Date [redacted]

INVENTORY

Inventory is the stock of any item or resources that are used in any organisation It may be defined as stock in hand at a given time and it may be held for the purpose of later use or sale.

It is a usable but idle resource having an economic value and it may include Raw material, work in process inventory, semi-finished inventory or finished goods

Imp * **Purpose of Inventory** (15)

1. It helps in smooth and continuous running of Production system.
2. Helps to meet the variation in demand pattern.
3. It provides a safe gaud against the variation in raw material delivery time.
4. Bulk purchasing may give quantity discount.
5. Gives better service level to the customers

Inventory Cost

1. Purchase or Nominal Cost
2. Ordering or Setup Cost: Bringing to the Produc^{n} system
3. Holding or Carrying Cost : Storing & Holding
4. Shortage or Back Order or Stock Out Cost.

1 **Purchase or Nominal Cost. (P C)**

It is the cost of purchasing Inventory item and it depends upon the quantity or Volume to be purchased

P.C = No. of Units purchased x Cost per unit

Ordering or Set-up Cost (O.C)

→ It is the cost associated with bringing Inventory item to the production system and it includes cost associated with processing and chasing of Purchased order, tendering cost, quality inspection cost, transportation cost etc.

It is also Known as Procurement Cost.

→ When the Units are produced internally, then the cost associated with bringing production system again into play is called Set-Up Cost.

It includes schedule chart preparation cost, labour and raw material, arrangement cost, Maintenance cost of Machines etc.

O.C = No. of Orders × cost/order

Holding or Carrying Cost (H.C) (16)

- It is the cost spend in storing and keeping Inventory items within production system.

- It includes storage cost, Damage & Depreciation cost, Handling cost, Insuarance cost, Logged Up capital interest etc.

- It depends upon the quantity to be stored and the period for which it is stored.

H.C = Average Inventory cost × Holding cost/Unit

4 Shortage Cost (S.C)

- Shortage simply means absence of Inventory items and the cost associated with not serving the customer is called shortage cost

S.C = No. of Units short × shortage cost/unit

- only used for Large cost (like Mercedees, Benz) and where Holding cost is more

Inventory Classification (17)

1. Transit or Pipeline or Movement Inventory

Those inventory items which are in transportation can not provide service and that inventory item is called Transit or Pipeline or Movement Inventory

2. Buffer or Safety Stock Inventory

It is the minimum amount of Inventory item i.e kept for protecting against the fluctuation in Demand and Lead time.

These are not used under normal working cordition and used only to prevent stock out during adverse situation.

Adverse Situation: Actual demand is more than the Average demand or Actual Lead time is more than the Average lead time

Lead Time :-

Lead time is the time gap between placing an order and the inventory item in hand so that it can be consume.

3 Seasonal Inventory :-

These inventories are build-up to meet the future demand of a product due to seasonal variation

4. Anticipation Inventory :- (18)

These inventory items are build up due to Anticipated demand in future like vig selling forecast, Govt. Policy change, strike or plant shutdown, price high etc.

Characteristics of Inventory

A Dependent & Independent Demand Item

1. Dependent Demand Item

The need for any one item is a direct result of the lead for some other item, usually of a higher level of which it becomes a part

2 Independent Demand Item

These are those items whose demand is not directly linked or related to any other item.

B. Inventory Review System.

1. Q- System or Fixed Order System or Re-orde Point system or Two bin system

→ In this system, a reorder point is fixed and as Inventory level reaches that point a fresh order for a fixed quantity is placed at that time. In this, size of order is fixed while period of order is not fixed.

2. P- System or Periodic Review System or Fixed Period System

→ In this system, Inventory is reviewed after a fixed period of time and fresh orders are placed at that time. In this, Period of order is fixed while size of order is not fixed.

3 S-S system: Combination of Q & P- system

→ Now-a-days S-S system are used.

* Q-system is best over S-system as it gives a warning before stock out

(19)

C. Probalistic And Deterministic Models.

1. Deteministic Model

In these models, Demand & Lead time are constant & so we neednot to carry safety of buffer stock

