After this unit you should be able to answer following questions
A. Concept Questions B. Short notes

1. Inventory and Inventory management
2. Lead time
3. Reserve stock and safety stock
4. Reorder level
5. Economic order quantity
6. Trade off between total costs of inventory and order quantity
7. Customer Service levels
8. Average inventory
9. Selective Inventory Control
10. Pareto's rule
11. Quadrant technique
12. Non-Performing Asset
13. ABC analysis
14. Vendor managed Inventory
15. Inventory Turn Over Ratio
16. Review Period
17. Inventory functions
18. Inventory related costs

C. Section II descriptive questions [10 marks each questions]

1. What is inventory management? What costs are associated with inventory?
2. What is the economic order quantity in inventory problem? Discuss its basic square root formula along with assumptions and limitations
3. Explain how excessive inventories erode profit of the organization
4. What is the need of inventory in an organization? Explain the concept of EOQ and the expression for EOQ.
5. How does JIT influence the inventory management in an organization?
6. What are different functions of inventory? Emphasize disproportionate risks taken by different participants of a distribution channel?
7. Discuss **inventory** management
8. What is vendor managed inventory under JIT philosophy of procurement?
9. How do you decide inventory policy for an organization? What do you understand by asset turn over ratio?

10. Outline major differences in inventory control of manufacturing unit, raw material stores & field distribution warehouse.
11. Why is safety stock necessary? Establish its relationship with reorder level consumption rate & lead time
12. What is Inventory? Types of inventory, Functions of inventory, Some Inventory related definitions
13. What are fundamental approaches to managing Inventory?
14. What is Economic Order Quantity
15. What is Selective Inventory control? Explain various techniques of Selective Inventory control?
16. What is quadrant technique? How is this used for inventory management?
17. What are various Inventory management methods

INVENTORY MANAGEMENT

What is Inventory?

- Inventory is an unused asset, which lies in stock without participating in value adding process.
- Unused equipment, raw material, WIP and Finished goods, consumables, spare parts, bought out parts, tools and tackles, gauge and fixtures etc.
- In India 9 to 12 months of sales quantity lies in the form of Inventory [R/M, WIP, Bought out parts and Finished goods] as against a few days in Japan and a month in the US and Europe
- Huge amount of NPAs in our country, Banks, PSUs
- If look around in our facilities we find stocks lying unused for years catching dust and rust in the form of plant and equipment, raw material, WIP and Finished goods.
- In our country inventory is always viewed as asset [working capital], in fact, though it is called an asset, it is a big liability
- Reluctance to scrap useless inventory on time is one of the reasons why we carry huge stocks
- Inventory is biggest source of waste
- Japanese companies focused their attention on Inventory through now well known concept of 5S.

Symptoms of Poor Inventory Management

1. An increase in the number of backorders, indicating too many stock outs
2. Rising inventory investment

3. High customer turnover
4. An increasing number of cancelled orders
5. Insufficient storage space – too much inventory on hand
6. An increase in the volume and value of obsolete products
7. Low Inventory Turn Over Ratio [about 50 is a good ratio]
8. working capital problems

- **TYPES OF INVENTORY**
- **Manufacturing:** R/M, components, WIP, F/G. manufacturer's commitment to inventory is deep and duration is long.
- **MRO:** Maintenance, repairs and operating supplies.
- **Location inventory:** inventory at a fixed location
- **In transit inventory also known as pipeline inventory:** inventory in the process of transfer or under going transportation and waiting to be transported.
- **Wholesale inventory:** Wholesalers stock large quantities and sell in small quantities to retailers. Products with seasonal demand, products to satisfy assorted, small and urgent needs of retailers are stocked. As the product line expands risk of retailers increases and the risk becomes wider and deeper.
- **Retail inventory:** retailers stock variety of products to satisfy demand. But they push the volume backwards to wholesalers and reduce the depth of risk although the risk is wide

Functions of inventory

- Inventory overcomes geographical separation to integrates components into assembly. Inventories also make market assortments possible when manufacturing is separated by geography. Geographical separation has made manufacturing economical.
- De coupling from uncertainties of market, poor infrastructure
- Balancing supply and demand: seasonal production and year round consumption [agricultural products], seasonal consumption non seasonal production [woolen garments].
- Buffer uncertainties of lead time and demand
- Technical requirement of batch production

Costs of carrying inventories

- Capital cost

- Taxes, insurance
- Obsolescence
- Storage: handling, space, maintenance, security
- Opportunity cost
- Cost of bad quality

