
Inventory Management



Overview

- Opposing Views of Inventories
- Nature of Inventories
- Fixed Order Quantity Systems
- Fixed Order Period Systems
- Other Inventory Models
- Some Realities of Inventory Planning
- Wrap-Up: What World-Class Companies Do

Opposing Views of Inventory

- Why We Want to Hold Inventories
- Why We Not Want to Hold Inventories

Why We Want to Hold Inventories

- Improve customer service
- Reduce certain costs such as
 - ordering costs
 - stockout costs
 - acquisition costs
 - start-up quality costs
- Contribute to the efficient and effective operation of the production system

Why We Want to Hold Inventories

- Finished Goods
 - Essential in produce-to-stock positioning strategies
 - Necessary in level aggregate capacity plans
 - Products can be displayed to customers
- Work-in-Process
 - Necessary in process-focused production
 - May reduce material-handling & production costs
- Raw Material
 - Suppliers may produce/ship materials in batches
 - Quantity discounts and freight/handling \$\$ savings

Why We Do Not Want to Hold Inventories

- Certain costs increase such as
 - carrying costs
 - cost of customer responsiveness
 - cost of coordinating production
 - cost of diluted return on investment
 - reduced-capacity costs
 - large-lot quality cost
 - cost of production problems

Nature of Inventory

- Two Fundamental Inventory Decisions
- Terminology of Inventories
- Independent Demand Inventory Systems
- Dependent Demand Inventory Systems
- Inventory Costs

Two Fundamental Inventory Decisions

- How much to order of each material when orders are placed with either outside suppliers or production departments within organizations
- When to place the orders

Independent Demand Inventory Systems

- Demand for an item carried in inventory is independent of the demand for any other item in inventory
- Finished goods inventory is an example
- Demands are estimated from forecasts and/or customer orders

Dependent Demand Inventory Systems

- Items whose demand depends on the demands for other items
- For example, the demand for raw materials and components can be calculated from the demand for finished goods
- The systems used to manage these inventories are different from those used to manage independent demand items

