:**

$$TC_{EPQ} = \left(\frac{D}{Q}S\right) + \left(\frac{I_{MAX}}{2}H\right)$$

- **Maximum inventory:**
  - d=avg. daily demand rate
  - p=daily production rate

$$I_{MAX} = Q\left(1 - \frac{d}{p}\right)$$

- **Calculating EPQ**

$$EPQ = \sqrt{\frac{2DS}{H\left(1 - \frac{d}{p}\right)}}$$

EPQ Problem: HP Ltd. Produces its premium plant food in 50# bags. Demand is 100,000 lbs. per week and they operate 50 wks. each year and HP can produce 250,000 lbs. per week. The setup cost is $200 and the annual holding cost rate is $.55 per bag. Calculate the EPQ. Determine the maximum inventory level. Calculate the total cost of using the EPQ policy.

$$\mathbf{EPQ} = \sqrt{\frac{\mathbf{2DS}}{\mathbf{H}\left(\mathbf{1}-\frac{\mathbf{d}}{\mathbf{p}}\right)}}$$

$$\mathbf{I_{MAX}} = \mathbf{Q}\left(\mathbf{1}-\frac{\mathbf{d}}{\mathbf{p}}\right)$$

$$\mathbf{TC_{EPQ}} = \left(\frac{\mathbf{D}}{\mathbf{Q}}\mathbf{S}\right)+\left(\frac{\mathbf{I_{MAX}}}{\mathbf{2}}\mathbf{H}\right)$$

$$EPQ = \sqrt{\frac{2(50)(100{,}000)(200)}{.55\left(1-\frac{100{,}000}{250000}\right)}} = 77{,}850 Bags$$

$$I_{MAX} = 77{,}850\left(1-\frac{100{,}000}{250{,}000}\right) = 46{,}710 bags$$

$$TC = \left(\frac{5{,}000{,}000}{77{,}850}\right)(200)+\left(\frac{46{,}710}{2}\right)(.55) = \$25{,}690$$

Class exercise 14.3

The Production Quantity Model

Assume that the ePaint Store has its own manufacturing facility in which it produces Iron-coat paint. The ordering cost, C_o, is the cost of setting up the production process to make paint. $C_o = \$150$. Recall that $C_c = \$0.75$ per gallon and $D = 10{,}000$ gallons per year. The manufacturing facility operates the same days the store is open (i.e., 311 days) and produces 150 gallons of paint per day. Determine the optimal order size, total inventory cost, the length of time to receive an order, the number of orders per year, and the maximum inventory level.

$C_o = \$150$

$C_c = \$0.75$ per gallons

$D = 10{,}000$ gallons

$d = \dfrac{10{,}000}{311} = 32.2$ gallons per day

$p = 150$ gallons per day

The optimal order size is determined as follows:

$$Q_{opt} = \sqrt{\frac{2C_oD}{C_c\left(1-\frac{d}{p}\right)}}$$

$$= \sqrt{\frac{2(150)(10{,}000)}{0.75\left(1-\frac{32.2}{150}\right)}}$$

$$= 2256.8 \text{ gallons}$$

Although an order of 2256.8 gallons should be rounded to 2257, we will use the 2256.8 to compute total cost. This value is substituted into the following formula to determine total minimum annual inventory cost:

$$TC_{min} = \frac{C_oD}{Q} + \frac{C_cQ}{2}\left(1-\frac{d}{p}\right)$$

$$= \frac{(150)(10{,}000)}{2256.8} + \frac{(0.75)(2256.8)}{2}\left(1-\frac{32.2}{150}\right)$$

$$= \$1329$$

The length of time to receive an order for this type of manufacturing operation is commonly called the length of the *production run*.

$$\text{Production run} = \frac{Q}{p}$$

$$= \frac{2256.8}{150}$$

$$= 15.05 \text{ days per order}$$

The number of orders per year is actually the number of production runs that will be made:

$$\text{Number of production runs (from orders)} = \frac{D}{Q}$$

$$= \frac{10{,}000}{2256.8}$$

$$= 4.43 \text{ runs per year}$$

Finally, the maximum inventory level is

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

$$= 2256.8\left(1-\frac{32.2}{150}\right)$$

$$= 1772 \text{ gallons}$$

Thus, ePaint will need to set aside storage space sufficient to accommodate these 1772 gallons of paint.

Quantity Discount Model p.601

Whenever the price per unit is not fixed but varies based on the size of your order, the total annual cost formula for any inventory policy used must include the cost of material.