Economic order quantity

Assumptions of Wilson's lot size formula or Classical EOQ model

1. Demand is at a constant rate and continuous
2. Process is continuous
3. No constraints are imposed on quantities ordered, storage capacity, budget etc.
4. Replenishment is instantaneous
5. All costs are time invariant
6. No shortages are allowed
7. Quantity discounts are not considered

Salient features of EOQ model

- Replenishment Cycle – is the time between two replenishments
- Concept of average inventory – the amount of inventory that remains in stock on an average during replenishment cycle
- Inventory related total costs
- Ordering Cost and Carrying Costs – their relationship, when are they equal to each other?
- Follow the classroom discussion, refer to the graphics used

EOQ = $\sqrt{}$ 2AD/H…….when all the assumptions are valid

EOQ = $\sqrt{}$ 2AD/H(1-D/P)…….when instantaneous replenishment is not assumed

Total Inventory related costs at EOQ = $\sqrt{}$2ADH…….when all the assumptions are valid

Total Inventory related costs at EOQ = $\sqrt{}$ 2ADH(1-D/P)…….when instantaneous replenishment is not assumed

- Sensitivity Analysis: from the classroom analysis you may have noticed that when total costs are minimum, the Total Cost curve is nearly horizontal, indicating that for small changes may be made to the EOQ without upsetting the Total Cost. In short, inventory related total costs are not sensitive to changes in ordering quantity at EOQ level

Probabilistic Inventory Control Models – Impact of uncertainties of lead-time and demand on Re Order Level [ROL]

Determination of ROL:

Condition 1. when standard deviations of demand and or lead-time are expressed

R = Expected Demand during Lead-time + Buffer [Safety Stock]

$R = D\ L + K\ \sigma_{dl}$

$\sigma_{dl} = \sqrt{\text{Square of the } \sigma_d \text{ X L + Square of the } \sigma_l \text{ X square of D}}$

1. $\bar{D}\ \bar{L}$ is the lead-time demand
2. $K\ \sigma_{dl}$ is the buffer or safety stock
3. R is the re order level
4. $\bar{D}$ is the average demand rate
5. $\bar{L}$ is the average lead time
6. K is a factor obtainable from the normal distribution tables for the percentage of risk we are willing to take
7. σ_{dl} is standard deviation of lead-time demand
8. σ_d is standard deviation of demand
9. σ_l is standard deviation of lead-time

Condition 2.

- **a.** When the average lead-time, maximum lead-time and its probability of being maximum are given
- **b.** When average demand, maximum demand and its probability of being maximum are given

Calculate the lead-time consumption based on average values and find out the buffer based on probability calculations. Follow sums done in the class.

Limitations of Classical EOQ model

We have seen that Classical EOQ model made assumptions that are really not realistic. When the model is put to practical use we find that so many adjustments are needed to be made. Hence EOQ model is formulated under some limitations. If we are not conversant with these limitations, managerial application of this concept can be counter productive. Major limitations are some of the assumptions made

1. The demand or usage is predictable
2. The demand or usage is constant
3. The price of the item remains constant through out the procurement cycle

4. Materials in many processes are flow controlled i.e., materials move in pipe lines starting and stopping depending on operational requirements

If the concept of EOQ is applied without taking into account the limitations results can be disastrous.

Adjustments to EOQ

1. **Volume transportation rates**: EOQ model does not consider cost of transportation of goods from vendor's place to the purchaser. Transportation costs are sensitive to weight of consignment. If the quantity suggested by EOQ model does not get favorable transportation cost, summation of inventory cost and transportation cost may be detrimental to the interests of the organization. Hence we should always evaluate batch sizes from total cost perspective. In the traditional approach when inbound logistics are totally vendor's responsibility, the company never used to worry about this aspect. But as the concept is now enlightened and minimization of the costs in the supply chain is the focus, this aspect is very significant

Annual demand	2400 U
Unit value	$ 5.00
Inventory charge	20%
Ordering cost	$19.00 per order
EOQ	302 U
Shipment rate R1 [applicable to EOQ quantity = 300 U]	$1.00
Shipment rate R2 [applicable to 480 U quantity]	$.75

	Alternative 1 Q [EOQ] = 300	Alternative 1 Q = 480
Inventory carrying cost	$150	$240
Ordering cost	$152	$95

Transportation cost @ $1 per U	$2400	$1800
Total cost	$2702	$2135

2. Quantity discount: Impact of quantity discounts is seen if we look at the costs by doing summation of inventory costs and relief derived out of quantity discounts. Quantity discounts can upset the benefit of EOQ if we don't evaluate the situation from total costs perspective.