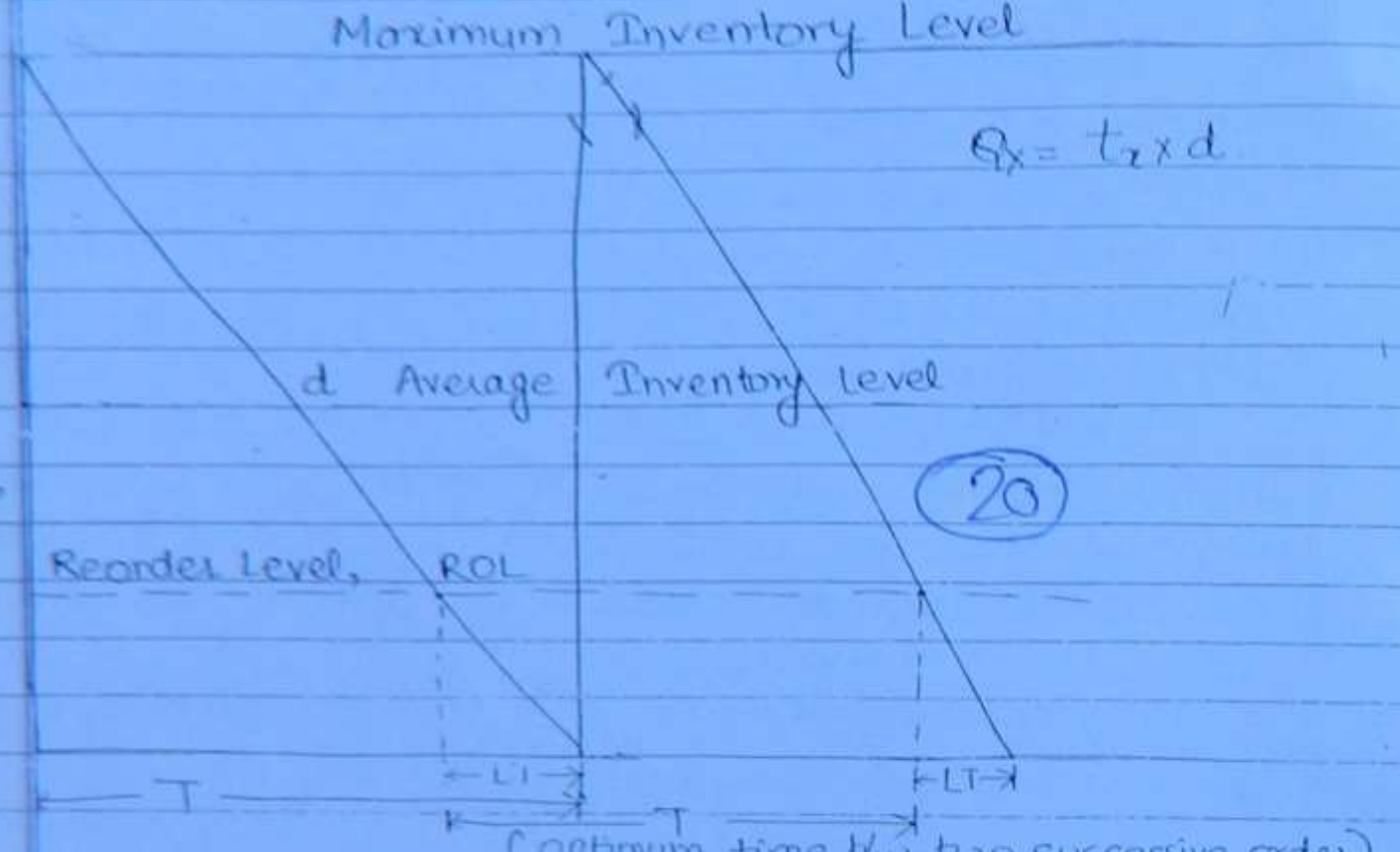
2. Probalistic Model

In these models, demand & Lead time are variable and they need not to be constant so, we need to carry safety or Buffer stock to prevent the stock out.

C.1* Deterministic Model

Economic Order Quantity [EOQ] or Harris Wilson Model

MODEL #1



D: Annual Demand of Inventory Item (Units/Year)
Q: Quantity to be ordered at each order point (Units/order)
C: Unit price of Inventory item (Rs/Unit)
C_o: Cost of placing an order (Rs/order)
C_h: Cost of Holding inventory of an item for 1 year (Rs/Unit/Year)

Total Annual Cost: Purchase cost + ordering cost + Holding cost

P.C = D.C

O.C = No. of orders × Cost/order = $D/Q \times C_o$

H.C = Average Inventory × Holding Cost/Unit/Year for the Year = $\frac{Q}{2} \times C_h$

Date :

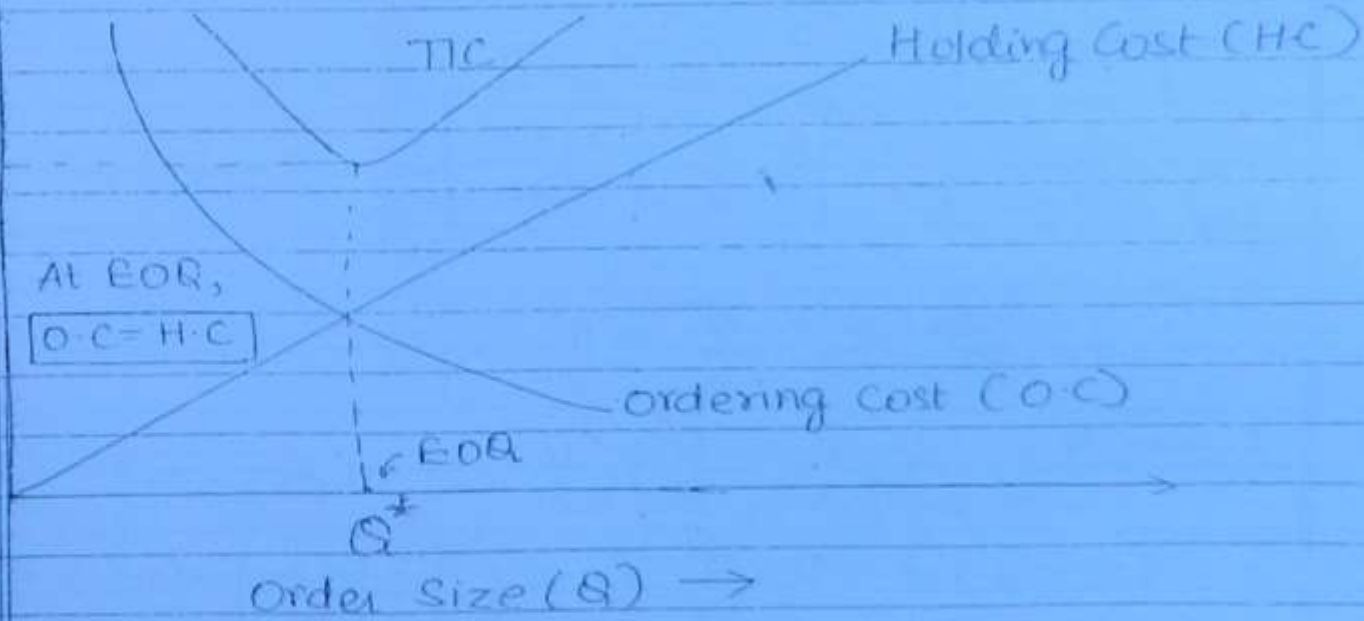
Total Annual Cost $= D \cdot C + \frac{D}{Q} \cdot C_o + \frac{Q}{2} \cdot C_h$

Q is only Variable, one ↑ and another dec ↓
so, the summation of O·C & H·C should be minimum so that Total Annual cost minimum.
Q → Order Size

Total Inventory Cost (TIC) = O·C + H·C
or Variable

$$\boxed{TIC(Q) = \frac{D}{Q} \cdot C_o + \frac{Q}{2} \cdot C_h}$$

By Graphical Method. (21)



The Order quantity (Q^*) at which H·C = O·C and Total Inventory Cost is minimum is known as Economic Order Quantity.