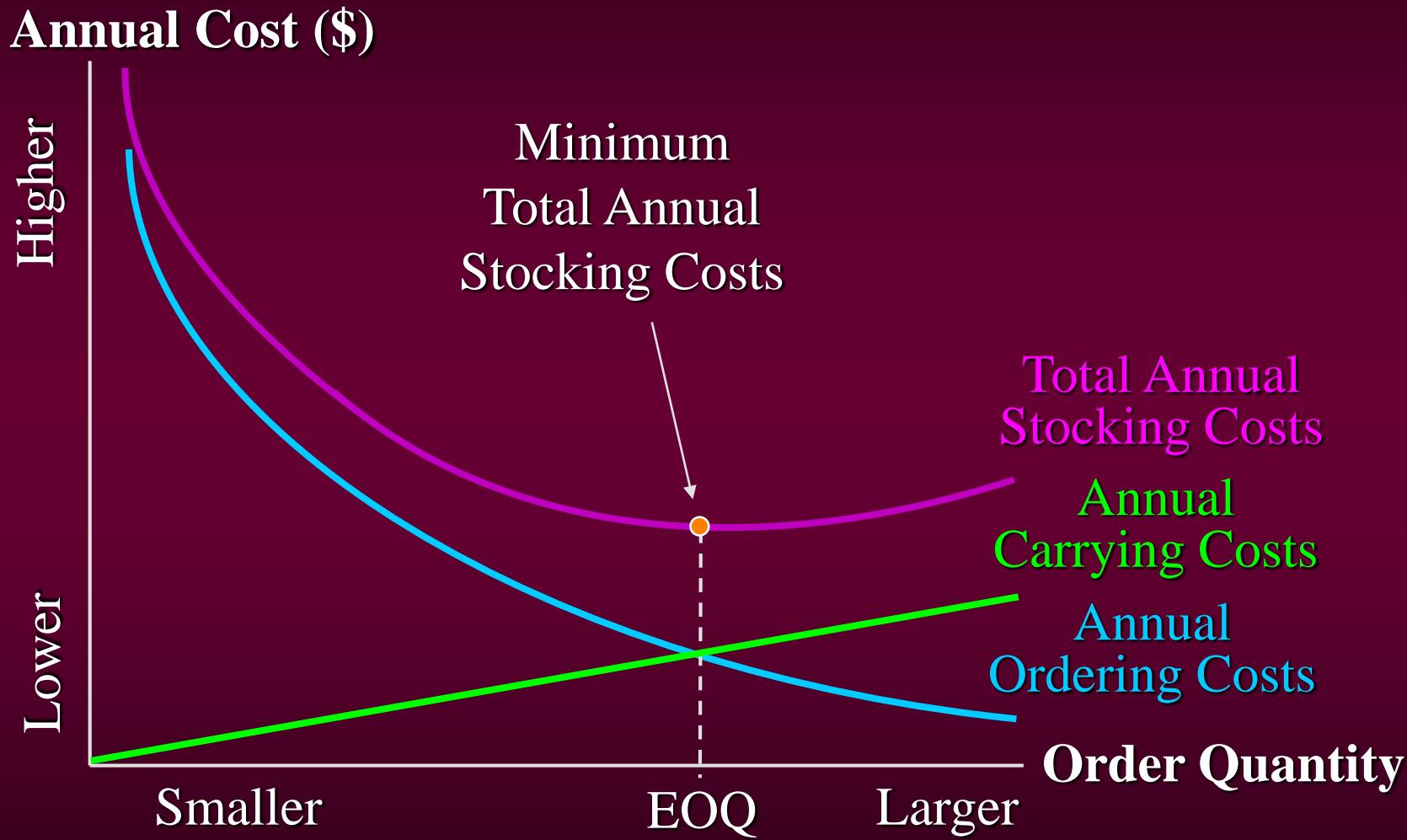
Inventory Costs

- **Holding (or carrying) costs**
 - Costs for storage, handling, insurance, etc
- **Ordering costs**
 - Costs of someone placing an order, etc
- **Shortage costs**
 - Costs of canceling an order, etc

Inventory Costs (continued)

- The sum of the two costs is the total stocking cost (TSC)
- When plotted against order quantity, the TSC decreases to a minimum cost and then increases
- This cost behavior is the basis for answering the first fundamental question: how much to order
- It is known as the economic order quantity (EOQ)

Balancing Carrying against Ordering Costs



Fixed Order Quantity Systems

- Behavior of Economic Order Quantity (EOQ) Systems
- Determining Order Quantities
- Determining Order Points

Behavior of EOQ Systems

- As demand for the inventoried item occurs, the inventory level drops
- When the inventory level drops to a critical point, the order point, the ordering process is triggered
- The amount ordered each time an order is placed is fixed or constant
- When the ordered quantity is received, the inventory level increases
- . . . more

Behavior of EOQ Systems

- An application of this type system is the two-bin system
- A perpetual inventory accounting system is usually associated with this type of system

Determining Order Quantities

- Basic EOQ
- EOQ for Production Lots
- EOQ with Quantity Discounts

Model I: Basic EOQ

- Typical assumptions made
 - annual demand (D), carrying cost (C) and ordering cost (S) can be estimated
 - average inventory level is the fixed order quantity (Q) divided by 2 which implies
 - no safety stock
 - orders are received all at once
 - demand occurs at a uniform rate
 - no inventory when an order arrives
 - . . . more

Model I: Basic EOQ

- Assumptions (continued)
 - Stockout, customer responsiveness, and other costs are inconsequential
 - acquisition cost is fixed, i.e., no quantity discounts
- Annual carrying cost = (average inventory level) x (carrying cost) = $(Q/2)C$
- Annual ordering cost = (average number of orders per year) x (ordering cost) = $(D/Q)S$
- . . . more

Model I: Basic EOQ

- Total annual stocking cost (TSC) = annual carrying cost + annual ordering cost = $(Q/2)C + (D/Q)S$
- The order quantity where the TSC is at a minimum (EOQ) can be found using calculus (take the first derivative, set it equal to zero and solve for Q)

$$\text{EOQ} = \sqrt{2DS/C}$$

Example: Basic EOQ

Zartex Co. produces fertilizer to sell to wholesalers. One raw material – calcium nitrate – is purchased from a nearby supplier at \$22.50 per ton. Zartex estimates it will need 5,750,000 tons of calcium nitrate next year.