3. Other EOQ adjustments:

a. **Production lot size:** buyers EOQ and suppliers EBQ some times do not match. Then some adjustment will have to be made to the EOQ to make it practicable.
b. **Multiple item purchase**: when a combination of several products is sourced from a supplier, the impact of quantity discounts and transportation costs will be different from that for individual product. So adjustment is required to EOQ from the angle of total cost for the combination of products
c. **Limited capital**: budgetary allocations play a significant role in buying. The budget has to satisfy the requirement of entire product line. So the EOQ of various items requires adjustment
d. **Private trucking:** if the company uses private transport for procurement, getting a full truck becomes significant from cost perspective
e. **Standard package:** when a standard package is used for transportation, if EOQ suggests one and a half package then transporting half package becomes more expensive than transporting two packages with enhanced order quantity.

Some Inventory related definitions

1. Inventory policy:

Inventory policy enables inventory manager to take inventory related decisions

a. Answers to 5W-1H questions on inventory – about buying and controlling inventory
b. Positioning and placement of inventory – when the inventory is to be placed at distribution centers? Or it should be held at plant?
c. Inventory management strategy: if the inventory should be controlled at various distribution centers independently or it should be controlled centrally

2. Service levels: Service levels are defined by management. They indicate the performance objectives the inventory function is expected to achieve. Service levels are indicators of quality of logistics performed in a company

a. **Order cycle time:** time between receipt of a purchase order from a customer and dispatch of the shipment to his place. Order cycle time is perceived from the supplier's perspective as a measure of performance. When the customer looks at the same time dimension he considers as the time between placement of order and replenishment of stock. This concept from customer's view point is called lead-time.
b. **Case fill rate:** percentage of cases deliverable to a customer from the stock against the number of cases he ordered.
c. **Line fill rate:** the customer orders several products [lines] in various quantities in his order. The percentage of product lines fully delivered to the product lines ordered is the line fill rate.
d. **Order fill rate:** percentage of orders completely fulfilled to orders received is **order fill rate**

Case: customer xyz placed an order for 75 units of product A and 25 units of product B. he received 75 units of product A and 20 units of product B from suppliers stock within 2days from placement of order. Calculate various service levels

a. **Order cycle time: 2 days**
b. **Case fill rate:** no. of units ordered = 100, no. of units received = 95, **case fill rate = 95%**
c. **Line fill rate:** no. of product lines ordered = 2, no. of product lines received = 1,

Line fill rate = 50%

d. **Order fill rate**: no. of orders placed = 1, no. of orders fulfilled = 0,

Order fill rate = 0

Average inventory: It is the level of inventory on an average one finds in the organization. This concept includes cycle, safety stock and transit inventory components

Cycle inventory: is that part of average inventory that results from replenishment cycle. This is also known as base stock or lot size stock. The quantity ordered is known as order quantity or the base stock is ½ of order quantity.

Safety Stock Inventory: this component of average inventory takes care of short-term fluctuations in lead-time and consumption.

Reserve Stock: provides for abnormal consumption. It is a product of average lead-time and the difference between maximum consumption and average consumption. The term

Safety Stock is also used to denote that part of the stock which provides for abnormal lead-time. It is the product of average demand and the difference between maximum lead-time and average lead-time.

Transit Inventory: Stock that is moving or awaiting movement in transportation vehicles. This is also known is **Pipe Line Inventory.** This inventory is necessary for order replenishment. There are two aspects important from logistics point of view. One is that the transit inventory is an asset that is paid for but not usable. The second aspect is that we do not know exactly where the transport vehicle is located and when it is likely to arrive. Under the conditions of transfer of ownership at origin, transit inventory is to be treated as part of average inventory.

Selective Inventory control

ABC Analysis, VED Analysis, FSN Analysis, HML Analysis……make your own notes on the above concepts.

Classifying Inventory: we already know that inventory adds cost to the deliverables to the customer. Hence management of inventory becomes primary concern of managements everywhere. These management decisions with respect to inventory are expected to minimize the costs without sacrificing customer satisfaction. As an example, if we stock high value items to avoid stock out, the carrying costs would increase while stock out would result into loss of high value sale. From logistics perspective we need to strategize our stocking policy for maximizing benefit for the company.

To facilitate such management decisions, inventory classification becomes essential. This need to classify inventory was first recognized in 1951 by H. Ford Dicky in GE for the first time. He suggested that the inventory can be ranked as per sales volume, lead time, stock out cost etc. we now refer to this analysis as ABC which is used as a primary management tool for prioritization. Analysis rooted firmly in 80-20 rule or Pareto's rule.

