* PPC *

- General Supply chain :-

Supplier $\xrightarrow{\text{supply}}$ Manufacturer $\xrightarrow{\text{supply}}$ wholesaler $\xrightarrow{\text{supply}}$ retailer $\xrightarrow{\text{supply}}$ Customer

Supplier $\xleftarrow{\text{demand}}$ Manufacturer $\xleftarrow{\text{demand}}$ wholesaler $\xleftarrow{\text{demand}}$ retailer $\xleftarrow{\text{demand}}$ Customer

Manufacturer
– Functions –

production	Sales
logistics	Marketing
Quality	Finance
IT	HR

Supply chain management :- Matching the "Supply" with the "demand".

- Logistics (activities)

1. Forcasting
2. Inventory management
3. aggregate planning
4. Scheduling
5. Material requirements Planning

transportation

warehousing

purchasing ← Logistics

Schedule

waste

: and so on

SKU: (Stock keeping Unit) any item stocked somewhere in supply chain operation - with a unified code.

Ch14

[1] Forcasting

- actual activity -

what to forcast?

↳ level of aggregation

↳ units of measurements

choosing forcasting system

choosing forcasting technique

✗ level of aggregation :-

highest level → all products (unit/year)

lower level → each group of products

lowest level → each $\underbrace{\text{product or item}}_{\text{SKU: Stock keeping unit}}$

* units of measurements :-

- highest level → unit/year : long term
- lower level → unit/month , unit/quarter medium ~~term~~
- lowest level → unit/day , Unit/week , Unit/shift / hours
  Shortest term

Forcasting

- what to forcast?
- Choosing Forcasting System
- Choosing Forcasting technique
  - "SKUs with unknown previous data for the demand"
    - Judgmental methods :-
      - executive opinion
      - market research
      - Delphi method
      - Salesforce estimates
  - SKUs with known previous data for demand
    - Quantitative techniques :-
      - causal methods
      - Time series analysis

* Choosing forcasting ~~tech~~ technique *

↓

" for SKUs with previous demand "

↓

* Quantitative techniques *

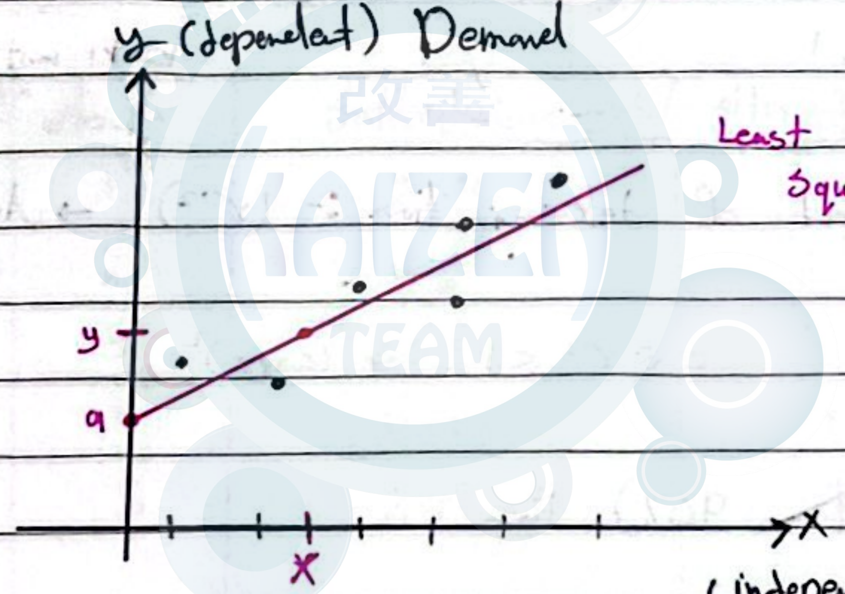
Causal methods
- Simple linear regression
- Multiple linear regression

Time series analysis
- Naive approach
- Simple moving average
- exponential smoothing avg
- Trend
- multiplicative Seasonal method.

Causal Methods :-

1. Simple linear regression :- "relationship between 2-variables" X and Y.

Period	X	Y	XY	X^2	Y^2
1	X_1	Y_1	$X_1 Y_1$	$(X_1)^2$	$(Y_1)^2$
2	X_2	Y_2	$X_2 Y_2$	⋮	⋮
3	X_3	Y_3	$X_3 Y_3$		
⋮	⋮	⋮	⋮		
	ΣX	ΣY	ΣXY	ΣX^2	ΣY^2



Least Square method

Σ the squared deviation about line is (minimum)

(independent Variable)

$$y = a + bx$$

$$a = \bar{y} - b\bar{x}$$

y-Intercept

$$b = \frac{\Sigma xy - n\bar{x}\bar{y}}{\Sigma x^2 - n\bar{x}^2}$$

Slope

Then →

* Measures to test the regression :-

[1] correlation Coefficient :- (r) → direction, → strength ..

$$r = \frac{n \sum xy - \sum x \sum y}{\sqrt{\left(n \sum x^2 - (\sum x)^2\right) * \left(n \sum y^2 - (\sum y)^2\right)}}$$

$$-1 \leq r \leq 1$$

" inversly " proportional ← * ↓ zero → " directly " proportional

(1) no relation (2) There's a relation but not linear ..

$r = 1$ or $r = -1$
→ perfectly linear relation
→ strongest relation

[2] Coefficent of determination :- (r^2) → Amount of Variation

$$0 \leq r^2 \leq 1 \rightarrow (corr)^2$$

if ($r^2 = 0.9 = 90\%$) then :-

→ 90% of y-Variation caused by x-variation
or
→ 90% of the variation fitted the model

③ standard error of estimate :- (S)

$$S = \sqrt{\frac{\Sigma y^2 - a\Sigma y - b\,\Sigma xy}{n-2}}$$

(S) indicates the variation of the measured points about the regression line.

→ So, the smallest (S) the better..

but the highest (r) → (the closest to 1, -1) the better...

"Ex"

Month	Sales (thousand) y	Advertise x (thousand $)
1	264	2.5
2	116	1.3
3	165	1.4
4	101	1
5	209	2

* the effect of advertising on the Sales .. (2 variables) { independent (advertise), dependent (Sales) }

we need $\Sigma x, \Sigma y, \Sigma x^2, \Sigma y^2, \Sigma(xy)$

$a = -8.135$

$b = 109.22$

$r = 0.979 \simeq 0.98$ ✓

$y = -8.135 + 109.22\,x$

* The company will spend 1750$ on advertising So the sale will be?!

$\boxed{1.75 \text{ thous of } \$}$

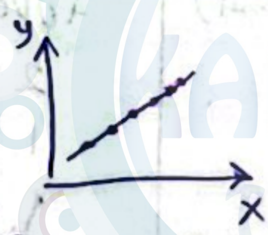
$-8.135 + 109.22(1.75) = \underline{183}$ (thous unit)

183000 unit

5
↳ important in company

Remark:

$(r = 1)$

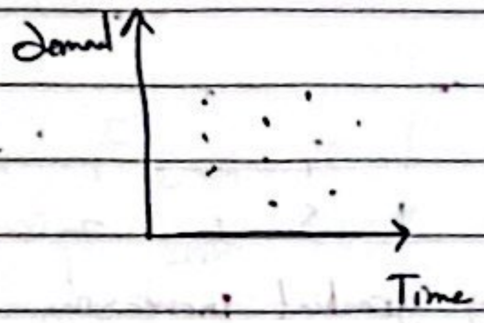


Linear Relationship

↳ perbictly fitted the regression

$r^2 = (1) \rightarrow 100\%$ fitted

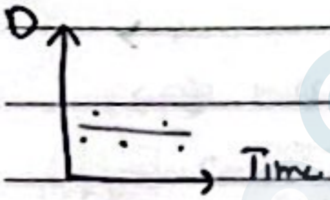
* Time series analysis *



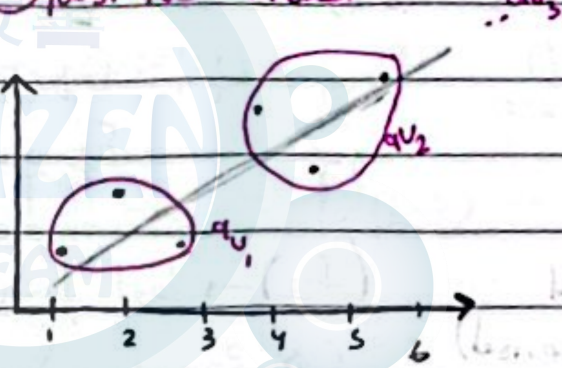
The time series patterns:-

1) horizontal
2) trend
3) Seasonal
4) cyclical
5) Random
   ↳ doesn't follow any pattern.