The annual carrying cost for this material is 40% of the acquisition cost, and the ordering cost is \$595.

- a) What is the most economical order quantity?
- b) How many orders will be placed per year?
- c) How much time will elapse between orders?

Example: Basic EOQ

- Economical Order Quantity (EOQ)

$$D = 5,750,000 \text{ tons/year}$$

$$C = .40(22.50) = \$9.00/\text{ton/year}$$

$$S = \$595/\text{order}$$

$$\text{EOQ} = \sqrt{2DS/C}$$

$$\text{EOQ} = \sqrt{2(5,750,000)(595)/9.00}$$

$$= 27,573.135 \text{ tons per order}$$

Example: Basic EOQ

- Total Annual Stocking Cost (TSC)

$$\begin{aligned} \text{TSC} &= (Q/2)C + (D/Q)S \\ &= (27,573.135/2)(9.00) \\ &\quad + (5,750,000/27,573.135)(595) \\ &= 124,079.11 + 124,079.11 \\ &= \$248,158.22 \end{aligned}$$

Note: Total Carrying Cost
equals Total Ordering Cost

Example: Basic EOQ

- Number of Orders Per Year

$$= D/Q$$

$$= 5,750,000/27,573.135$$

$$= 208.5 \text{ orders/year}$$

- Time Between Orders

$$= Q/D$$

$$= 1/208.5$$

$$= .004796 \text{ years/order}$$

$$= .004796(365 \text{ days/year}) = 1.75 \text{ days/order}$$

Note: This is the inverse
of the formula above.

Model II: EOQ for Production Lots

- Used to determine the order size, production lot, if an item is produced at one stage of production, stored in inventory, and then sent to the next stage or the customer
- Differs from Model I because orders are assumed to be supplied or produced at a uniform rate (p) rate rather than the order being received all at once
- . . . more

Model III: EOQ for Production Lots

- It is also assumed that the supply rate, p , is greater than the demand rate, d
- The change in maximum inventory level requires modification of the TSC equation
- $TSC = (Q/2)[(p-d)/p]C + (D/Q)S$
- The optimization results in

$$EOQ = \sqrt{\frac{2DS}{C} \left[\frac{p}{p-d} \right]}$$

Example: EOQ for Production Lots

Highland Electric Co. buys coal from Cedar Creek Coal Co. to generate electricity. CCCC can supply coal at the rate of 3,500 tons per day for \$10.50 per ton. HEC uses the coal at a rate of 800 tons per day and operates 365 days per year.

HEC's annual carrying cost for coal is 20% of the acquisition cost, and the ordering cost is \$5,000.

- a) What is the economical production lot size?
- b) What is HEC's maximum inventory level for coal?

Example: EOQ for Production Lots

- Economical Production Lot Size

$$d = 800 \text{ tons/day}; \quad D = 365(800) = 292,000 \text{ tons/year}$$

$$p = 3,500 \text{ tons/day}$$

$$S = \$5,000/\text{order} \quad C = .20(10.50) = \$2.10/\text{ton/year}$$

$$\text{EOQ} = \sqrt{(2DS/C)[p/(p-d)]}$$

$$\begin{aligned}\text{EOQ} &= \sqrt{2(292,000)(5,000)/2.10[3,500/(3,500-800)]} \\ &= 42,455.5 \quad \text{tons per order}\end{aligned}$$

Example: EOQ for Production Lots

- Total Annual Stocking Cost (TSC)

$$\begin{aligned} TSC &= (Q/2)((p-d)/p)C + (D/Q)S \\ &= (42,455.5/2)((3,500-800)/3,500)(2.10) \\ &\quad + (292,000/42,455.5)(5,000) \\ &= 34,388.95 + 34,388.95 \\ &= \$68,777.90 \end{aligned}$$



Note: Total Carrying Cost equals Total Ordering Cost

Example: EOQ for Production Lots

- Maximum Inventory Level

$$= Q(p-d)/p$$

$$= 42,455.5(3,500 - 800)/3,500$$

$$= 42,455.5(.771429)$$

$$= 32,751.4 \text{ tons}$$



Note: HEC will use 23% of the production lot by the time it receives the full lot.