As an example let us perform ABC Analysis on the following data obtained from a company from sales volume perspective

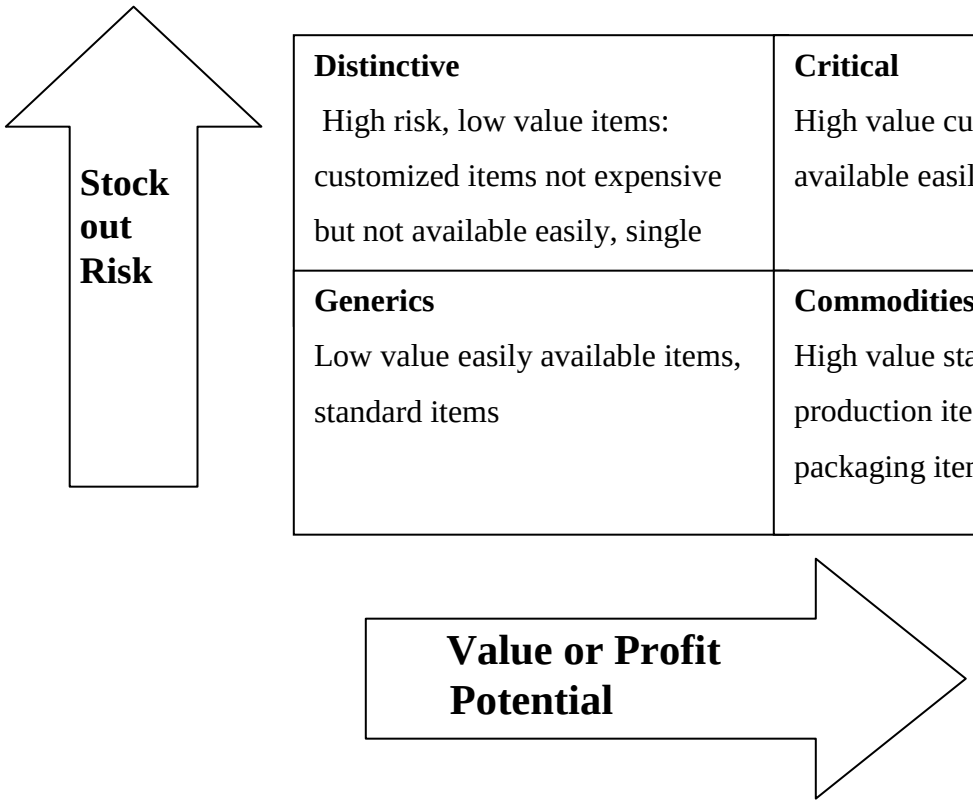
Item code	Annual sales volume Rs/-	Annual sales volume Rs/- in desc. order	Item codes in same order	Percentage of sales volume	Cum. sales	Percentage of items	Classif. catagory
001	200						
002	150						

003	200						
004	200						
005	6800						
006	500						
007	400						
008	1200						
009	200						
010	150						
	total						

Quadrant Technique

Results of ABC Analysis should be applied judiciously to a situation while deciding priorities. ABC Analysis analyses the items in stock from the perspective of cost or value alone. In running business other considerations also play significant roles. One such consideration is risk of stock-out. Standard items have a low risk of stock-out, as they are available with several suppliers with low lead times. Specifically engineered items being non-standard in nature run the risk of stock-out.

An approach keeping the above quadrant in mind is sound from logistical perspective.



ABC Analysis: What is 80 –20 rule or Pareto Analysis based on value ref. KKK for example and make your own notes in the class.

Inventory policies: Q System, P System, Single order system.

Which policy is suitable for what inventory? Pl. make your own notes in the class.