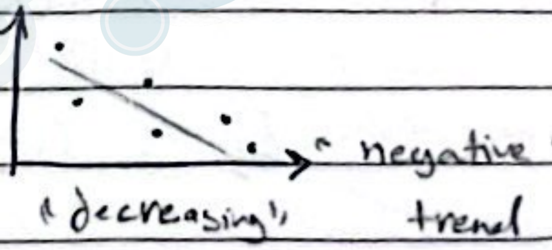
① Horizontal



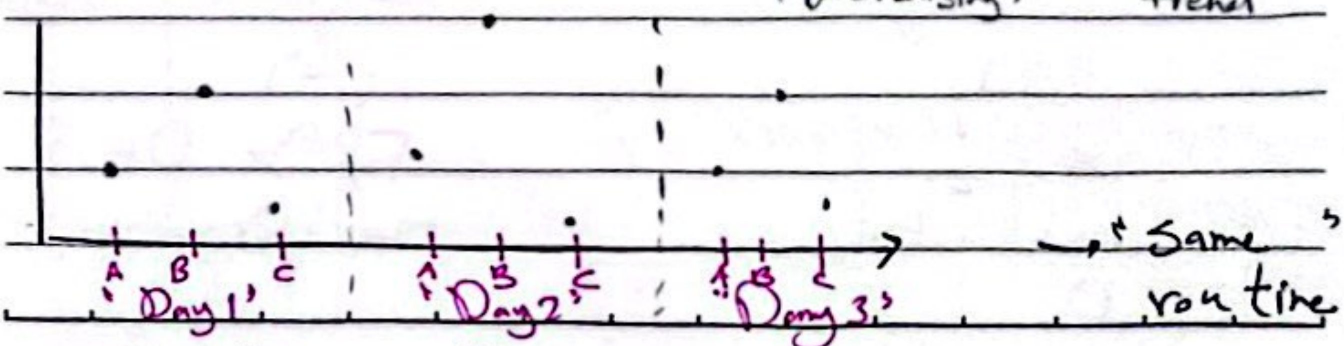
② positive trend



$av_3 > av_2 > av_1$

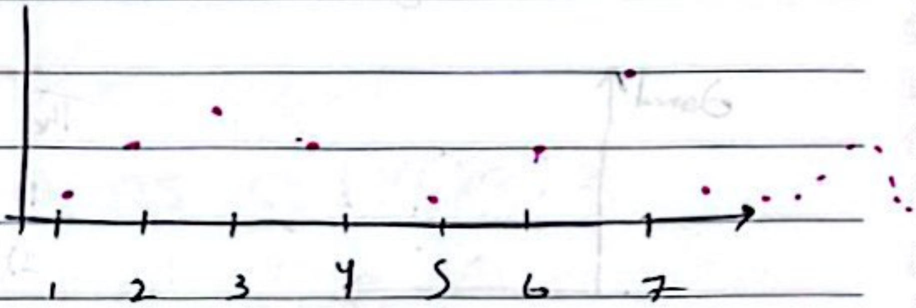


③ Seasonal



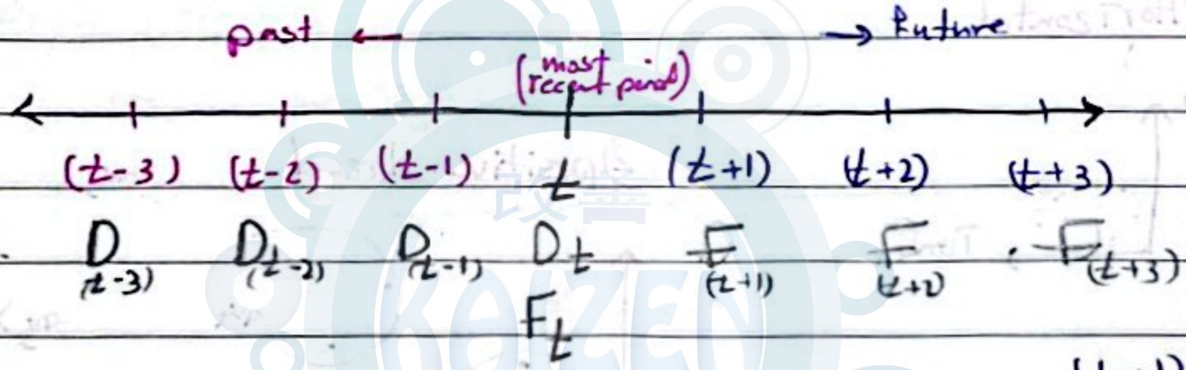
periods → Days
Season → shift

④ Cyclical:-



gradual decreasing followed by gradual increasing and so on..

Time Series Analysis Tech.



(t-1) second most recent period or (last period)

(t+1) next period

$(F_t) \rightarrow$ last period forcast

↳ forcas done at the last period

$$E_t = D_t - F_t$$

(+)

$F_t < D_t$

underestimating D

(−)

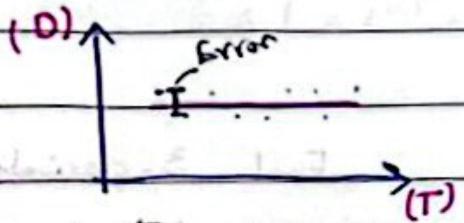
$F_t > D_t$

overestimating D

Time series techniques

[1] Naive approach:- (horizontal)

$$F_{t+1} = D_t$$



Small error

* The narrower point, the smaller error

error ‒ stable..

[2] simple moving average:- (most recent periods) $(t, t-1, t-2..)$

(this could have 2, 3, ... periods)

$$F_{(t+1)} = \frac{D_t + D_{(t-1)} + D_{(t-2)} \cdots}{n}$$

3-s.M.avg

$$F_{(t+1)} = \frac{D_t + D_{(t-1)} + D_{(t-2)}}{3}$$

3-periods Moving-avg.

week	Patient arrived
1	400
2	380
3	411
4	?

$$F_4 = \frac{400+380+411}{3} = 397 \text{ patients}$$

③ weighted moving average

$$F_{(t+1)} = w_1 D_t + w_2 D_{(t-1)} + w_3 D_{(t-2)}$$

" $w_1 > w_2 > w_3$ "

" $w_1 + w_2 + w_3 = 1$ "

Month	Customer arrival
1	800
2	740
3	810
4	790
5	?

• Find 3-periods weighted moving avg
$w_1 = 0.5$
$w_2 = 0.3$
$w_3 = 0.2$

$$F_{(5)} = 0.5(790) + 0.3(810) + 0.2(740)$$
$$= \underline{\underline{786 \text{ customers}}}$$

don't forget to round up or down if the avg isn't integer ..
↙ ↘
$.5 >$ down $.5 \leq$ up

* if the $(\text{Demand}_5 = 805)$ Calculate the error :-

$(805 - 786 = 19 \text{ cust})$
↓
$(+)$ under estimating for $\underline{D}$

Important

Forcast month 4 through 7 :- means

F_4, F_5, F_6, F_7 each one (of the forcasting) alone..

(4) Exponential Smoothing :- (α)

$$F_{(t+1)} = \alpha D_t + (1-\alpha) F_t$$

D_t: this period demand

F_t: last period Forcast

α: exponential smoothing parameter

t (t+1)

D_t ✓, F_t ✓ → $F_{(t+1)}$ ✓

$$\boxed{0 \leq \alpha \leq 1}$$

(0.1, 0.3, 0.5 ..)

↳ The greater "α" gives a greater influencing for the demand.

if $\alpha = 0.1$ find $F_{(3)}$

week	patients
1	400
2	380

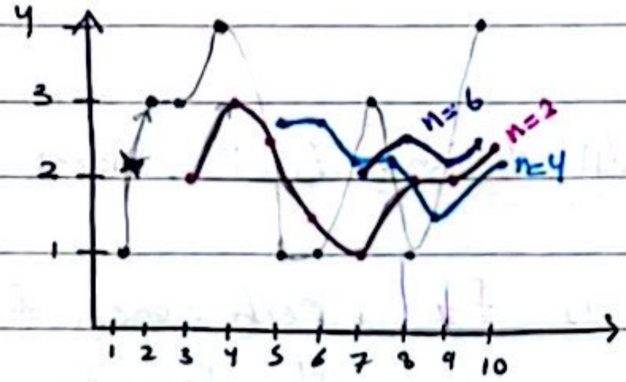
(1) we assume $F_1 = D_1 = 400$ p

(2) $F_2 = 0.1(400) + 0.9(400) = 400$ p

F_3 ?!

$F_3 = 0.1(380) + 0.9(400) = 398$ patient

$n=6$
~~smoo~~ $\rightarrow$ closer and smoother



$\boxed{n=2}$ (small)
$\rightarrow$ more emphasis for the last 2-periods only

$\nearrow$ $\searrow$

$\rightarrow$ Responsive behavior for forcast

$\boxed{1}$ Simpel moving avg $\underset{}{\overset{n=2}{\text{2 periods}}}$ $(T \geq 3)$

$F_3 = \frac{1+3}{2} = 2$, $F_4 = \frac{3+3}{2} = 3$, $F_5 = \frac{4+3}{2} = 3.5$

$F_6 = \frac{1+4}{2} = 2.5$, $F_7 = \frac{1+1}{2} = 1$, $F_8 = \frac{3+1}{2} = 2$

$F_9 = \frac{1+3}{2} = 2$, $F_{10} = \frac{1+4}{2} = 2.5$

$\boxed{2}$ Simple moving avg $(n=4)$ $(T \geq 5)$

$F_5 = 2.75$, $F_6 = 2.75$, $F_7 = 2.25$, $F_8 = 2.25$, $F_9 = 1.5$, $F_{10} = 2.25$

$(n=4)$ larger 'n' the behavior becomes smoother
$\rightarrow$ the points are closer to each othe

Simple moving avg $\rightarrow$ Small n : Responsiveness
Simple moving avg $\rightarrow$ large n : smoother forcast

In
- Simple moving avg
- weighted moving avg

n smaller : more responsive Forcast

n larger : more smoothed

- responsive forcast since it'll be affected by only small number of periods → high variation
- Smooth, since it's affected by large "n" so, the behavior will seem to be horizontal

In "exponential-smoothing"

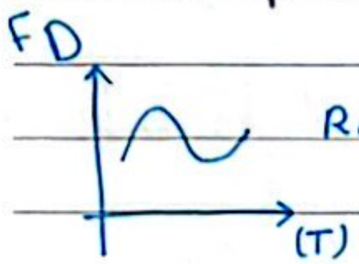
$F_t = \boxed{\alpha} D_t + (1-\alpha) F_t$

↳ larger α will give more emphasis for last period demand only, and less emphasis for the forcast

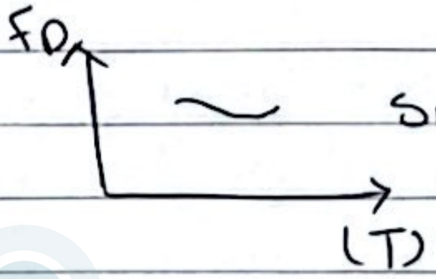
α is Large → and Last period demand high → high effect on the forcast → Responsive

In (exponential smoothing)
- α larger : More responsive forcast
- α smaller : More smoothed forcast

Horizontal Time-Series-pattern → Naive approach, simple moving avg, weighted moving avg, exponential smoothing → lowest error



Responsive



Smooth

- Forcast for the demand to be ordered from the supplier
→ Smooth, so we use large "n" (in simple.M.avg)

- Forcast to the production in a Flexable production line
→ Smaller "n" and Responsive demand.