- **Same as the EOQ model, except:**
  - Unit price depends upon the quantity ordered

- **The total cost equation becomes:**

$$TC_{QD} = \left(\frac{D}{Q}S\right) + \left(\frac{Q}{2}H\right) + CD$$

D annual demand in units
Q order quantity in units
S ordering or setup cost
H annual holding cost
C unit price

Quantity Discount Procedure

- Calculate the EOQ at the lowest price
- Determine whether the EOQ is feasible at that price
  - Will the vendor sell that quantity at that price?
- If yes, stop – if no, continue
- Check the feasibility of EOQ at the next higher price

QD Procedure

- Continue until you identify a feasible EOQ
- Calculate the total costs (including total item cost) for the feasible EOQ model
- Calculate the total costs of buying at the minimum quantity required for each of the cheaper unit prices
- Compare the total cost of each option & choose the lowest cost alternative
- Any other issues to consider?

Quantity Discount Example: Collin's Sport store is considering going to a different hat supplier. The present supplier charges $10 each and requires minimum quantities of 490 hats. The annual demand is 12,000 hats, the ordering cost is $20, and the inventory carrying cost is 20% of the hat cost, a new supplier is offering hats at $9 in lots of 4000. Who should he buy from?

- **EOQ at lowest price $9. Is it feasible?**

$$EOQ_{\$9} = \sqrt{\frac{2(12{,}000)(20)}{\$1.80}} = 516 \text{ hats}$$

- **Since the EOQ of 516 is not feasible, calculate the total cost (C) for each price to make the decision**

$$C_{\$10} = \frac{12{,}000}{490}(\$20) + \frac{490}{2}(\$2) + \$10(12{,}000) = \$120{,}980$$

$$C_{\$9} = \frac{12{,}000}{4000}(\$20) + \frac{4000}{2}(\$1.80) + \$9(12{,}000) = \$101{,}660$$

- **4000 hats at $9 each saves $19,320 annually. Space?**

Determining the Optimal Order Quantity When There Are Quantity Discounts and Carrying Costs are Constant

- The maintenance department of a large hospital uses about 816 cases of liquid cleanser annually. Ordering costs are $12, carrying costs are $4 per case a year, and the new price schedule indicates that orders of less than 50 cases will cost $20 per case, 50 to 79 cases will cost $18 per case, 80 to 99 cases will cost $17 per case, and larger orders will cost $16 per case. Determine the optimal order quantity and the total cost.

$D = 816$ cases per year $\qquad S = \$12 \qquad H = \$4$ per case per year

Range	Price
1 to 49	$20
50 to 79	18
80 to 99	17
100 or more	16

1. Compute the common minimum quantity Q: $= \sqrt{\frac{2DS}{H}} = \sqrt{\frac{2(816)12}{4}} = 69.97 \approx 70$ cases.

The 70 cases can be bought at $18 per case because 70 falls in the range of 50 to 79 cases. The total cost to purchase 816 cases a year, at the rate of 70 cases per order, will be

$$\begin{aligned} TC_{70} &= \text{Carrying cost} + \text{Order cost} + \text{Purchase cost} \\ &= (Q/2)H + (D/Q)S + PD \\ &= (70/2)4 + (816/70)12 + 18(816) = \$14{,}968 \end{aligned}$$

$$TC_{80} = (80/2)4 + (816/80)12 + 17(816) = \$14{,}154$$

$$TC_{100} = (100/2)4 + (816/100)12 + 16(816) = \$13{,}354$$

Example 14.4 (home practice)

EXAMPLE 14.4

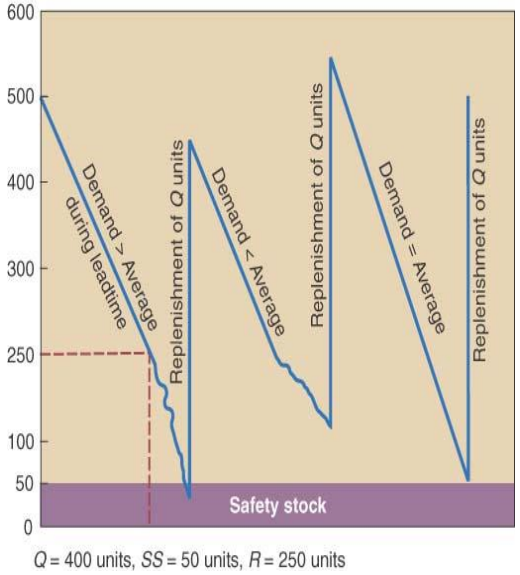
A Quantity Discount with Constant Carrying Cost

Avtek, a distributor of audio and video equipment, wants to reduce a large stock of televisions. It has offered a local chain of stores a quantity discount pricing schedule, as follows:

Quantity	Price
1–49	$1400
50–89	1100
90+	900

The annual carrying cost for the stores for a TV is $190, the ordering cost is $2500, and annual demand for this particular model TV is estimated to be 200 units. The chain wants to determine if it should take advantage of this discount or order the basic EOQ order size.