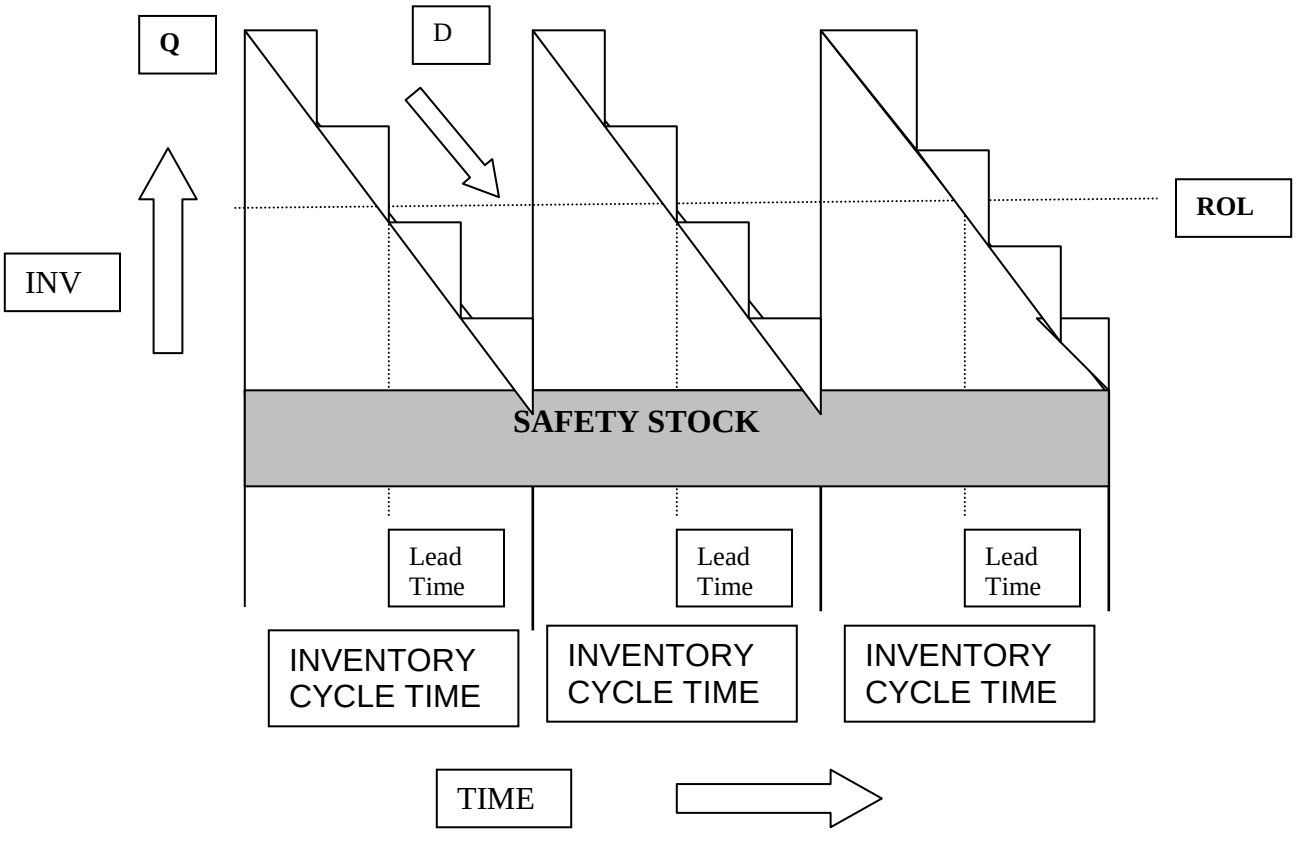
Fundamental approaches to managing Inventory

Traditional Inventory management has been deciding how much to order? And when to order? But challenges of today require inventory managers to find answer to the question 'where' to stock the material as this greatly influences customer satisfaction level.

High level of inventory indicates higher customer satisfaction level, but cost of high inventory is obviously high. Hence the modern challenge is high customer satisfaction at minimum inventory

Fixed Order Quantity Approach: 'Q' model

The above approach also called Q model signifies that the order quantity can be fixed at a level depending on demand, value and inventory related costs. A stock level called Re Order Level [ROL] is fixed, which triggers ordering. Re Order Level is the lead-time consumption or product of lead-time and demand rate during lead-time. When we follow this approach order quantity is fixed by calculating EOQ and ROL is fixed by calculating lead time consumption. Inventory cycles can be conceptualized by looking at the figure given below and drawn in the class.



Constant monitoring is the main disadvantage of this model

Salient Features of the above approach

1. Widely used technique
2. Requires constant monitoring of stock levels
3. Suitable for high value and critical items
4. Limited by the assumptions made – cost of in transit inventory, volume transportation rates, use of private carriage, etc