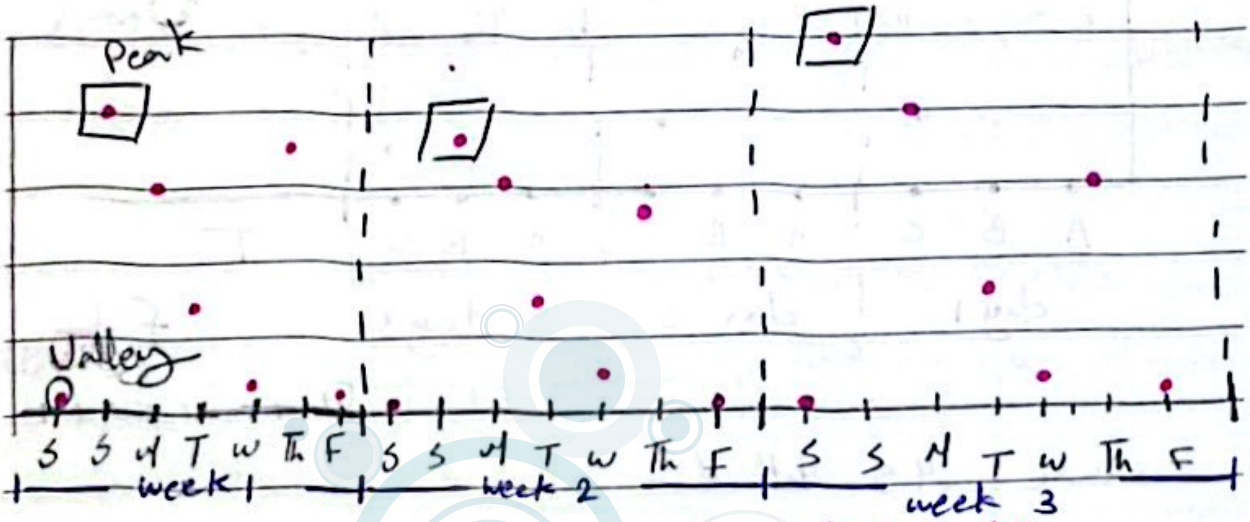
cost ~~is~~ is not affecting by the amount of items ..

$D_t = 5$, $D_{t-1} = 6$ → $F_{t+1} = 5.5$ or F_{t+1} any value
→ same cost will be used.

Smooth → Small α, large n

Responsive → large α, Small n

(5) Multiplicative Seasonal Method :- (Seasonal pattern)



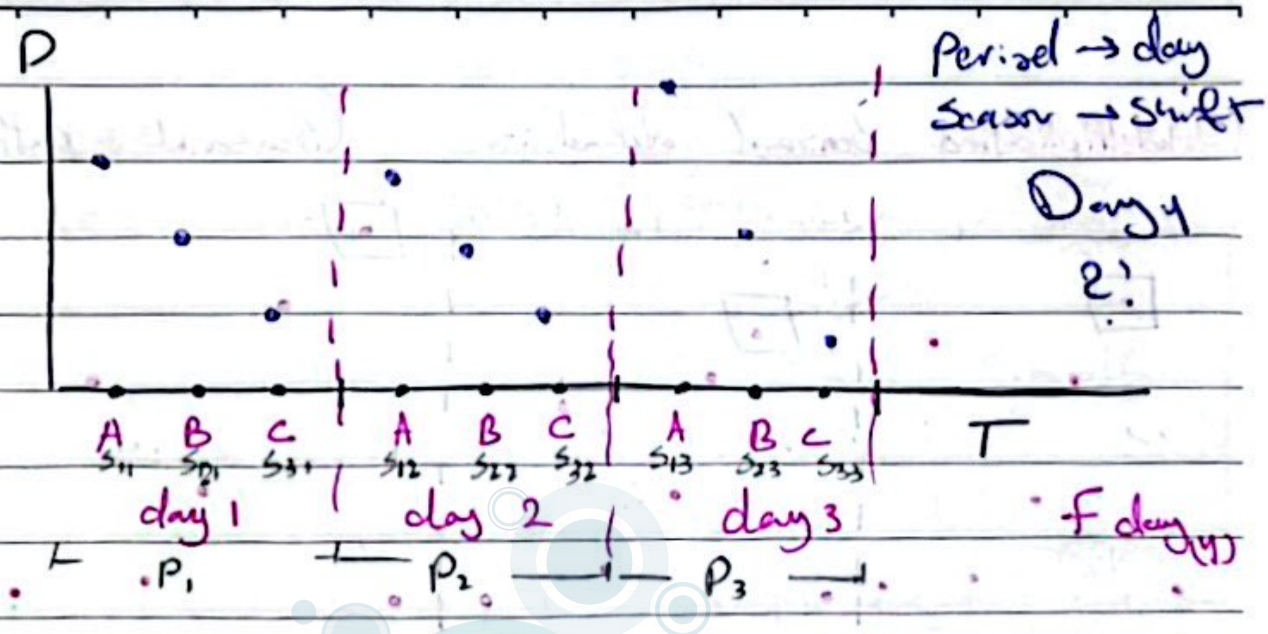
→ Seasonal pattern at least (3 periods)

Period → week , Season → day .

each period → has a 7 Seasons with the Same behavior (peak, and Valley)

In seasonal pattern :-
The previous Methods are not appropriate at all .

$F_{Sun} = D_{Sat}$ in Naive → too much error



→ using M.S. Method :-

Season	D_1	Seasonal Index SI (Period 1)	D_2	Seasonal index SI (Period 2)	avg SI	Forcast P_3
S_1	$D_{P_1 S_1}$	$SI_{S_1 P_1} = \frac{D_{P_1 S_1}}{ADP_1}$	$D_{P_2 S_1}$	$SI_{S_1 P_2} = \frac{D_{S_1 P_2}}{ADP_2}$	ASI_{S_1}	$ASI_{S_1} * EAD_{P_3}$
S_2	$D_{P_1 S_2}$	$SI_{S_2 P_1} = \frac{D_{S_2 P_1}}{ADP_1}$	$D_{P_2 S_2}$	$SI_{S_2 P_2} = \frac{D_{S_2 P_2}}{ADP_2}$	ASI_{S_2}	$ASI_{S_2} * EAD_{P_3}$
S_3	$D_{P_1 S_2}$	$SI_{S_3 P_1} = \frac{D_{S_3 P_1}}{ADP_1}$	$D_{P_2 S_3}$	$SI_{S_3 P_2} = \frac{D_{S_3 P_2}}{ADP_2}$	ASI_{S_3}	$ASI_{S_3} * EAD_{P_3}$
	$DT_{(1)} P_1$		$DT_{(2)} P_2$			$F_s P_3$

$$AD(P) = \frac{DT}{\# \text{ Season}}$$ → avg demand for period's season

$$ASI_{(S)} = \frac{\sum SI_{P_n, S}}{\# \text{ of periods}}$$

① Estimation (DT_{P_3})
→ avg DT_{P_1} ⊕ DT_{P_2} ..
→ detect the behavior

② Estimation ($AD P_3$)

$$EDT_{P_3} = \frac{(EAD_{P_3})}{\# \text{ Seasons}}$$

[1] Total demand for each period $\sum D_p$

[2] Avg demand for each period's season

$$AD_p = \frac{\sum D_p}{\#\ \text{seasons}} \longrightarrow \text{avg demand per season}$$

(3) SI (Seasonal Index for each season in each period)

$$SI_{ps} = \frac{D_{sp}}{AD_p}$$

(4) Total (SI) for each season

(5) Avg SI for each season

$$ASI_{(s)} = \frac{\sum SI_{ps}}{\#\ \text{periods}}$$

(6) Estimation $\rightarrow$ E(DT) for the forecast period

$$\longrightarrow E(AD_p) = \frac{EDT}{\#\ \text{seasons}}$$

(7) Forecast each season :

$$FD_{(s)} = ASI_{(s)} * EAD_{(p)}$$

$$SI = \frac{D}{\text{avg } D} \Rightarrow FD_{(s)} = SI_{(s)} * A.D_{(p)}$$

Scanned with CamScanner

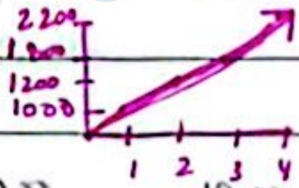
Ex: The manager needs a quarterly Forecast of the number of customers expected (next year), Seasonal pattern with peak in the 3th quarter, trough (Valley) in the First quarter given (data) for 4 past years..