Model III: EOQ with Quantity Discounts

- Under quantity discounts, a supplier offers a lower unit price if larger quantities are ordered at one time
- This is presented as a price or discount schedule, i.e., a certain unit price over a certain order quantity range
- This means this model differs from Model I because the acquisition cost (ac) may vary with the quantity ordered, i.e., it is not necessarily constant
- . . . more

Model III: EOQ with Quantity Discounts

- Under this condition, acquisition cost becomes an incremental cost and must be considered in the determination of the EOQ
- The total annual material costs (TMC) = Total annual stocking costs (TSC) + annual acquisition cost

$$TSC = (Q/2)C + (D/Q)S + (D)ac$$

- . . . more

Model III: EOQ with Quantity Discounts

To find the EOQ, the following procedure is used:

- 1.** Compute the EOQ using the lowest acquisition cost.
 - If the resulting EOQ is feasible (the quantity can be purchased at the acquisition cost used), this quantity is optimal and you are finished.
 - If the resulting EOQ is not feasible, go to Step 2
- 2.** Identify the next higher acquisition cost.

Model III: EOQ with Quantity Discounts

3. Compute the EOQ using the acquisition cost from Step 2.
 - If the resulting EOQ is feasible, go to Step 4.
 - Otherwise, go to Step 2.
4. Compute the TMC for the feasible EOQ (just found in Step 3) and its corresponding acquisition cost.
5. Compute the TMC for each of the lower acquisition costs using the minimum allowed order quantity for each cost.
6. The quantity with the lowest TMC is optimal.

Example: EOQ with Quantity Discounts

A-1 Auto Parts has a regional tire warehouse in Atlanta. One popular tire, the XRX75, has estimated demand of 25,000 next year. It costs A-1 \$100 to place an order for the tires, and the annual carrying cost is 30% of the acquisition cost. The supplier quotes these prices for the tire:

Q	ac
1 – 499	\$21.60
500 – 999	20.95
1,000 +	20.90

Example: EOQ with Quantity Discounts

- Economical Order Quantity

$$EOQ_i = \sqrt{2DS/C_i}$$

$$EOQ_3 = \sqrt{2(25,000)100/(.3(20.90))} = 893.00$$

This quantity is not feasible, so try ac = \$20.95

$$EOQ_2 = \sqrt{2(25,000)100/(.3(20.95))} = 891.93$$

This quantity is feasible, so there is no reason to try ac = \$21.60

Example: EOQ with Quantity Discounts

- Compare Total Annual Material Costs (TMCs)

$$TMC = (Q/2)C + (D/Q)S + (D)ac$$

Compute TMC for $Q = 891.93$ and $ac = \$20.95$

$$\begin{aligned} TMC_2 &= (891.93/2)(.3)(20.95) + (25,000/891.93)100 \\ &\quad + (25,000)20.95 \\ &= 2,802.89 + 2,802.91 + 523,750 \\ &= \$529,355.80 \end{aligned}$$

... more



Example: EOQ with Quantity Discounts

Compute TMC for $Q = 1,000$ and $ac = \$20.90$

$$\begin{aligned} TMC_3 &= (1,000/2)(.3)(20.90) + (25,000/1,000)100 \\ &\quad + (25,000)20.90 \\ &= 3,135.00 + 2,500.00 + 522,500 \\ &= \$528,135.00 \text{ (lower than } TMC_2) \end{aligned}$$

The EOQ is 1,000 tires
at an acquisition cost of \$20.90.

Demerits of EOQ

1. Erratic Usage
2. Faulty basic information
3. Costly calculations

TYPES OF REVIEW SYSTEM:

Two inventory control systems are used for independent demand items are-

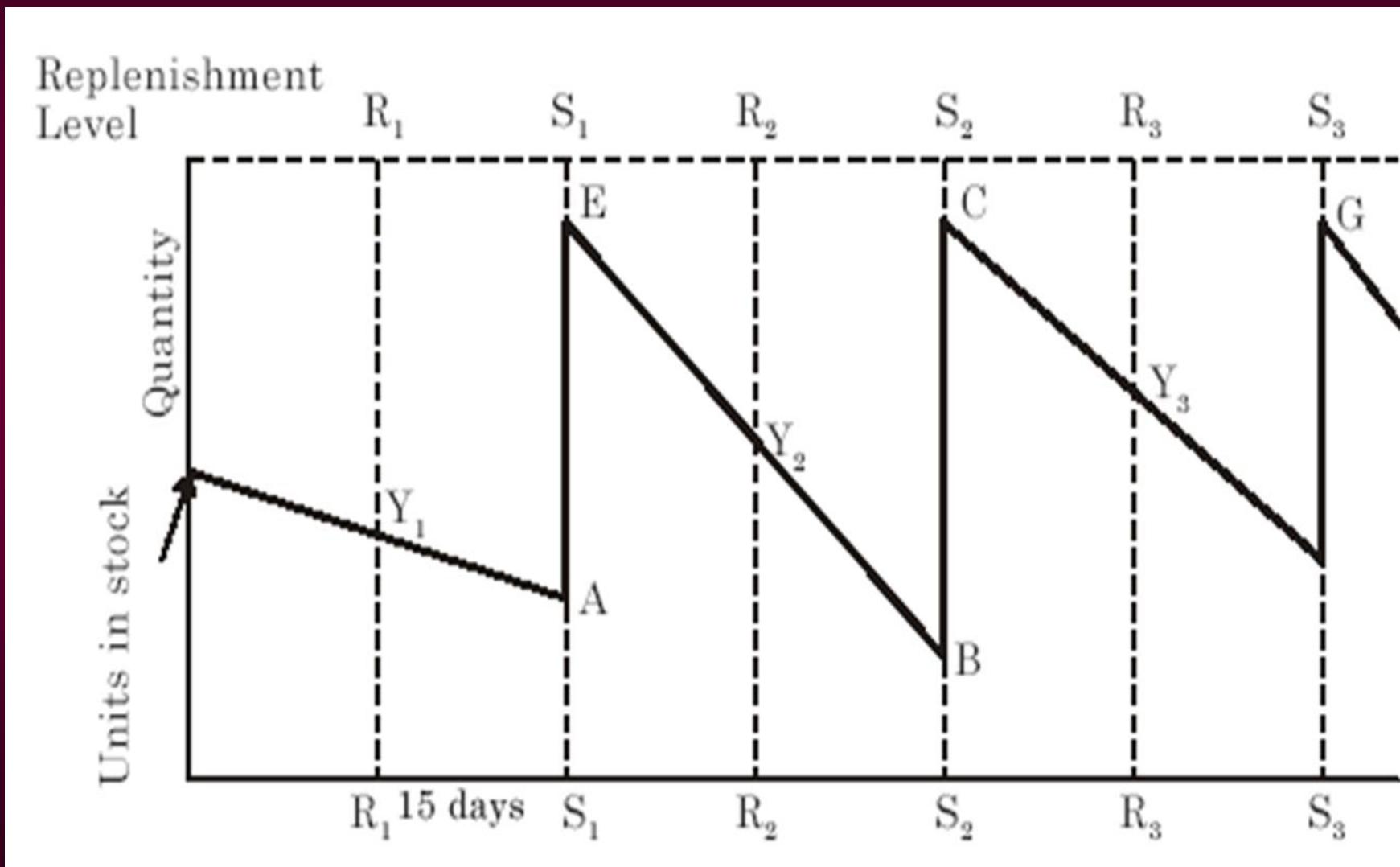
1. P-System (Periodic Review System)

- Known as P system
- Stock position of each item of material is regularly reviewed.
- When stock level becomes insufficient to sustain production until the next scheduled review, an order is placed replenishing the supply.
- The frequency of review varies from firm to firm