At EOQ, O·C = H·C

$$\frac{D}{Q^*} C_o = \frac{Q^*}{2} \cdot C_h$$

$$Q^{*2} = \frac{2DC_o}{C_h}$$

$$\boxed{Q^* = \sqrt{\frac{2DC_o}{C_h}}}$$

2. By Analytical method. (22)

$$TIC(Q) = \frac{D}{Q} \cdot C_o + \frac{Q}{2} \cdot C_h$$

$$\frac{d}{dQ}[TIC(Q)] = 0, \text{ Minimum if } \frac{d^2}{dQ^2} TIC(Q) = +ve$$

$$\frac{C_h}{2} - \frac{D}{Q^{*2}} \cdot C_o = 0$$

$$\boxed{Q^* = \sqrt{\frac{2DC_o}{C_h}}}$$

$$TIC = \frac{D}{Q^*} \cdot C_o + \frac{Q^*}{2} \cdot C_h$$

At EOQ = $\frac{D}{Q^*} C_o = \frac{Q^*}{2} \cdot C_h$

$$TIC(Q^*) = 2 \cdot \frac{Q^*}{2} \cdot C_h = \left(\sqrt{\frac{2DC_o}{C_h}}\right) \cdot C_h$$

$$\boxed{TIC(Q^*) = \sqrt{2DC_oC_h}}$$

C.1.b ROBUSTNESS OR MODEL SENSITIVITY

Date :

It is defined as the ratio of Total Inventory cost at any point to the minimum Inventory cost corresponding to EOQ $= \frac{TIC(Q)}{TIC(Q^*)}$

$\boxed{Q = K \cdot Q^*}$; K less than or greater than one.
(20% less, K = 0.8) (20% more, K = 1.2)

$$TIC(Q^*) = \frac{D}{Q^*} \cdot C_o + \frac{Q^*}{2} C_h$$

At EOQ, $\frac{D}{Q^*} \cdot C_o = \frac{Q^*}{2} \cdot C_h$

$$\boxed{TIC(Q^*) = 2 \frac{D}{Q^*} \cdot C_o} \rightarrow (A) \quad (23)$$

At Any other Point, $TIC(Q) = \frac{D}{Q} C_o + \frac{Q}{2} \cdot C_h$

Now, putting, $Q = K \cdot Q^*$

$$TIC(Q) = \frac{D}{K \cdot Q^*} C_o + \frac{K \cdot Q^*}{2} C_h$$

$$= \frac{D}{K \cdot Q^*} \cdot C_o + K \cdot \frac{D}{Q^*} C_o$$

$$\boxed{TIC(Q) = \frac{D}{Q^*} C_o \left[\frac{1}{K} + K\right]} \rightarrow (B)$$

$B \div A$: $* \boxed{\frac{TIC(Q)}{TIC(Q^*)} = \frac{1}{2}\left[\frac{1}{K} + K\right]} *$

$TIC(Q) \geq TIC(Q^*)$ and it will be equal when $K = 1$ i.e $Q = Q^*$

Date :

Formulae :-

1. Reorder Level (R.O.L)

ROL = Lead time x demand rate (Units same)

$$\boxed{ROL = LT \times d}$$

2. Optimum Nos of Order per year

$$\boxed{N^* = \frac{D}{Q^*}} \quad \frac{\text{Units/Year}}{\text{Units/order}}, \quad \frac{\text{order}}{\text{Year}}$$

3. Optimum time between two successive order

$$\boxed{T^* = \frac{Q^*}{D} = \frac{1}{N^*}} \quad \frac{\text{Year}}{\text{order}}$$

(24)

4. When holding cost is given in terms of Holding Rate of Unit purchase price.

C = Rs 50/unit, C_h = 10% of C/annum.

$C_h = 0.1 \times 50 =$ Rs 5/Unit/year

i = %/month (x12 /Year)

v. Imp * MODEL #2 (IES: 12)

EOQ with Price Break or Quantity Discount

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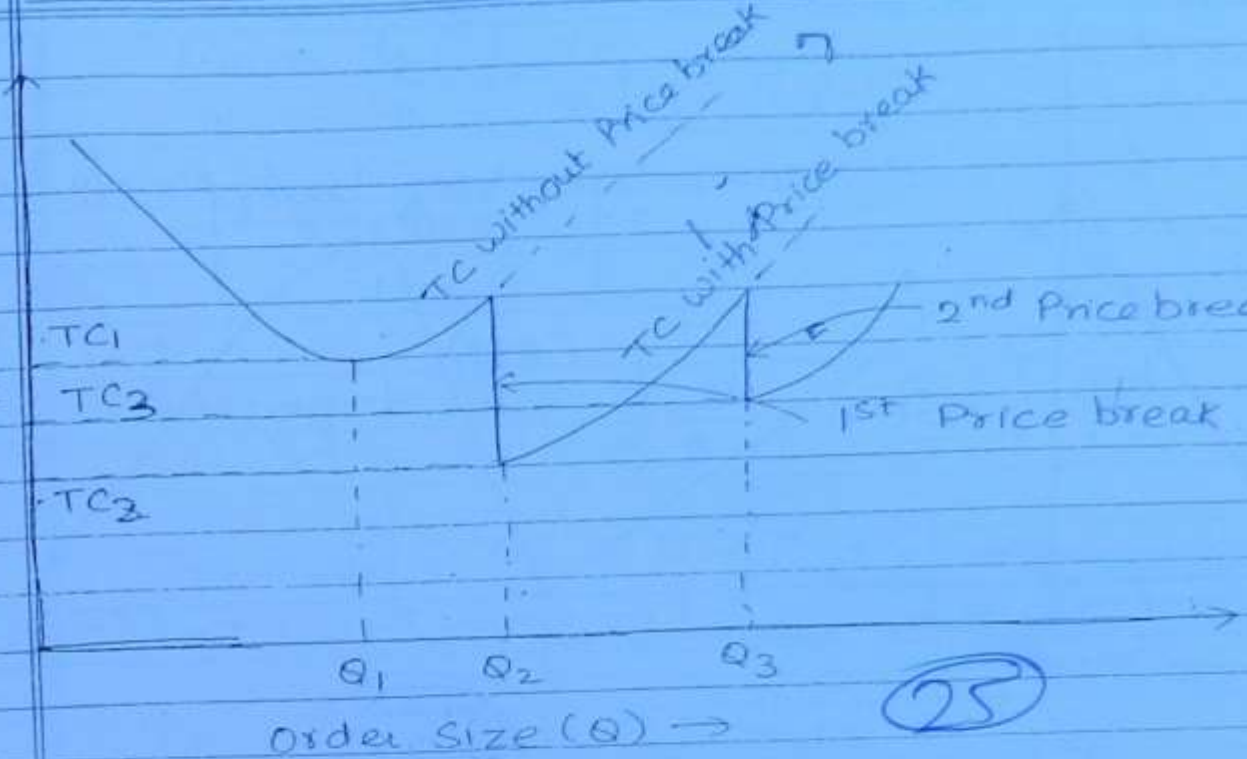
Date :