Min-Max Approach – a modification to EOQ model

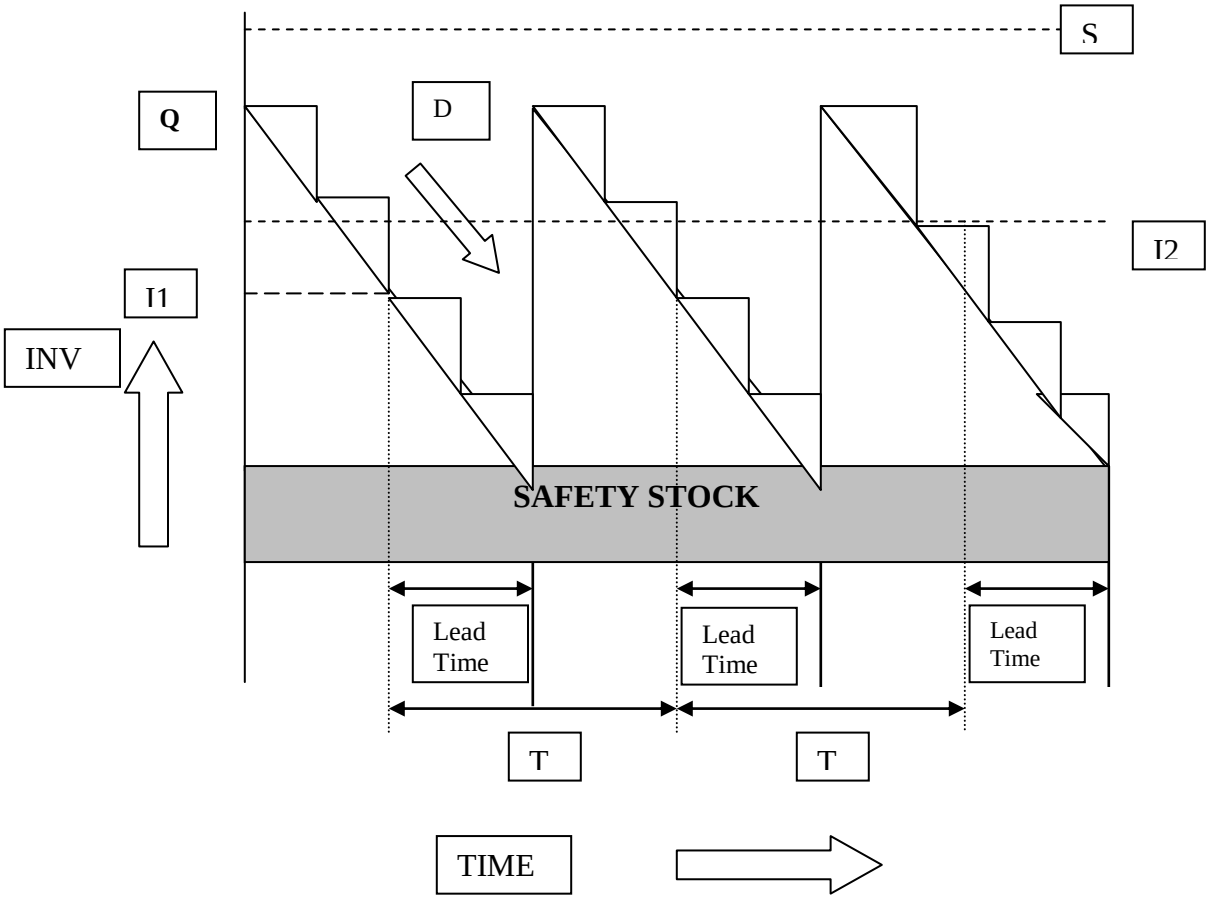
When we follow EOQ model, an order is released when ROL is reached. Here the assumption is stock depletion is at a specific rate 'D' during replenishment cycle. In reality when stock depletes in larger increments we may suddenly find that we are suddenly way below ROL. Min-Max Approach suggests that the actual order quantity should be the sum of EOQ and the difference between ROL and actual stock on hand at the time ROL occurs.

Fixed Order Interval Approach :'P' model

The time between two successive orders [order interval], T is fixed and the maximum stock that can be stored, S is also fixed as pre-requisites for this approach. The inventory level is not monitored as in 'Q' model continuously but checked in intervals of T fixed as a policy decision. On the fixed day as per 'T' the stock is checked and the difference between current stock level and maximum sock 'S' is calculated. This difference is the order quantity, which will be ordered immediately. The order quantity arrives after the lead-time. Next inventory check will be only after the interval 'T'.

Salient Features of the above approach

5. Widely used technique
6. Does not require constant monitoring of stock levels
7. Suitable for lower value and non critical items