Safety Stock and Service Levels Page 604



- If demand or lead time is uncertain, safety stock can be added to improve order-cycle service levels
  - **Re order point for basic EOQ (R) = dL**
  - For computation of safety stock we need to compute the required service level.
  - SL is defined as probability that the amount of inventory on hand during the lead time to meet expected demand.
  - ROP with variable demand =

Average daily demand (d) x Lead time (L) + $\mathbf{z\sigma_d}\sqrt{L}$ (safety stock)

Where $\sigma_d\sqrt{L}$

Variance= (daily variance)*number of days of the lead time

$\Sigma^2 d*L$

Standard deviation= $\sqrt{}$variance

Order-cycle service level

- The probability that demand during lead time will not exceed on-hand inventory
- A 95% service level (stockout risk of 5%) has a Z=1.645

Reorder point computation exercise

The e-paint store having average demand of 30 gallons and a standard deviation of 5 gallons of paint per day. The lead time for receiving new order of paint is 10 days. Determine the ROP and SS if the store wants to maintain a service level of 95%.

Answer

d=30

L=10

$\sigma_{d= 5 \text{ gallons}}$

$SS= z\sigma_d\sqrt{L} = 1.65*5*\sqrt{10} = 26.1$ gallons

ROP= 26.1+dL= 300+26.1= 326.1 gallons

ABC Inventory Classification p.592

- **ABC classification** is a method for determining level of control and frequency of review of inventory items
- A Pareto analysis can be done to segment items into value categories depending on annual dollar volume
- **A Items** – typically 20% of the items accounting for 80% of the inventory value-use Q system
- **B Items** – typically an additional 30% of the items accounting for 15% of the inventory value-use Q or P
- **C Items** – Typically the remaining 50% of the items accounting for only 5% of the inventory value-use P

EXAMPLE 14.1

ABC System Classification

The maintenance department for a small manufacturing firm has responsibility for maintaining an inventory of spare parts for the machinery it services. The parts inventory, unit cost, and annual usage are as follows:

Part	Unit Cost	Annual Usage
1	$60	90
2	350	40
3	30	130
4	80	60
5	30	100
6	20	180
7	10	170
8	320	50
9	510	60
10	20	120

The department manager wants to classify the inventory parts according to the ABC system to determine which stocks of parts should most closely be monitored.

First rank the items according to their total value and also compute each item's percentage of total value and quantity.

Part	Total Value	% of Total Value	% of Total Quantity	% Cumulative
9	$30,600	35.9	6.0	6.0
8	16,000	18.7	5.0	11.0
2	14,000	16.4	4.0	15.0
1	5,400	6.3	9.0	24.0
4	4,800	5.6	6.0	30.0
3	3,900	4.6	13.0	43.0
6	3,600	4.2	18.0	61.0
5	3,000	3.5	10.0	71.0
10	2,400	2.8	12.0	83.0
7	1,700	2.0	17.0	100.0
	$85,400			

Class	Items	% of Total Value	% of Total Quantity
A	9, 8, 2	71.0	15.0
B	1, 4, 3	16.5	28.0
C	6, 5, 10, 7	12.5	57.0

ABC ANALYSIS

(ABC = Always Better Control)

- This is based on cost criteria.
- It helps to exercise selective control when confronted with large number of items it rationalizes the number of orders, number of items & reduce the inventory.
- About 10 % of materials consume 70 % of resources
- About 20 % of materials consume 20 % of resources
- About 70 % of materials consume 10 % of resources

‘A’ ITEMS

Small in number, but consume large amount of resources

Must have:

- **Tight control**
- **Rigid estimate of requirements**
- **Strict & closer watch**
- **Low safety stocks**
- **Managed by top management**

‘B’ ITEM

Intermediate

Must have:

- **Moderate control**
- **Purchase based on rigid requirements**
- **Reasonably strict watch & control**
- **Moderate safety stocks**
- **Managed by middle level management**

‘C’ ITEMS

Larger in number, but consume lesser amount of resources

Must have:

- **Ordinary control measures**
- **Purchase based on usage estimates**
- **High safety stocks**

ABC analysis does not stress on items those are less costly but may be vital

ABC ANALYSIS WORK SHEET

10 %

20 %

70 %

ITEM	ANNUAL COST [Rs.]	CUMMULATIVE COST [Rs.]
1	90000	90000
2	50000	140000
3	20000	160000
4	7500	167500
5	7500	175000
6	5000	180000
7	4500	184500
8	4000	188500
9	2750	191250
10	1750	193000
11	1500	194500
12	1500	196000
13	500	196500
14	500	197000
15	500	197500
16	500	198000
17	500	198500
18	500	199000
19	500	199500
20	500	200000

70 %

20 %

10 %

VED ANALYSIS

- Based on critical value & shortage cost of an item

– It is a subjective analysis.

- Items are classified into:

Vital:

- Shortage cannot be tolerated.

Essential:

- Shortage can be tolerated for a short period.

Desirable:

- Shortage will not adversely affect but may be using more resources. These must be strictly Scrutinized

	V	E	D		ITEM	COST
A	AV	AE	AD	CATEGORY 1	10	70%
B	BV	BE	BD	CATEGORY 2	20	20%
C	CV	CE	CD	CATEGORY 3	70	10%

CATEGORY 1 - NEEDS CLOSE MONITORING & CONTROL
CATEGORY 2 - MODERATE CONTROL.
CATEGORY 3 - NO NEED FOR CONTROL

SDE ANALYIS

Based on availability

- Scarce
  - Managed by top level management
  - Maintain big safety stocks
- Difficult
  - Maintain sufficient safety stocks
- Easily available
  - Minimum safety stocks

FSN ANALYSIS

- Based on utilization.
- Fast moving.
- Slow moving.
- Non-moving.
- Non-moving items must be periodically reviewed to prevent expiry & obsolescence

HML ANALYSIS

Based on cost per unit

- Highest
- Medium
- Low

This is used to keep control over consumption at departmental level for deciding the frequency of physical verification.

The AAU Corp. is considering doing an ABC analysis on its entire inventory but has decided to test the technique on a small sample of 15 of its SKU's. The annual usage and unit cost of each item is shown below

ABC Problem Data

Item	Unit $ Value	Annual Usage (in units)
101	12.00	80
102	50.00	10
103	15.00	50
104	50.00	40
105	40.00	80
106	75.00	220
107	4.00	250
108	1.50	400
109	2.00	250
110	25.00	500
111	5.00	450
112	7.50	80
113	3.50	250
114	1.00	1200
115	15.00	300

(A) First calculate the annual dollar volume for each item

- **Solution**

(a)

ABC Annual Usage Values

Item	Unit $ Value	Annual Usage (in units)	Annual Usage ($)
101	12.00	80	960
102	50.00	10	500
103	15.00	50	750
104	50.00	40	2000
105	40.00	80	3200
106	75.00	220	16,500
107	4.00	250	1000
108	1.50	400	600
109	2.00	250	500
110	25.00	500	12,500
111	5.00	450	2250
112	7.50	80	600
113	3.50	250	875
114	1.00	1200	1200
115	15.00	300	4500
		Total	$47,935

B) List the items in descending order based on annual dollar volume. (C) Calculate the cumulative annual dollar volume as a percentage of total dollars. (D) Classify the items into groups

(b, c, and d)

ABC Solution

Item	Annual Usage ($)	Percentage of Total Dollars	Cumulative Percentage of Total Dollars	Item Classification
106	16,500	34.4	34.4	A
110	12,500	26.1	60.5	A
115	4500	9.4	69.9	B
105	3200	6.7	76.6	B
111	2250	4.7	81.3	B
104	2000	4.2	85.5	B
114	1200	2.5	88.0	C
107	1000	2.1	90.1	C
101	960	2.0	92.1	C
113	875	1.8	93.9	C
103	750	1.6	95.5	C
108	600	1.3	96.8	C
112	600	1.3	98.1	C
102	500	1.0	99.1	C
109	500	1.0	100.1*	C
Total	**$47,935**			

*Total exceeds 100% due to rounding.

Remember that these are not absolute rules for classifying items. Your company wants to group their more valuable items together to make sure that they get the most control.

Graphical solution

- The A items (106 and 110) account for 60.5% of the value and 13.3% of the items
- The B items (115,105,111,and 104) account for 25% of the value and 26.7% of the items
- The C items make up the last 14.5% of the value and 60% of the items
- How might you control each item classification? Different ordering rules for each?