Q	Year 1		Year 2		Year 3		Year 4	
	D	SI	D	SI	D	SI	D	SI
1	45	0.18	70	0.233	100	0.22	100	0.182
2	335	1.34	370	1.233	585	1.3	725	1.3182
3	520	2.08	590	1.9667	830	1.844	1160	2.11
4	100	0.4	170	0.5667	285	0.633	215	0.391
DT	1000	+200	1200	+600	1800	+400	2200	
ADP	250		300		450		550	

Q	$ASI_{(5)}$ $\sum SI_{(5)}/(4)$
1	0.2037
2	1.2978
3	2.008
4	0.4977

Estimation

$DT(P_5)$:-



1000 —— 1200 —— 1800 —— 2200

+200 +600 +400

$$Tm\ (avg) = \frac{200 + 600 + 400}{3} = 400(+)$$

$$EDT_{P_5} = 2600, \quad EAD_{P_5} = \frac{2600}{4} = 650$$

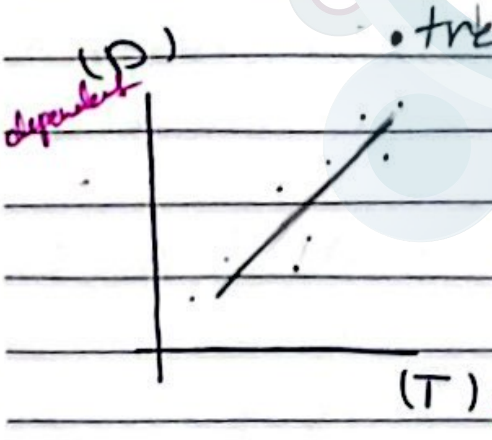
Q	$F_{P5, s}$	$F_{P5}(S)$	Rounded (number of Customer)
1	$ASI_{S_1} * \overline{ED}_{P5}$	132.795	133 customer (valley) ✓
2	$ASI_{S_2} * \overline{ED}_{P5}$	843.57	844 customer
3	$ASI_{S_3} * EAP_{P5}$	1305.2	1305 customer (Peak) ✓
4	$ASI_{S_4} * EAP_{P5}$	323.5	324 customer

(Horizontal) $\xrightarrow{\text{Forcast}}$. Simple - Moving - avg
. wighted - Moving - avg
. Exponintial - Smoothing
. Naive approch

averaging
→ low error

(Seasonal) $\xrightarrow{\text{Forcast}}$ Multiplicative - Seasonal - Method
Additive - Seasonal - Method, SARIMA

(Trend) $\xrightarrow{\text{Forcast}}$. Simple - linear - regression, ARIMA
. treed adjusted Exponential Smoothing



" positive trend "

$\boxed{1}$ $(y) = a + b(x)$

$\boxed{2}$ test the regression by measures like (R, R^2, s) → strength

How to choose the Best technique ?!

Period (t)	D_t	F_t	Error (E)
1	D_1	F_1	$D_1 - F_1$
2	D_2	F_2	$D_2 - F_2$
3	D_3	F_3	$D_3 - F_3$
4	D_4	F_4	$D_4 - F_4$
5	D_5	F_5	$D_5 - F_5$

① we should have a previous data for the errors at least (5) periods

② we use the measures of error
→ to compare between the methods and to find the best one :-

* Measures of error :-

1. Cumulative Sum of Forcast error $CFE = \sum_{t=1}^{t=n} E_t$

Period	Method (1)	Method (2)
1	-2	+2
2	+4	-4
3	+3	-3
4	+5	-5
CFE	+10	-10

→ Indicates the bias direction
→ amount of bias

+10: Mostly under estimated demand

-10: Mostly over estimated demand

2 Mean bias (E) = $\frac{CFE}{n}$ → (+) under estimation

→ (−) over estimation

indicates ① the bias direction

② avg bias during (n - periods)

3 Mean absolute deviation (MAD)

$$MAD = \frac{\sum_{t=1}^{t=n} |E_t|}{n}$$

* avg amount of deviation from the actual demand

4 Mean absolute Percent error (MAPE)

$$MAPE = \frac{\sum_{t=1}^{t=n} \left(\frac{|E_t| * 100}{D_t} \right)}{n}$$

* The error as a percent of the actual demand

E	D	|E|/D
1	1000	0.001
1	10	0.1

(1 — 5) Measures of (Central-tendency), (6) Variation

(5) Mean Squared Error (MSE)

$$MSE = \frac{\sum_{t=1}^{t=n} (E_t)^2}{n}$$

→ to detect the large errors in some periods → that isn't detected by MAD

P	M₁	M₂
1	1	0
2	1	0
3	1	0
4	1	4
MAD	1	1
MSE	1	4

→ large error is a bad error

(6) Standard-deviation of error (σ_E)

$$\sigma_E = \sqrt{\frac{\sum (E_t - \bar{E})^2}{n-1}}$$

$\bar{E}$: Mean bias

→ Important to know the variation on the errors' values.

Ex: Calculate the measures of error:-

M	D	F	E	$\|E\|$	$\frac{\|E\|}{D} \times 100$	E^2
1	200	225	-25	25	12.5%	625
2	240	220	+20	20	8.33%	400
3	300	285	+15	15	05%	225
4	370	390	-20	20	5.4%	400
5	230	250	-20	20	8.7%	400
6	260	240	+20	20	7.69%	400
7	210	250	-40	40	19.05%	1600
8	275	240	+35	35	12.7%	1225
Sum			-15	195	79.37%	5275
avg			-1.875	24.375	9.9%	659.375

1. CFE = ~~[illegible]~~ -15 (mostly over estimation) ✓
2. Mean bias ($\bar{E}$) = -1.875 ✓
3. MAD = 24.375 ✓
4. MSE = 659.375 ✓
5. MAPE = 9.9%
6. σ_E = 27.4 ✓

→ if the SKU has previous data about the actual demand and we have two methods that are considered to be the Best

[1] Combination Forcasting (avg)

Period	Method (1)	Method (2)	Combination (F)
10	$F_{M_1 P_{10}}$	$F_{M_2 P_{10}}$	$\frac{F_{M_1 P_{10}} \oplus F_{M_2 P_{10}}}{2}$

→ but M_1 and M_2 must have a close Measures of errors to use the ((Combination forcasting))

[2] Focus Forcasting: (we focus on the method with the least Measure of error at the last period)

(MAD)	M_1				M_2				Forecast
Period	D	F_{M_1}	E_{M_1}	MAD	D	F_2	E_2	MAD	(Decision)
10	D_{10}	$F_{M_1 D_{10}}$	$E_{M_1 D_{10}}$	MAD 10	D_{10}	F_{M_2}	E_{M_2}	MAD less	F_{11} (Method 2) → less MAD at Period 10
11	D_{11}	F_{M_1}	E_{M_1}	less $MAD_{M_1 P_{11}}$	D_{11}	F_{M_2}	E_{M_2}	$MAD_{M_2 P_{11}}$	F_{12} (Method 1) → less (MAD) at Period 11
12		$F_{M_1 P_{12}}$							

$\left(MAD = \frac{\sum^{t+n} |E|}{n} \right)$ changes with time

→ according to its Value we choose the Best-Method

→ Some time the measure of interest isn't the (MAD) So, we use this method with the interesting measure

"Tracking signal" to check if the process of forcasting by the choosed technique is in control ? or not

$$TS = \frac{CFE}{MAD}$$ plotted →

→ (alarming system)
at (P=12) there's something wrong

* In Focus forcasting, we focus on the least measure of interest at the last period it could be MAD or MAPE or $\bar{E}$ ... and so on

Forcasting

Do SKU have a previous data about the actual demand ?
- yes → Quantitative methods
- No → Judgemental methods

Judgemental Methods
- market research
- executive opinion
- Delphi (anonymous experts)
- Sales force estimates

Quantitative methods
- Causal method :- assumption there's variable affecting the demand
- Time series analysis :- there's a pattern of the demand's behaviour ..

Causal methods ("Relation")
- linear Relation : Simple linear regression
  Multiple " "
- non linear Relation

Time series analysis
- Horizontal : Simple.mavg, wighted.mavg, E.S, Naive
- trend : (Simple linear regression, ARIMA)
- Seasonal : (Multiplicative - Seasonal-Method) SARIMA

↓ Random ↓ cyclical

Measures of error

To chose between technique
- CFE, $\bar{E}$ (interested to not have bias)
- MSE (to not produce large error)
- MAD (to not produce forecast away from actual demand)
- MAPE (to not produce large error as a period of demand)
- $\bar{E}$ (to not produce Variability in Error)

if more than one is suitable → chose between them
based on measures of errors
→ Combination Forcast
→ Focus forcast

Check if the used Method controls the forcasting process → Tracking Signal

(Tracking Signal) Control Chart
→ In control → keep using
→ out of control → use another technique

"Questions"

$a = 42.46$ $r = 0.87$

$b = 2.45$

	X	y
1	Jan	41
2	Feb	46
3	Mar	57
4	Apr	52
5	May	59
6	Jun	51
7	Jul	60
8	Aug	62
⋮		
12	Des	
13	Jan	

Simple linear regression

$y = a + bx$

$$b = \frac{\sum yx - n\bar{x}\bar{y}}{\sum x^2 - n(\bar{x})^2}$$

$$= \frac{2029 - 8(4.5)(53.5)}{204 - 8(4.5)^2}$$

$$= 2.45$$

$a = \bar{y} - b\bar{x}$

$= 53.5 - 2.45(4.5)$

$= 42.46$

$y = 42.46 + 2.45x$

y for $x = 9$, $x = 10$, $x = 11$

$(x = 9)$ $y = 64.51$ oil change

"prob 2"

Seasonal Factor = Seasonal Index

Days	P_1 week 1	P_2 week 2	SI_{P_1}	SI_{P_2}	$ASI_{(s)}$
s_1 Sun	5	8	0.156	0.2667	0.21135
s_2 Mon	20	15	0.625	0.5	0.5625
s_3 Tue	30	32	0.9375	1.0667	1.002
s_4 Wed	35	30	1.09375	1	1.04688
s_5 Thu	49	45	1.53	1.5	1.51563
s_6 Fri	70	70	2.19	2.33	2.26042
s_7 Sat	15	10	0.47	0.333	0.40104
Sum	224	210			
avg	32	30			

TD week = 230 tho of mail

$ADT_{(3)} = 32.857$

Period		$ASI_{(s)}$	F
1	Sun	0.21135	7
2	Mon	0.5625	18
3	Tue	1.002	33
4	Wed	1.04688	34
5	Thu	1.51563	50
6	Fri	2.26042	74
7	Sat	0.40104	13.