25

Total Cost = Purchase Cost + Ordering cost + Holding cost

$$= D \cdot C + \frac{D}{Q} \cdot C_o + \frac{Q}{2} \cdot C_h$$

In some situations discount are offered on unit purchase price of inventory and these discounts take the form of price break. Discount is always offered on Unit Purchase Price of Inventory. So, in these Models, Purchasing cost is also considered along with Ordering and Holding cost in determining Best order size.

In this Model, First of all Feasible EOQ is computed and then total Cost is calculated at Feasible EOQ and the next Price break points. The order size at which Total Cost comes out to be Minimum is the Best Order Size.

MODEL #3

PRODUCTION OR BUILD-UP MODEL

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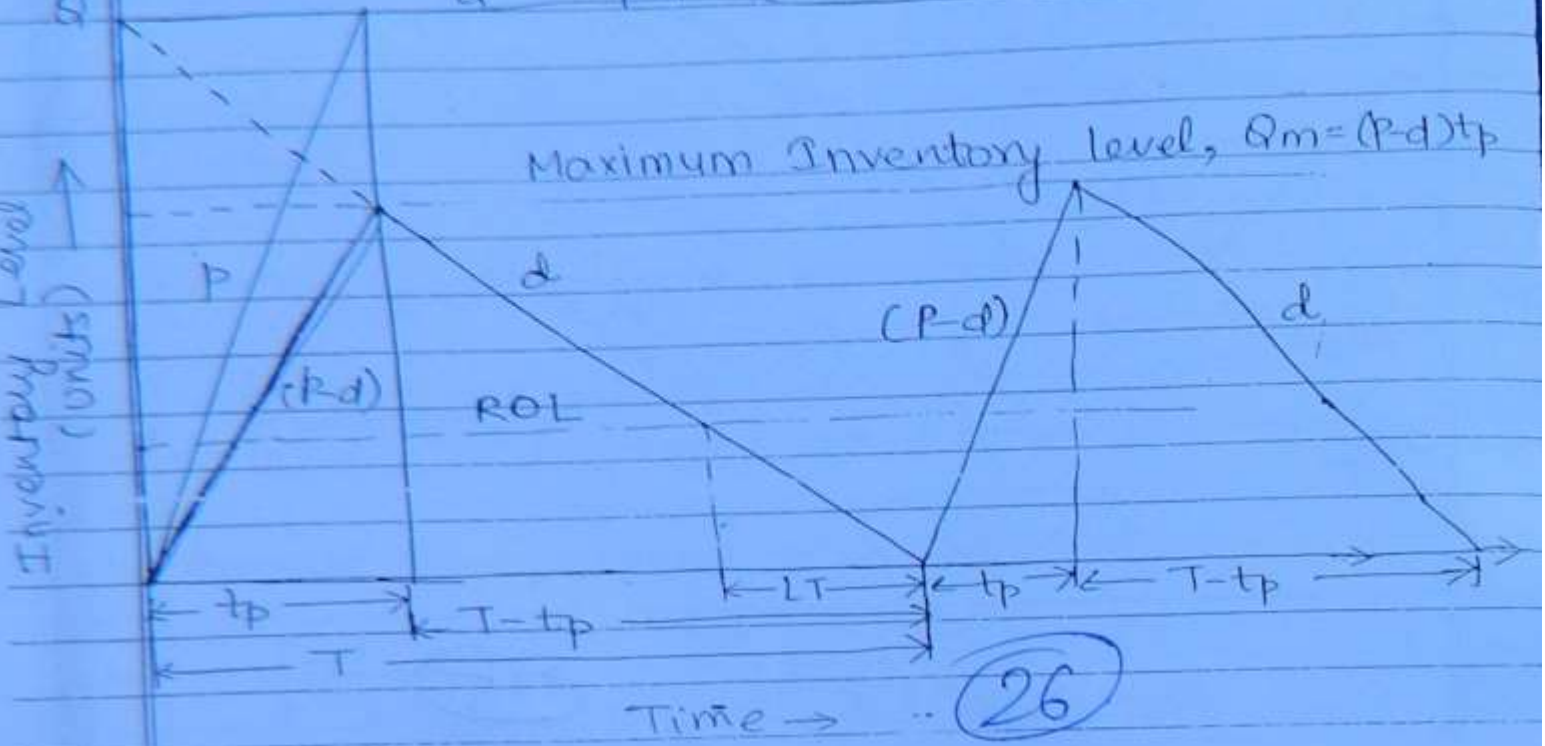
Date :

$Q = t_p \cdot P = T \times d$



This Model is similar to first Model EOQ, the only difference that Inventory build up is gradual rather than instantaneous.