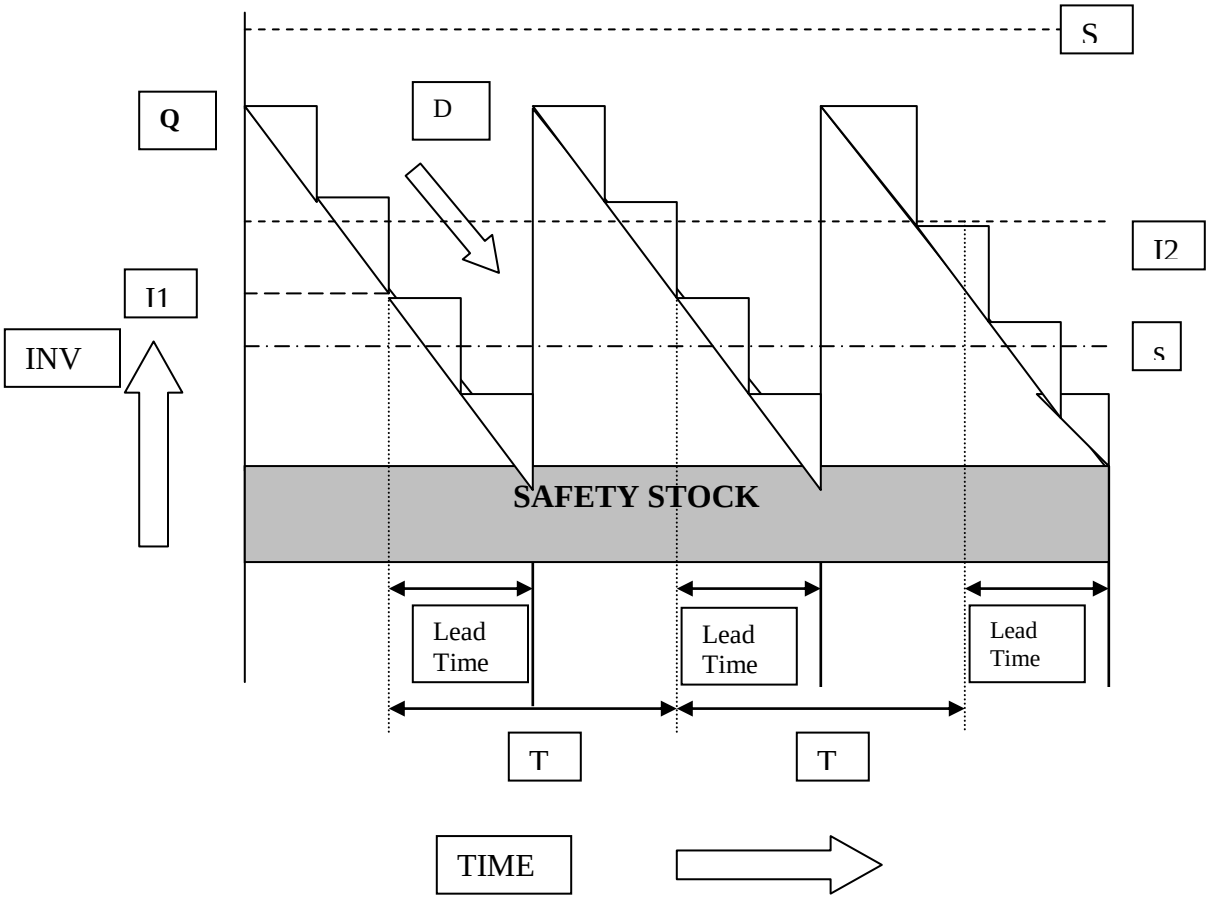


<u>Fixed Order Interval Approach :</u>'P' model, Optional Replenishment

As in the earlier case, 'T'& 'S' are fixed. But we also fix an additional parameter called 's' called minimum stock. Inventory is reviewed as per interval P, but order is placed only when current inventory level is less than s. If the current inventory level is more than 's' order is not placed and inventory will be reviewed only after T

Salient Features of the above approach

8. Widely used technique
9. Does not require constant monitoring of stock levels
10. Suitable for low value and non-critical items



Types of Inventory management methods

[Bowersox pages 287……]

Reactive methods or systems

Reactive methods or systems are those systems that respond to customer's pulls for products. The system responds only when there is pull. 'Q' model responds to 'D' from the market. When ROL is reached an order is placed for 'Q' items. Even though there is an element of planning here, this system is called pull, system.

Likewise ‘P’ model, when inventory is reviewed, based on the pull by the customer decides to place order which is the difference between predetermined max stock ‘S’ and current inventory level ‘I’ that is the result of pull.

Limitations of these systems are

1. It eliminates the logic of anticipatory inventory movements and remains restricted to pull. Any unexpected move by the customers upsets the system
2. It assumes that the quantities can be produced and stocked at production facilities waiting for dispatch without any constraint
3. It assumes that the quantities can be produced and stocked at supply facilities waiting for dispatch without any constraint
4. It assumes that performance cycle times are predictable & cycle lengths are independent
5. Customer demand patterns should be stable for the system to run smoothly
6. Handling multiple distribution centers is a limitation.
7. Performance cycles are considered to be independent of demand

In simplified terms the above limitations indicate problems of oversimplified demand patterns, unlimited production & supply facilities and lack of information flow across multiple facilities.