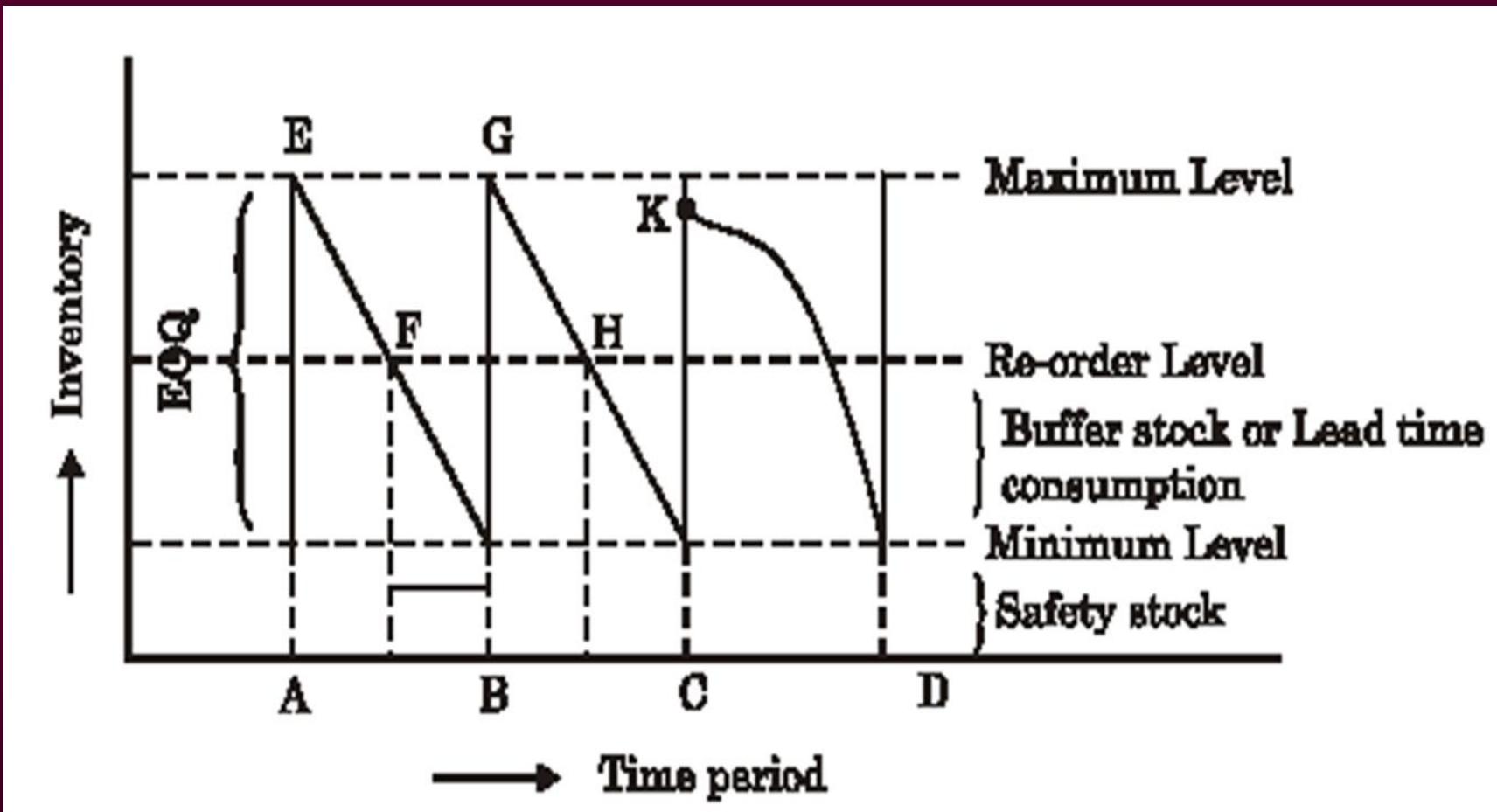
2. Q-System (Continuous Review System)

- Fixed quantity of material is ordered whenever the stock on hand reaches the reorder point
- When new assignments arrive, the total stock (existing + new arrival) shall be within the max and min limits.

Periodic Review System



Continuous Review System



Fixed Order Quantity System

Q model

Idle state
Waiting for demand

Demand Occurs
Units withdrawn from
inventory

Compute inventory position
Position=On hand +on-order
- backorder

Is position \leq
Reorder pt.?

Issue an order for exactly
Q units.