If P: Production rate, d: consumption/demand rate

Then, Total Inventory cycle, T is divided into two parts :-

a) t_p (Production or Manufacturing time)
It is the time during which there is production and inventory builds up at the rate of (P-d) units per unit time

b) $T - t_p$ (I
It is the time during which there is no ~~consumpti~~ production and only consumption with a demand rate of 'd' units per unit time

Date

$$Q_m = t_p(P-d)$$

$$Q = t_p \cdot P \Rightarrow \boxed{t_p = Q/P}$$

$$\boxed{Q_m = \frac{Q(P-d)}{P}}$$

$$Q_{average} = \frac{\text{Area of } \Delta}{\text{Base of } \Delta} = \frac{\frac{1}{2} \times T \times Q_m}{T} = \frac{Q_m}{2}$$

$$\boxed{Q_{average} = \frac{Q_m}{2} = \frac{Q}{2}\left(\frac{P-d}{P}\right)} \quad (27)$$

$$TIC(Q) = O \cdot C + H \cdot C$$

$$\boxed{TTC(Q) = \frac{D}{Q} \times C_o + \frac{Q}{2}\left(\frac{P-d}{P}\right) \times C_h}$$

$$\frac{dTIC(Q)}{dQ} = 0$$

$$\frac{1}{2}\left(\frac{P-d}{P}\right) \times C_h - \frac{D}{Q^2} C_o = 0$$

$$Q^* = \sqrt{\frac{2DC_o}{C_h}\left(\frac{P}{P-d}\right)}$$

$$\boxed{Q^* = \sqrt{\frac{2DC_o}{C_h}} \cdot \sqrt{\frac{P}{P-d}}} \Rightarrow \text{Production factor} > 1.$$

At EOQ, $\Rightarrow O \cdot C = H \cdot C$

$$\boxed{TIC^* = \sqrt{2DC_oC_h\left(\frac{P-d}{P}\right)}} < 1 \text{ (compare to model EOQ#1)}$$

MODEL #4

Shortage or Back Order

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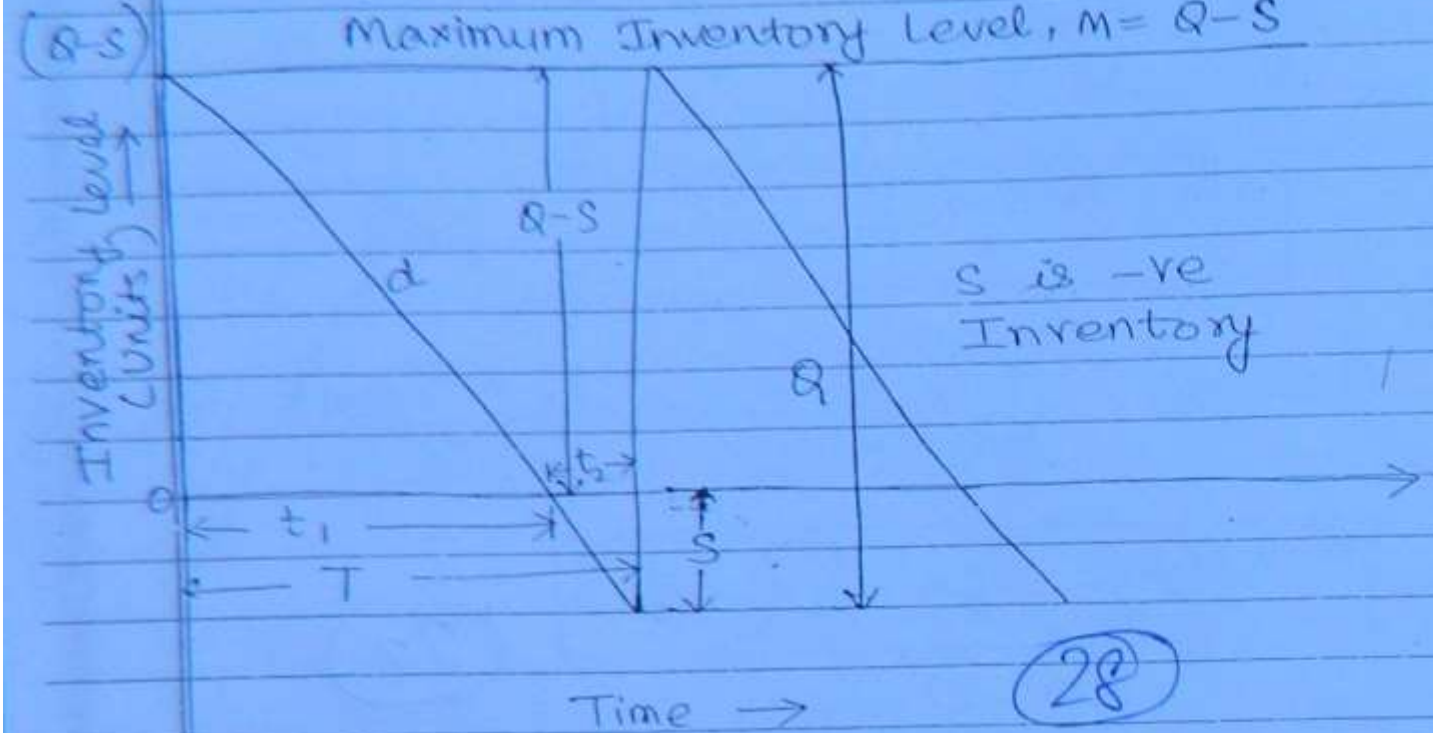


28

This model is extension of First Model EOQ. The only difference that here shortages are allowed.

Planned Shortage or Back order is the situation in which a customer places an order and finds that inventory is out of stock. When the customer wait for the next shipment to arrive to get his order fullfilled.