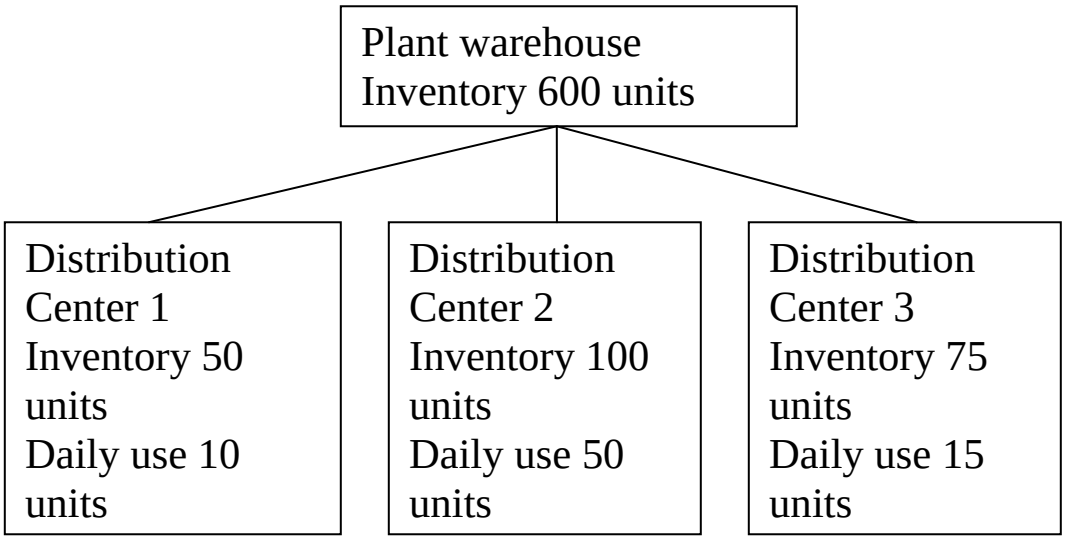
The above limitations pose great problems to inventory managers who try to overcome these limitations by manual overrides. But this further complicates the matters.

Planning methods [push or proactive methods] for inventory management

Planning methods overcome some
of the above drawbacks of reactive methods.

Fair Share Allocation

Inventory planners decide to allocate an amount of inventory to a ware house based on the past consumption pattern of that particular facility from the available inventory volume at the source.



In the above example, in the plant warehouse the inventory is 600 units. If we decide to keep aside 100 units and allocate the balance, the allocation is done keeping the daily use performance pattern of the distribution centers. The methodology as given below.

Let A be the amount of inventory available for allocation.

Let I be the inventory in distribution center.

Let D be the daily demand,

Then a common day's supply, DS, for distribution center inventories is,

$$DS = \frac{A + \sum I}{\sum D}$$

$$DS = \frac{500 + \sum 50+100+75}{\sum 10+50+15}$$

9.67days.

Now amount of inventory allocated to distribution center 1 is

[9.67 – 50/10]/10 = 4.67X10 = 46.7 units, say 47 units.

Similarly we can find allocations for distribution centers 2 & 3. We get 383 & 70 units.

Fair share allocation method doesn't take into account performance cycle times, EOQ & safety stock considerations.

DRP approach is discussed earlier.

Other approaches to inventory management

Just In Time

[Bowersox pages 490…….]

The time-based approach to inventory management came into focus when Toyota Motors Company came out with the concept of kanban in 1950. This lead to the dramatic reduction in WIP quantities tying the inventory closely to the demand from subsequent process or internal customer. Kanban is conceptually a two-bin system, a signal being raised to warrant replenishment.

JIT approach became a modern production system seeking to implant concept of stockless production. JIT embraced a variety of manufacturing concepts like reduced lot sizes, quick switch over [SMED], load leveling [response to tact time], group technology, statistical process control [control charts], preventive maintenance and quality circles. American disappointment with the attempts to incorporate Japanese methods lead to other concepts like DRP that we have discussed earlier.

QR, CR, AR, response-based techniques

Quick response

When a retailer places an order for replenishment, the supplier with the help of EDI [Electronic data interchange] finalizes the delivery details and communicates them to the customer in advance. This facilitates scheduling labor and other facilities. This reduces inventories as uncertainties are reduced and total cost resulting into better performance.

Continuous replenishment strategy

Also known as **vendor managed inventory.** This approach eliminates the need for placing an order. A supply chain relationship is established that ensures continuous replenishment of stock at customers place by the vendor.

There are two basic needs in CR

1. Effective communication system to provide key information between customer and supplier

2. Sufficiently large volumes to make transportation viable

Finally customer should honor the shipment from the supplier for payment

Automatic or profile Replenishment or AR

AR enables the supplier to anticipate the customers' requirement in advance to make replenishment. The responsibility for inventory management is placed squarely on the supplier. There should be information flow between customer & supplier that makes inventory visibility possible. While this takes away the inventory management from the customer and gives it to the supplier, supplier gets the benefit of inventory visibility and more effective management to reduce total costs