"prob 4"

① 3-Simple Moving avg:

w_1	50
w_2	65
w_3	52
w_4	56
w_5	55
w_6	60
w_7	

$F_{23} = F_{(23-30)} = 55.667 = 56$ pizzas

$F_{30} = F_{(30-7)} = 57.6 = 58$ pizzas

$F_7 = F_{(7-14)} = 54.33 = 54$ pizzas

$F_{14} = F_{(14-21)} = 57$ pizzas

② 3-weighted Moving avg:-

$F_{23} = F_{(23-30)} = 55.5 = 56$ pizzas

$F_{30} = F_{(30-7)} = 57$ pizzas

$F_7 = F_{(7-14)} = 55$ pizzas

$F_{14} = F_{(14-21)} = 58$ pizzas

D	$F_{S.M.avg}$	$F_{W.M.avg}$	$\lvert E_s \rvert$	$\lvert E_w \rvert$
W_{23} 56	56	56	0	0
W_{30} 55	58	57	3	2
W_7 60	54	55	6	5
Sum			9	7
M.A.D			3	2.333

So, weighted moving avg for this small set of data is better since, it gives lower deviation (Error) 'prob 5'

week	Sales	Forcast	E	|E|	E^2	$\frac{\|E\|}{D} \times 100$
1	46	44	2	2		4.35%
2	49	47	2	2		4.08%
3	43	49	-6	6		13.95%
4	50	51	-1	1		2 %
5	53	53	0	0		0 %
6	58	56	2	2		3.45%
7	62	58	4	4		6.45%
8	56	60	-4	4		7.1%
9	63	62	1	1		1.587%
10	~~[illegible]~~	65				
11		67				
12		69				
Sum			0	22		
Avg			0	2.44	9.1[illegible]	4.774%

$y = 42.083 + 2.25(x)$

$r = 0.88479$

$(r^2 = 0.78)$

$r^2 = 78.28\%$

CFE = 0, $\bar{E} = 0$

MAD = 2.44, MSE = 9.1

MAPE = 4.774%

$(\alpha = 0.2)$

Month	Units	forcast	$\lvert E \rvert$	$\frac{\lvert E \rvert}{D} * 100$
May	100	105		
• June	80	104	+24	30%
July	110	99	11	10%
August	115	101	14	12.17%
September	105	104	1	0.95%
October	110	104	6	5.45%
November	125	105	20	16%
December	120	109	11	9.16%
• January		111		
Sum			87	83.78%
avg			12.43	

MAD = 12.43

APE = 83.78%

Tracking signal = $\frac{CFE}{MAD} = \frac{39}{12.43} = 3.137 = 3.14$

Period	Demand	Forcast	$\|E\|$	$\frac{\|E\|}{D} * 100$
1	45	67	22	48.889%
2	70	91	21	30%
3	100	120	20	20%
4	43	61	18	41.86%

Sum

avg

MAPE = $\boxed{35.2\%}$

Year	Demand	α (0.6) Forcast	(α = 0.9)
1	41	41	41
2	46	41	41
3	54	44	46
4	55	50	53
5	58	53	55

"ch 9"

Inventory & Warehouse

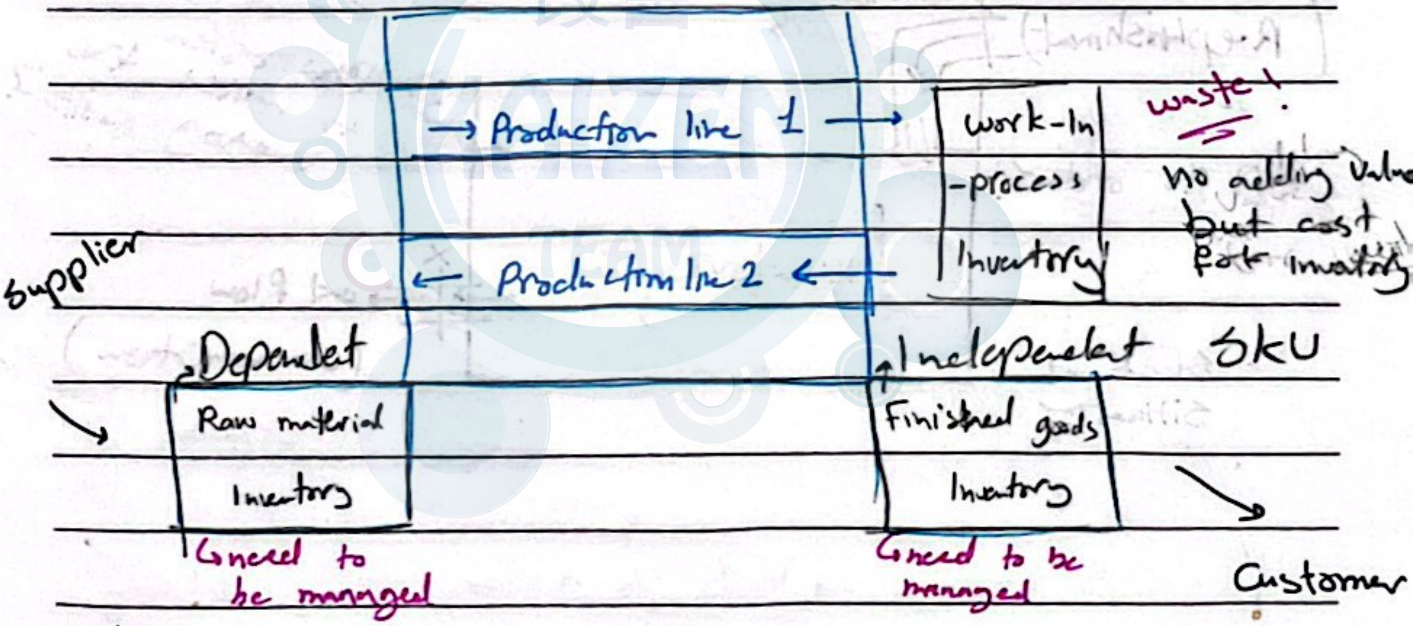
Inventory

"Stock itself"
products, items
SKUs

warehouse

the space and place
for storing Inventory

[warehouse management $\xleftrightarrow{\text{related}}$ Inventory management]



-(Work-In-Process-Inventory) it's considered a waste.
Since it has ① no value to have a storage space
and ② increased the Lead time of production process.

"P ch"

Suppling

Manufacturer → [ ] → [ ] → [ ] → Customer

→ Finished goods (order to the Customer)

The Raw material depends on the demand of the finished goods.

Supplier → Raw material → Finished good ← order → Customer

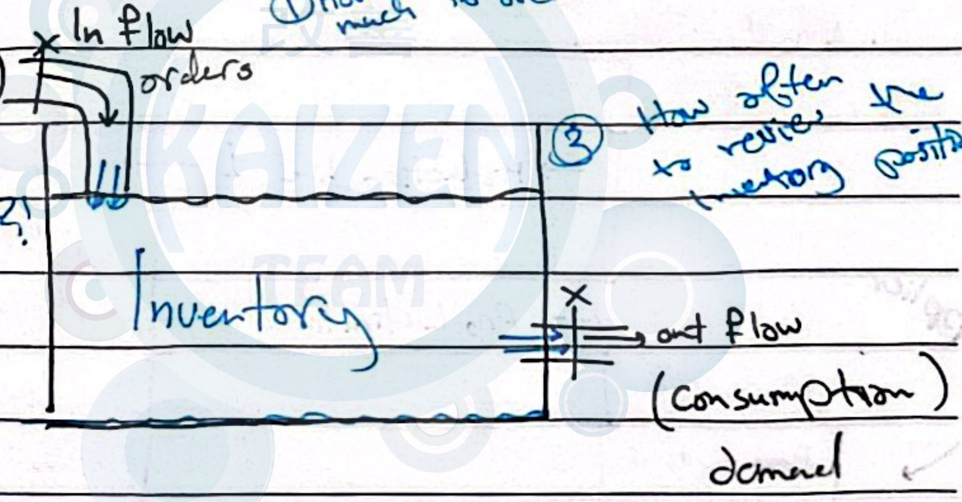
dependent — Independent

① How much to order?

(Replenishment) Re-supply

② When to order?

③ How often to review the inventory position?



Having No inventory → leads to a very long delivering time

Stockless Inventory → Required ① Reliable transportation
② Reliable Information quality and Manufacturing

Independent — dependent

Customer $\xrightarrow{\text{order}}$ Finished Goods Inventory $\xrightarrow{\text{order}}$ Raw material Inventory

Inventory management

Classification of SKUs

- ABC classification

Choosing Inventory control System :-

- How much to order ?
- When to order ?
- How much to review the Inventory position?