Shortages also have certain advantages :-

1. Shortage results in a decrease net stock in inventory thus reducing holding cost
2. Shortages increases the cycle time & thus lowers the ordering cost

S: No. of Units back ordered

C_b: Back Order or Shortage cost Per Unit/bo/year (Rs/Unit/Year)

$$TIC(Q) = O.C + H.C + \text{shortage cost}$$

$$O.C = \frac{D}{Q} \times C_o$$

$$H.C = \frac{(Q-S)^2}{2Q} \times C_h$$

$$S.C = \frac{S^2}{2Q} \times C_b$$

$$\boxed{TIC(Q) = \frac{D}{Q} \times C_o + \frac{(Q-S)^2}{2Q} \times C_h + \frac{S^2}{2Q} \times C_b}$$

from Dia. $\left(\frac{Q-S}{2}\right) \times C_h \times t_1$ (29)

$$Q - S = t_1 \times d$$

$$Q = Td$$

$$t_1 = \frac{(Q-S)}{Q} \times T$$

$$\frac{(Q-S)^2}{2Q} \times C_h \times T$$

$$\boxed{Q^* = \sqrt{\frac{2DC_o}{C_h}\left(\frac{C_h + C_b}{C_b}\right)}}$$

At EOQ, $\boxed{OC = H.C + S.C}$

Put, $C_b = \infty$, to make it EOQ Model # 1. that's why we don't kept shortage coz shortage cost is very high in model # 1.

$$\boxed{TIC^* = \sqrt{2DC_oC_h\left(\frac{C_b}{C_h + C_b}\right)}}$$

Date :

Optimum No. of Units backordered, $S^* = ?$

First differenciate $\ell = 0$

$$\left(\frac{Q^* - S^*}{2}\right) C_h = \frac{S^*}{2} \cdot C_b$$

$$\frac{Q^* - S^*}{S^*} = \frac{C_b}{C_h}$$

$$\frac{Q^*}{S^*} = \frac{C_b + C_h}{C_h} \quad (36)$$

$$\boxed{S^* = Q^* \left(\frac{C_h}{C_b + C_h}\right)}$$

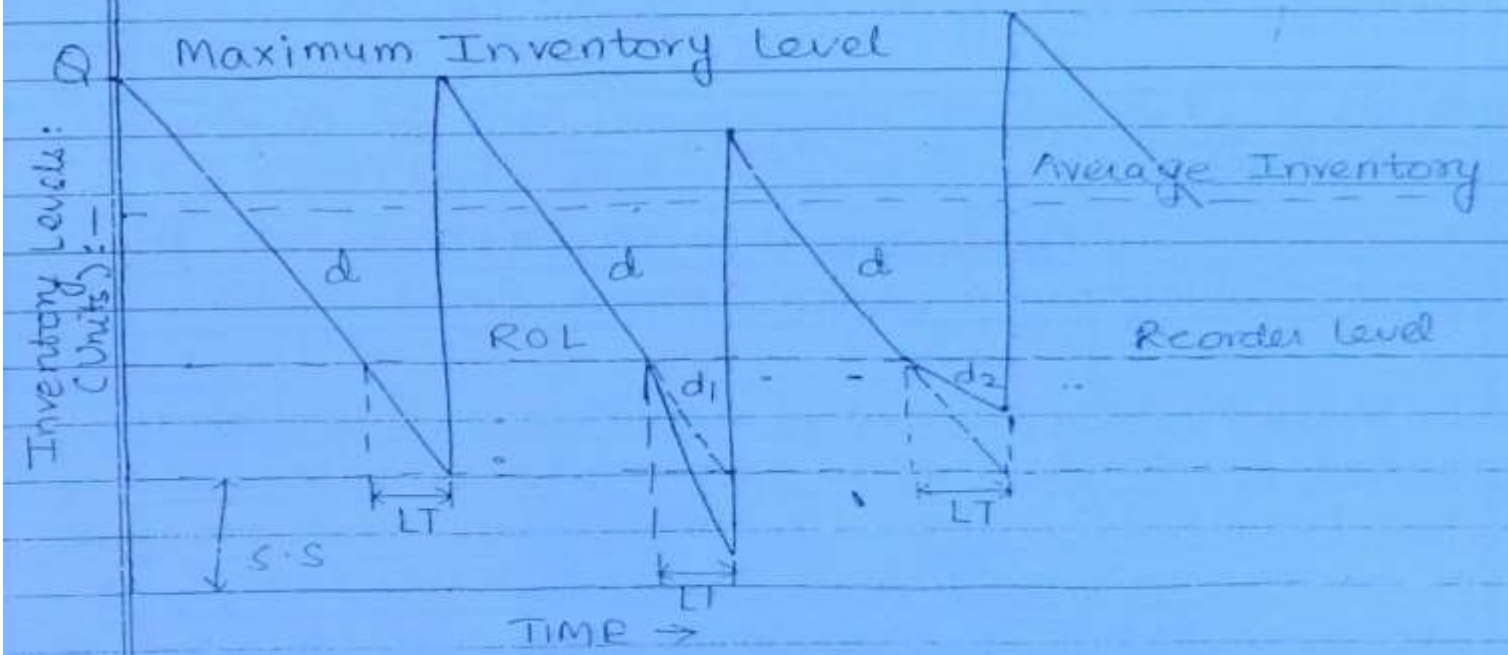
and Maximum Inventory level, $M^* = Q^* = S^*$

$$\boxed{M^* = Q^* \left(\frac{C_b}{C_h + C_b}\right)}$$

C.2 PROBALISTIC MODEL

In these Models, Demand & lead time fluctuates and they need not to be constant.
In these Models we carry safety or Buffer stock in order to prevent stock out during unfavourable conditions.

(31)



Factors Encouraging Higher Safety Stock

1. When demand rate vaiation is more
2. When Lead time fluctuates
3. When Inventory Carrying Cost is less and is of not much concerned
4. When stock out cost or loss due to stock out is very high.
5. When No. of orders in a year are more.
6. To provide better service level to the customers at a short notice.

Reorder Level = Average demand during Lead Time + Safety Stock

- ROL = ADDLT + SS
- ROL = LT x d + SS

(32)

$d_1 > d$

Average Inventory = $\frac{EOQ}{2} + S.S$ | $d_2 < d$

safety stock Cost = S*S x C_h

MODEL #1

Static Inventory Model or Demand Profit Model.

In these Models, Demand is uncertain and decision is based on single order. This Model is applicable for perishable items like vegetables, fruits, flower etc or for those items which becomes outdated very fast like newspaper, faishon goods items etc. Also known as Newspaper boy problem or Christmas Tree Problem.

In these models, Either replacement orders are not possible or become very expensive.

D: Demand of Inventory Item
S: Supply or quantity to be ordered.
p: Profit per unit
l: loss per unit

1. Overdemand / Under Supply
   D > S P(D-S)

2) over supply / Under demand.