Fixed Time Period Reordering System

P model

Idle state
Waiting for Demand

Demand occurs
Unit withdrawn from
Inventory or backordered

Has review
Time arrived

Compute inventory
position

Compute order quantity to
Bring inventory up to required
level

Issue an order for the
Number of units needed

Basis for Setting the Order Point

- In the fixed order quantity system, the ordering process is triggered when the inventory level drops to a critical point, the order point
- This starts the lead time for the item.
- Lead time is the time to complete all activities associated with placing, filling and receiving the order.
- . . . more

Basis for Setting the Order Point

- During the lead time, customers continue to draw down the inventory
- It is during this period that the inventory is vulnerable to stockout (run out of inventory)
- Customer service level is the probability that a stockout will not occur during the lead time
- . . . more

Stock Levels

- **Buffer Stock:**
 - Stock which is used during the lead time
- **Safety stock:**
 - Stock used during the extension in lead time.
- **Reserve Stock:**
 - It meets the excess usage during normal lead time

Ways to compute:

- **Minimum stock level**= safety stock + reserve stock
- **Reorder point**=lead time in days X average usage
- **Reorder level**: safety stock+ reserve stock+ buffer stock
- **Maximum Stock Level**=
- **Min. level+ quantity order**
- **Average stock level**= **(minimum level+ maximum level)/2**
- **Buffer stock**= average lead time X average usage rate
- **Reorder level**= safety stock+ reserve stock+ buffer stock
- **Reserve stock**= average lead time x excess usage during lead time.

Some Realities of Inventory Planning

- ABC Classification
- VED Classification
- FSN Analysis

ABC Classification

- ABC ANALYSIS
 - It is a popular technique which is commonly used for control of inventories.
 - ABC stands for Always Better Control
 - It divides inventory into 3 categories based on their annual consumption value
 - A=10% B=20% C=70%(BASED ON ACV)

ABC Classification

- In this analysis, the classification of existing inventory is based on annual consumption and the annual value of the items.
- Hence we obtain the quantity of inventory item consumed during the year and multiply it by unit cost to obtain annual usage cost.
- The items are then arranged in the descending order of such annual usage cost. The analysis is carried out by drawing a graph based on the cumulative number of items and cumulative usage of consumption cost.

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- (a) **A-Item:** Very tight control, the items being of high value. The control need be exercised at higher level of authority.
 - (b) **B-Item:** Moderate control, the items being of moderate value. The control need be exercised at middle level of authority.
 - (c) **C-Item:** The items being of low value, the control can be exercised at gross root level of authority, *i.e.*, by respective user department managers.

VED Analysis

- . It is another inventory control technique
- . It is also classified according to the degree of usage.

V- Vital E- Essential D- Desirable

FSN Analysis

- In F-S-N analysis, items are classified according to their rate of consumption. The items are classified broadly into three groups: F – means Fast moving, S – means Slow moving, N – means Non-moving. The FSN analysis is conducted generally on the following basis:
- The last date of receipt of the items or the last date of the issue of items, whichever is later, is taken into account.
- The time period is usually calculated in terms of months or number of days and it pertains to the time elapsed seems the last movement was recorded.
- FSN analysis helps a company in identification of the following
 - a) The items to be considered to be “active” may be reviewed regularly on more frequent basis.
 - b) Items whose stocks at hand are higher as compared to their rates of consumption.
 - c) Non-moving items whose consumption is “nil” or almost in significant.

EXAMPLE

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

PART	TOTAL VALUE	% OF TOTAL VALUE	% OF TOTAL QUANTITY	% CUMMULATIVE
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	A 15.0
1	5,400	6.3	9.0	24.0
4	4,800	5.6	6.0	B 30.0
3	3,900	4.6	10.0	40.0
6	3,600	4.2	18.0	58.0
5	3,000	3.5	13.0	71.0
10	2,400	2.8	12.0	C 83.0
7	1,700	2.0	17.0	100.0
	<hr/> \$85,400			

CLASS	ITEMS	% OF TOTAL VALUE	% OF TOTAL QUANTITY
A	9, 8, 2	71.0	15.0
B	1, 4, 3	16.5	25.0
C	6, 5, 10, 7	12.5	60.0

Wrap-Up: World-Class Practice

- Inventory cycle is the central focus of independent demand inventory systems
- Production planning and control systems are changing to support lean inventory strategies
- Information systems electronically link supply chain

End of Chapter 14