Independent demand SKU

① Continuous review system

② periodic review system

③ Hybrid System

- optional Replenishment System
  - (depends on the market needs)
- base stock System

dependent demand SKU

MRP : material requirement planning

(depends on Finished goods needed)

Finished goods — order — Market

supply

Factory

dependent

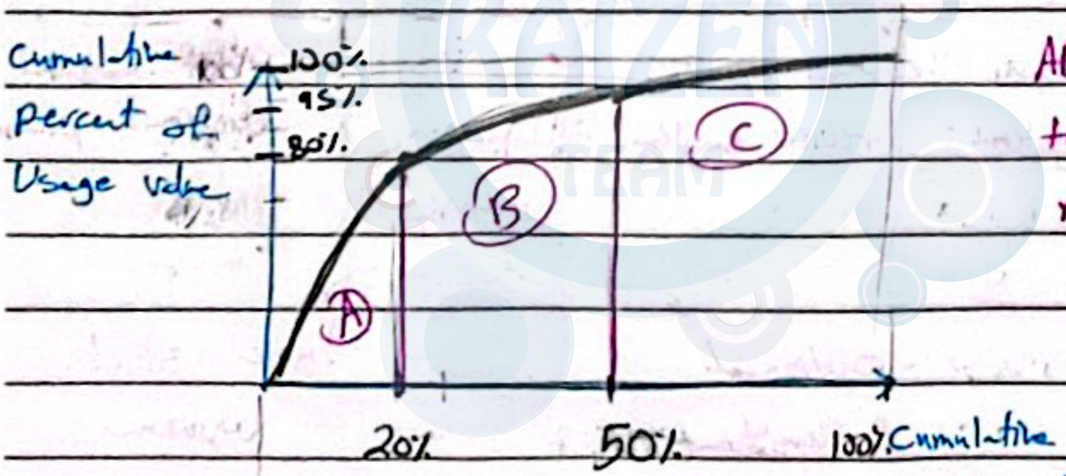
"Classification of SKU"

"ABC classification"

→ according to the SKU usage value

The Annual Usage Value = Cost * Annual demand

	Cost	Annual demand	Annual Usage Value
Product 1	1 $	100 000	100 000 $/year
Product 2	1000 $	5	5000 $/year



ABC follows the (80-20) rule of pareto.

—20% of SKU + 30% of SKU + 50% of SKU → 100% SKU

(A) → 20% SKU, 80% TAUV

(B) → 30% SKU, 15% TAUV

(C) → 5% TAUV, 50% SKU

SKU 100%
- A → 20% the fewest with the largest AUV (80%)
- B → 30% Modest amount with 15% of AUV
- C → 50% Many SKUs with the least AUV 5%

A.U.V 100%
- → 80% into class (A) 20% of SKU
- → 15% class (B) 30% of SKU
- → 5% class (C) 50% of SKU

Since, class (A) has the highest (A.U.V) so it need a frequently review and replineshment (attention)

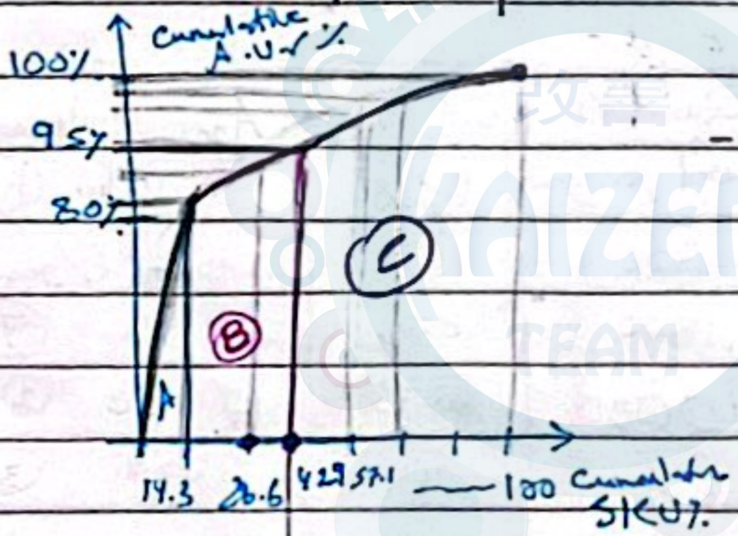
SKU	Description	Quantits used per year	unit Value ($)	Annual Usage Value ($/year)
1	Boxes	500	3	1500 $/year (4)
2	cardbord	1800	0.02	360 (7)
3	cover	10000	0.75	7500 (2)
4	glue	~~75~~	40	3000 (3)
5	Inside cover	20000	0.05	1000 (5)
6	tape	3000	0.15	450 (6)
7	Signature	150000	0.45	67500 (1)

by A.U.V to classify them into A,B,C

(6) SKU → 2 (B), → 4 (C)

Class B and (C) can't have the same (SKU%.)

SKU	Description	A.U.V	Cumulative SKU %.	A.U.V %.	Cumulative A.U.V %.
7	Signature	67500	(1/7)×100 = 14.3	83 %	83 %
3	Cover	7500	28.6 %	9.2 %	92.2 %
4	glue	3000	42.86 %	3.7 %	95.9 %
1	Boxes	1500	57.1 %	1.8 %	97.8 %
5	Inside cover	1000	71.4 %	1.2 %	99 %
6	tape	450	85.7 %	0.6 %	99.6 %
2	Coral barrel	360	100 %	0.4 %	100 %
Sum		81310		100 %	



- Class (A) : (7) signature
  - 83 % A.U.V ≈ 80 %
  - 14.3 % SKU ≈ 20 %

- Class (B) : (3) and (4)
  - 12.9 % A.U.V ≈ 15 %
  - 28.6 % SKU ≈ 30 %

Class (C) : hiegst amount of SKU with lowest A.U.V

- 57.1 % SKU ≈ 50 % SKU
- 4 % A.U.V ≈ 5 % A.U.V

7 SKU → 1 (A) (1), → 2 (B) ~~(3)~~, → 4 (C) (3)

C must have the largest num of SKU

Inventory Cost

Holding Cost (H)

- Capital Cost ↑
  - no profit get
  - unit cost ↑
- ↑ Storage and Handling Cost
  - workers
  - storage space
  - unit cost ↑
- Unit cost
  - ↑ taxes
  - ↑ Insurance, Safty
  - (Shrinkage)
    - (theft) ↑ pilferage
    - ↑ obsolescence (out-dated)
    - deterioration ↑ (- damaged - expiring -)

(ordering / setup cost) (S)

- production line → Replenishment preparing
- From supplier → purchasing - Replenishment -

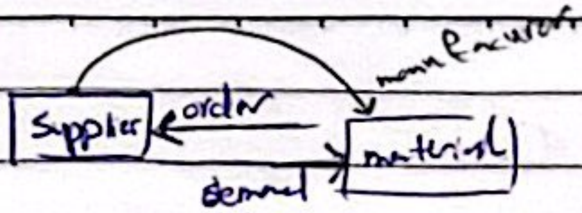
H: Unit Holding Cost
$ / unit / year
→ percent of its unit cost

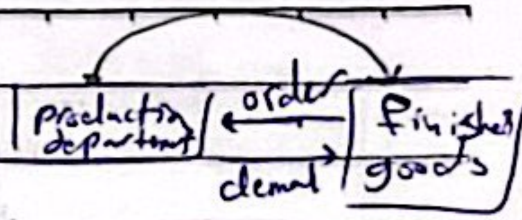
(unit cost) * 0.25 = (H)
↳ 25% of the unit cost

* purchasing cost
↳ cost of the unit itself (5$)

* ordering cost
↳ workers and transportation and (replenishment)

* Set up cost
↳ cleaning with scheduling for production line)
& workers)
(replenishment for Finished goods)





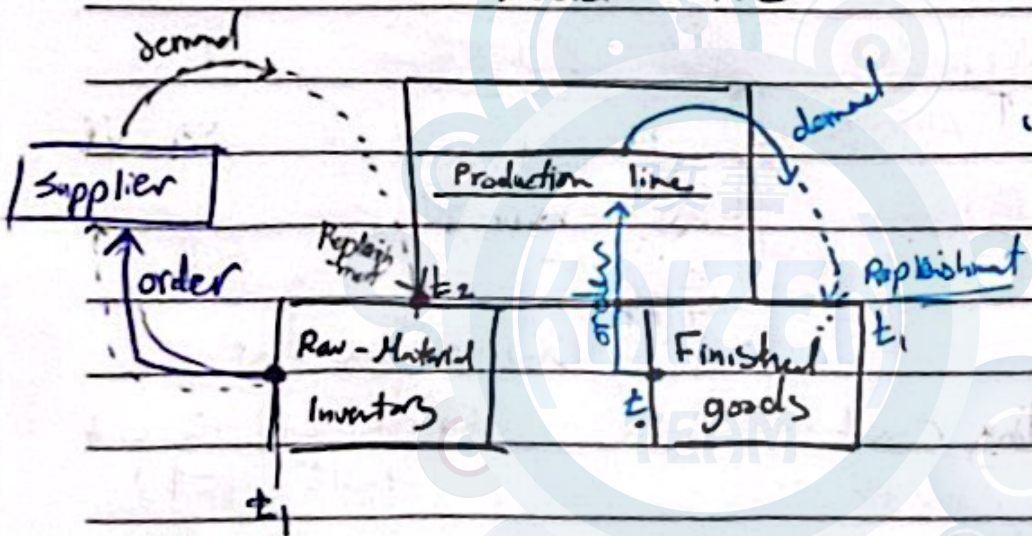
ordering cost

Replinshment of Raw material

setup cost

Replinshment of finished goods

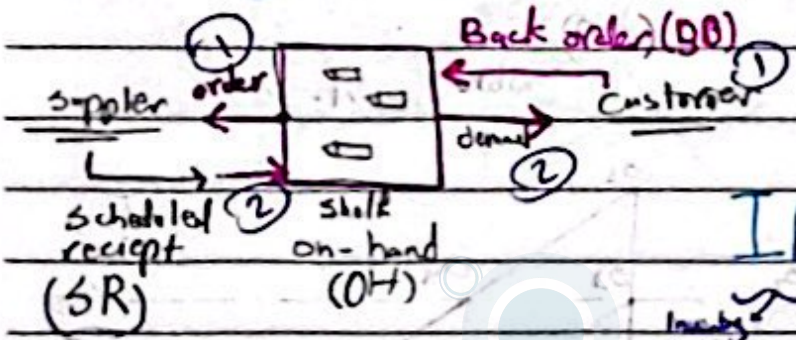
Lead Time



"Lead time"
total time from the moment of ordering from the production Line till it's on the shelf