$S > D$ $\quad\quad$ $l(S-D)$

Then choose the Order Quantity 'S' such that

$$P(S-1) < \frac{P}{P+l} \leq P(S)$$

(33)

P(S-1) is the cummulative probability of the demand for (S-1) Units and P(S) is the cummulative probabilty of the demand for 'S' units.

$$P(S-1) < \frac{C_b}{C_b+C_h} \leq P(S)$$

MODEL # 2

Serore Level or Safety Stock

- When stock out cost is not known
- In these Models, the amount of Safety stock is kept according to the level of Service, Management aims to achieve

$$\text{Service Level} = \frac{\text{NO. of Units supplied w/o delay}}{\text{Total NO. of Units demanded}}$$

Service level = In number = 0 - 1 (in fraction)

In Percentage = 0 - 100%

95% Service level would mean that 95% of the customers order are fullfilled and 5% of the orders are rejected due to stock out during lead Time.

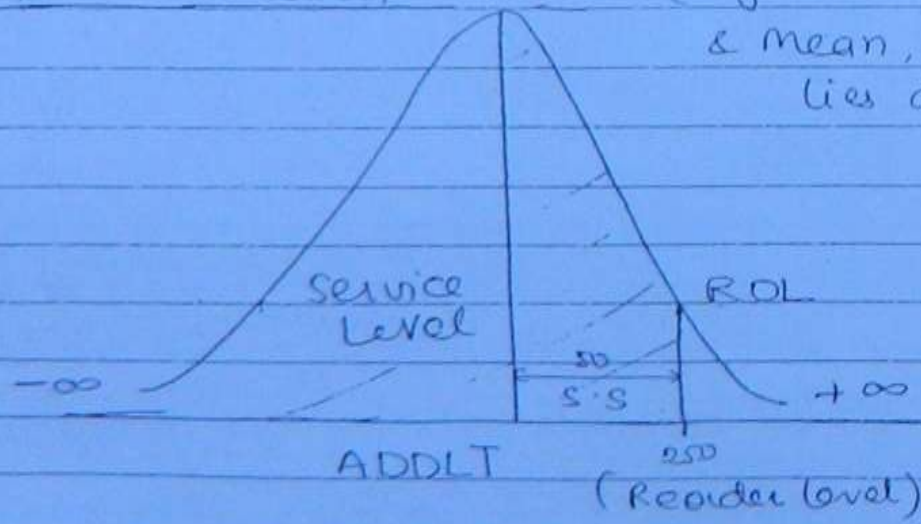
When the demand during lead Time may be approximated by a normal distribution curve with a certain mean. ($\bar{X}$ or μ) and standard deviation (σ). Then, the Reorder level is given by:-

$$\boxed{ROL(X) = \bar{X} = Z \cdot \sigma}$$ (3)

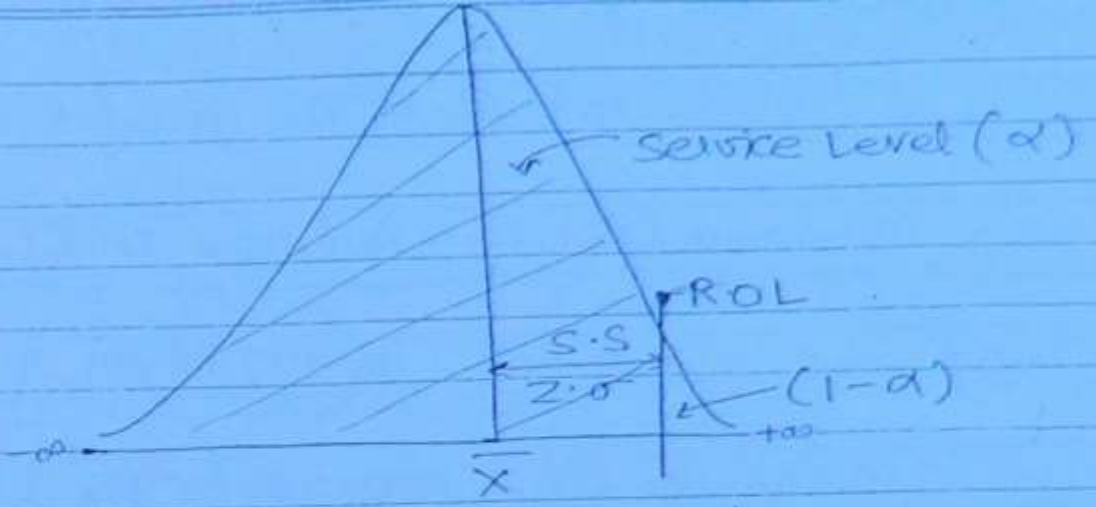
Where, Z is the standard Normal Variante whose value depends upon the level of service, management wants to achieve.

Z	Service Level (%)	
0.84	80%	
* 1.28	90%	
1.645	95%	→ Standard Value
2.33	99%	

Normal Distribution Curve :- (Symmetric about Y axis & Mean, Mode & Meadian lies at one Point).

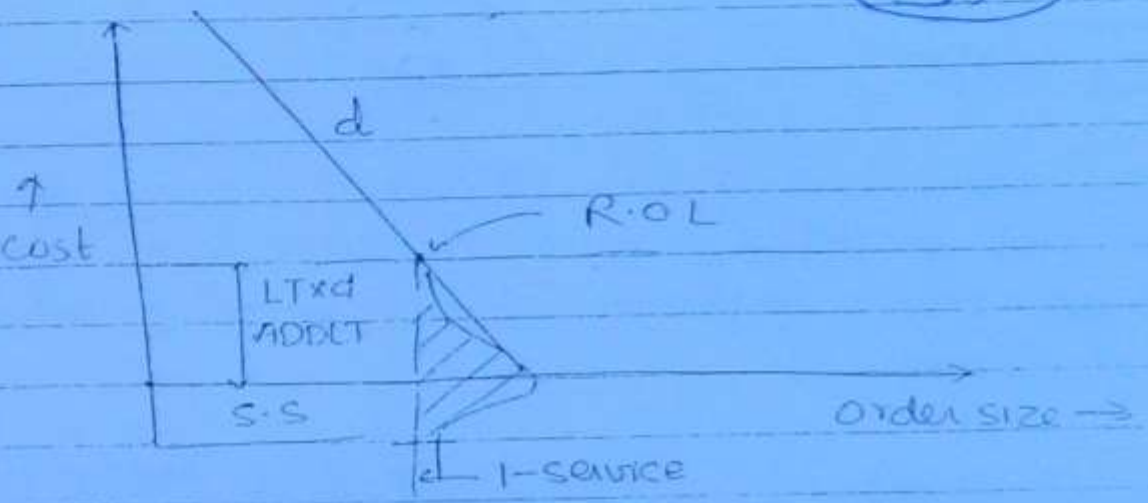


$\bar{X}$ =



ADDLT = LT x d

35



Service level shows in EOQ Model # 1

(S.S) Safety stock = Z · σ

$$X = \bar{X} + Z \cdot \sigma$$

$\bar{X}$ → ADDLT = LT x d.

For a half cycle, standard deviation, σ_1
For next half, standard deviation, σ_2

$$\sigma^2 = \sigma_1^2 + \sigma_2^2 \qquad \sigma = \sqrt{\sigma_1^2 + \sigma_2^2}$$

$$S.S = Z.\sigma$$

Date :

a) If Demands are given: 208, 242, 216, 233, 211

S.S = 242 - Average of the given demands

SS = Maximum DDLT − Average DDLT

b) If Lead time are given: 10, 14, 13, 19, 9

S.S = (Maximum LT − Average LT) x d

Inventory Controls

(36)

Inventory items are given different priority for their control & Management because some inventory items have more importance compared to other inventory items

1) A B C Control (80-20 Law) [Always Better Control]
(based on Pareto Law or Pareto Curve)

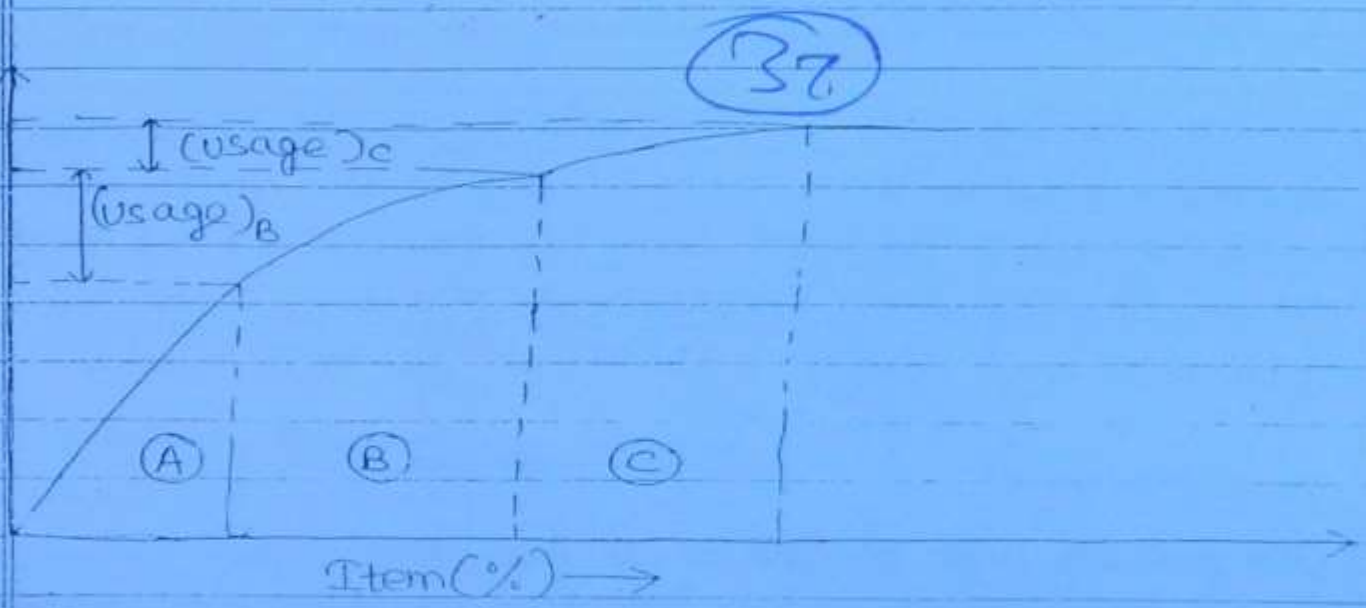
	Usage %	Item %
A	50-60%	10-20%
B	30-40%	30-40%
C	10-20%	50-60%

Item	Unit (Pound) Price	No. required (units/year)	Usage Value (Rs)	Usage %
	a	b	axb	$\frac{axb}{c} \times 100$

$\Sigma a = c$

In this system, Inventory system are classified on the basis of usage value of Inventory Item in monetary terms,

Inventories are classified into A, B & C categories. For 'A' category inventory item, Inventory is kept almost nill and fiequent review is done on the other hand For 'C' category item, Large inventory is kept & it is reviewed after long duration



VED Control (Vital, Essential & Desirable)
(depends on the criticality of items)

- Classified on the basis of Criticality of Inventory Items for production system

HML Control (High, Medium & Low)

- Classified on Unit purchase price of Inventory.

Date :

4) SDE control [Scarce, Difficult & Easily Available]

- Classified on the easiness or difficulty of availability of Inventory item.

38

5) Seasonal - Offseasonal

- Classified on the availability of Inventory based on seasonal variation

SEQUENCING

Sequencing problem comes when we are concerned with situation where is a choice as to the order in which a no of task on jobs can be performed so that utilisation of Man, power and Machine can be optimised and their idle time is minimised.

Assumptions:-

1. One job on one machine at a time.
2. Given processing order for the machine will remain constant
3. Each job once started on a machine must be fully completed.
4. The processing time for the different jobs remains constant irrespective of their order.
5. Time taken by job from one machine to other is negligible.