Lead time
from the moment we sent the order (to supplier) till this order is on-hand (put on the shelf)

Inventory Position (IP) Inventory

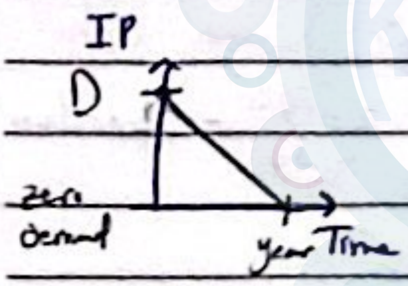


$$IP = OH \oplus SR \ominus BO$$

Inventory position; on hand Inv.; scheduled receipt (from supplier); Back order (to customer)

I(P)

- Manually (OH, SR, BO)
- Technology: barcodes, Scanners, Software (IP)
- Visually (OH)



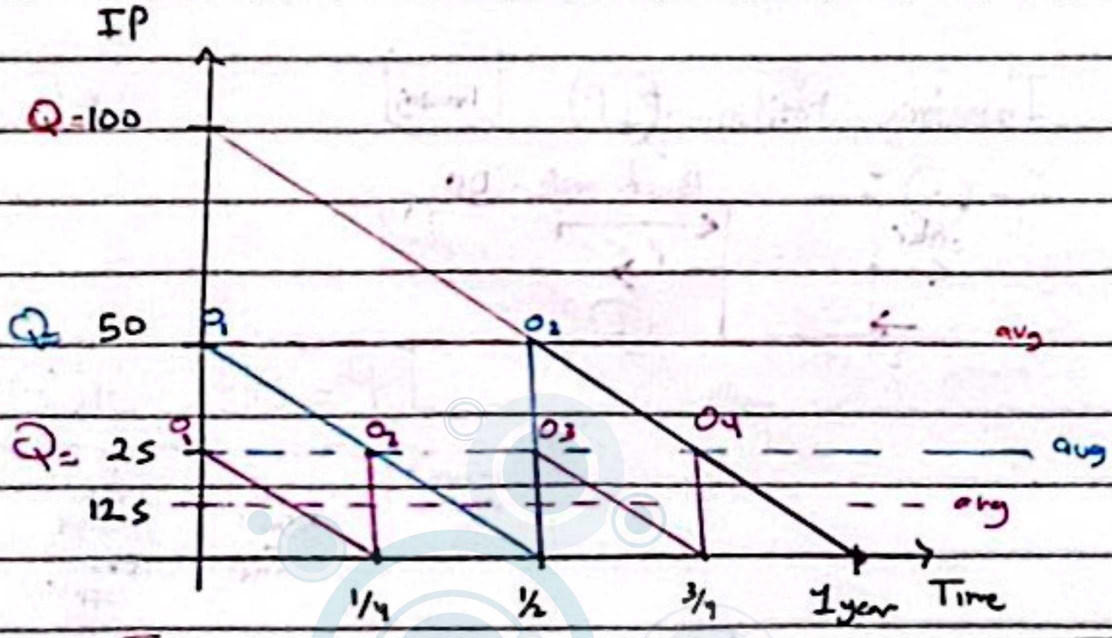
D: Annual Demand (unit/year)

d: (unit/month) or week, day ..

H: \$/unit/year (holding cost)

S: \$/order (ordering cost)

D = 100 unit/year



(Case 1) $\boxed{Q = D}$

Q (ordered quantity) → (Q = 100 unit), $\boxed{Q = D}$

no of orders = $\frac{D}{Q} = \frac{100}{100} = 1$ order

avg. inventory = $Q/2 = 100/2 = 50$ units

↪ $\frac{\sum IP}{\#parts} = \left(\sum_{0}^{100} X\right) / 101 = 50$ unit $(0 \rightarrow 100) = 101$

(Case 2) $\boxed{Q = D/2}$

Q = 50 unit, no. of orders = $\frac{100}{50} = 2$ orders

avg. Inv = $\frac{50}{2} = 25$ unit

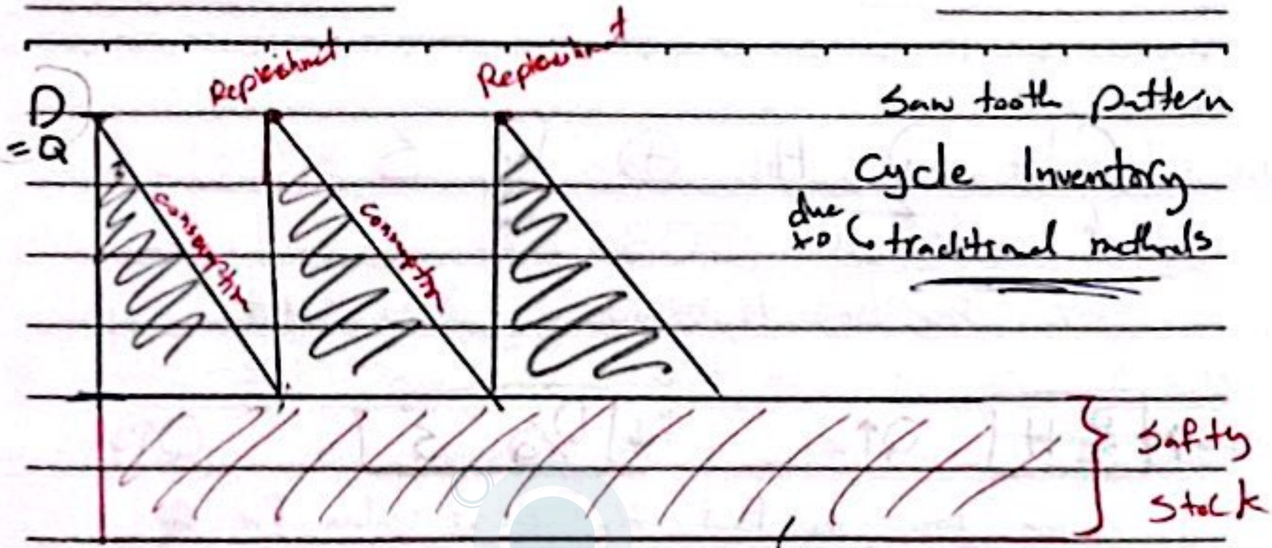
(Case 3) $\boxed{Q = 25}$

Q = 25 unit, no. of orders = $100/25 = 4$ orders

avg. Inv = $\frac{25}{2} = 12.5$ unit

Q↑ orders ↓ ordering cost ↓

Q↑ Holding cost ↑



Saw tooth pattern
Cycle Inventory
due to ↳ traditional methods

↳ Fixed quantity

↳ to avoid stock-out and over-stock

Pipeline-Inventory
↳ ordered but not delivered
(S.R). (d * L.T)

Total annual Cycle-Inventory Cost = Annual Holding cost
C ⊕ Annual ordering cost

$$C = \frac{Q}{2} H \oplus \frac{D}{Q} S$$

avg. Inventory * Holding cost

↳ num of orders * ordering cost

(1) Annual holding cost = Avg. Cycle. Inv * Unit. holding. Cost
$Q/2$ * H

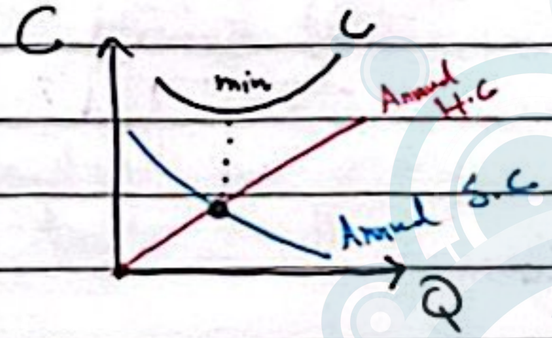
(2) Annual ordering cost = Num of orders per year * ordering cost
D/Q * S

$$\underset{b}{\boxed{C}} = \frac{Q}{2} H + \frac{D}{Q} S$$

Cost : we have to minimize this cost

$\downarrow\uparrow \boxed{\frac{Q}{2} H}$ $Q \uparrow \downarrow$ $\uparrow\downarrow \boxed{D/Q \; S}$ $Q \uparrow \downarrow$

→ we have to find the Best value for Q



Annual H.C = Annual S.C

C = minimum

$$\frac{Q}{2} H = \frac{D}{Q} S \rightarrow Q^2 = \frac{2DS}{H} \quad (1)$$

EOQ (model) $\rightarrow Q = \sqrt{\frac{2DS}{H}}$

$$\frac{dC}{dQ} = \frac{H}{2} + \frac{-DS}{Q^2} = \text{zero} \quad (\text{to find } C \text{ minimum})$$

$$\frac{dC}{dQ} = \frac{HQ^2 - 2DS}{2Q^2} \rightarrow HQ^2 - 2DS = 0 \quad (2)$$

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

$$Q = \sqrt{\frac{2DS}{H}}$$ → called the economic order Quantity

$$EOQ = \sqrt{\frac{2DS}{H}}$$ ← model

→ it'll give the lowest cost to order and hold the inventory.

$$\boxed{\text{Time between orders (TBO)} = \frac{1}{n} = \frac{Q}{D}}\ \text{year}$$

Ex// $TBO = \frac{Q}{D}$ year D (unit/year)

$= \frac{Q}{D} * 12$ months

$= \frac{Q}{D} * 52$ weeks

$= \frac{Q}{D} * 365$ days

Ex:

$\rightarrow D = \frac{18 \text{ unit}}{\text{week}} \times \frac{52 \text{ week}}{\text{year}}$

Sells (18 unit/week) $d = 18$ unit/week

the supplier charges 60\$ per unit   Unit cost = 60 \$

ordering cost is 45\$ $S = 45\$$

(Annual (Holding Cost) = 25% of Unit cost = $60 \times 0.25 = 15\$/u/y$

$(H = 15\$/\text{unit}/\text{year})$

Management chose a 390 unit lot size $Q_{current} = 390$ unit

Find $C_{current}$, EOQ, C_{EOQ}

$$C_Q = \frac{390}{2} 15 + \frac{(18 \times 52)}{390} (45) = 3033\$$$

$$EOQ = \sqrt{\frac{2(18 \times 52) \times 45}{15}} = 74.9 \approx 75 \text{ unit}$$

$1124.1 < 3033$

$C_{EOQ} = 1124.1\$$ $C_{EOQ} < C_{current}$

$$TBO = \frac{Q}{D} = \frac{75}{18 \times 52} = 0.08 \text{ year}$$

= 29 days

= 4 weeks

= 1 month

* 12 orders per year

monthly

Inventory Management

classification
SKU

Choosing Inventory Control System

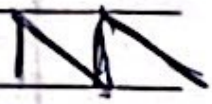
- How much to order?
- when to order?
- how often to review?

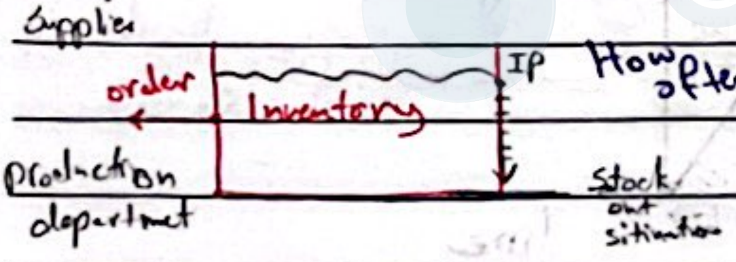
Independent SKU

- Continuous Review System
- periodic review system
- Hybrid system
  - optional Replenishment
  - base-stock system

dependent SKU
· MRP ·

Traditional Review systems





How often to review?!

When to order?!

How much to order?

These Questions would be answered by P (Control - Systems)

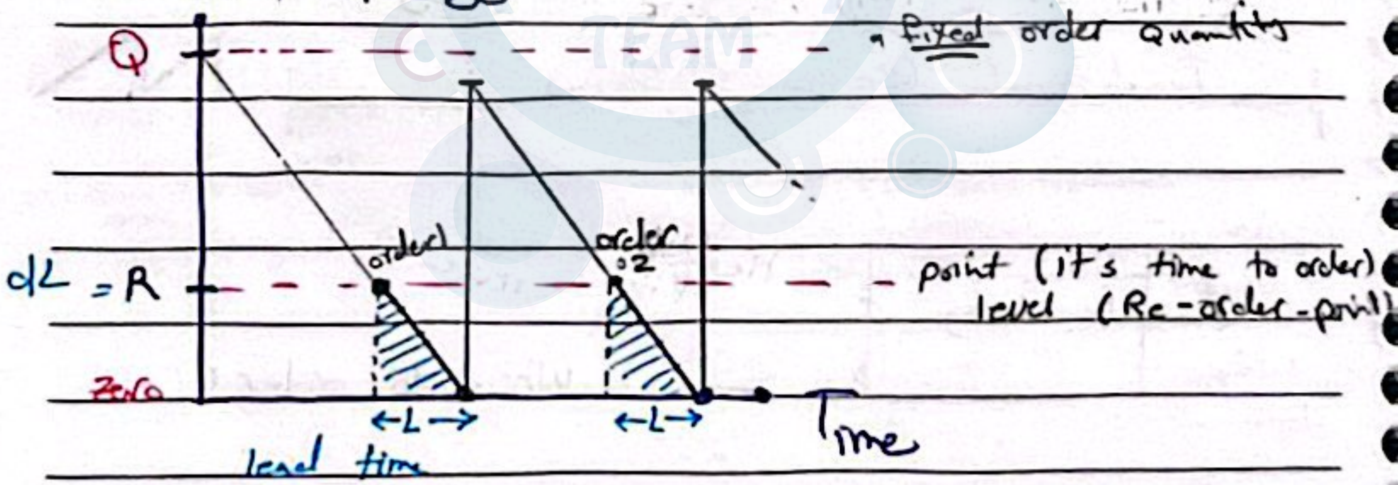
Continuous Review System

How often to review IP?	when to order?	How much to order?
Continuously, with each withdrawal	when (IP) reaches the predetermined level R	a fixed Quantity Q

Continuous Sys has another names like: Fixed quantity Sys, ROP system, Q system

ROP = Reorder point (R)

$IP = OH + SR - BO$



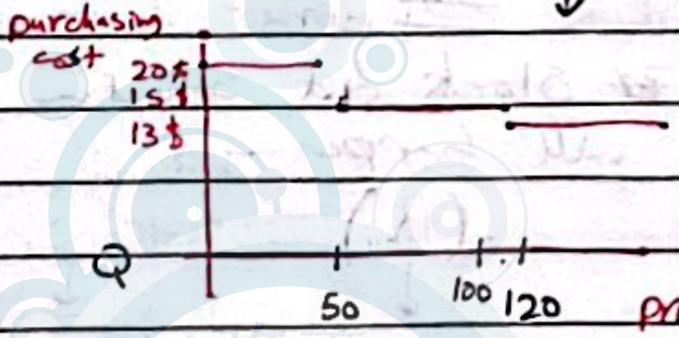
lead time till the Q is reached

(Q, R) are fixed Quantity

$R = dL$ → required demand during L

Q (How to be choosed?)

- EOQ
  - to minimize (C)
- Container Size
  - transportation
  - shelf
- Price-break quantity
- Convenient quantity
  - supplier
  - production
- expiry factor



price-break Quantity

* let say Q. EOQ. 100 unit

50 unit → 15$ per unit
100 unit → 15$ per unit
∴ 120 U → 13$/unit

* according to these factors we choose the best value for Q

(R)

demand needed during the lead time

when to order ?:

1. Zero stock ⟶ order ✗
2. R (level IP) ⟶ order ✓ ⟶ using R (IP)

Zero stock = order is reached → Q (IP)

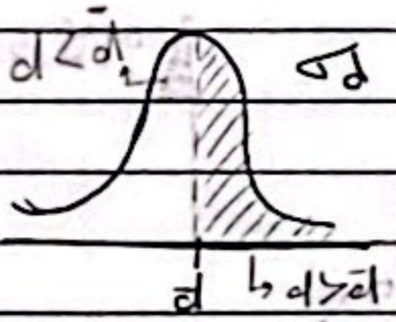
↳ No stock out situation will happen

(R)

Demand constant (d)	Demand var ($\frac{\bar{d}}{\sigma_d}$)	Demand var ($\bar{d}, \sigma_d$)
lead time constant (L)	Lead-time constant (L)	Lead-Time Var ($\frac{\bar{L}}{\sigma_L}$)
$R = d\ L$	$R = \bar{d}L \oplus$ Safty stock	
$d = 2$ unit/day	$S.S = Z_{SL} * \sigma_{dLT}$	$R = \bar{d}\bar{L} \oplus S.S$
$L = 2$ days	Z_{SL} : no of ST.Dev needed to achive Service level	$S.S = Z\ \sigma_{dLT}$
during $L = 2$ days we need 2 unit/day		Z : Z of service level
$R = 2 \times 2 = 4$ units	$\sigma_{dLT} = \sigma_d \sqrt{L}$	$\sigma_{dLT} = \sqrt{\bar{L}\ \sigma_d^2 + \bar{d}^2\ \sigma_{LT}^2}$
	$R = \bar{d}L \oplus Z_{SL}\ \sigma_d \cdot \sqrt{L}$	

1. d and L normally distributed
2. Safty, fixed due to stock (Normal distribution)

demand normally distributed:

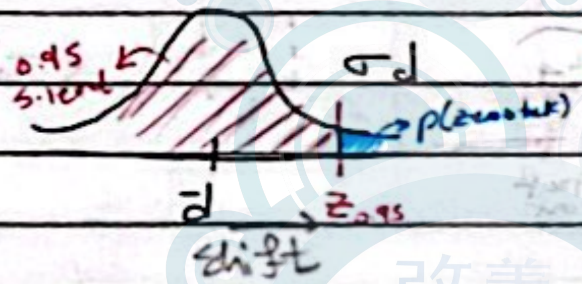


$p(d > \bar{d}) = 0.5$

$p(d < \bar{d}) = 0.5$

$\hookrightarrow$ (zero stock = 50%) is very high value.

$\rightarrow$ Service level :- avoiding zero stock situation.



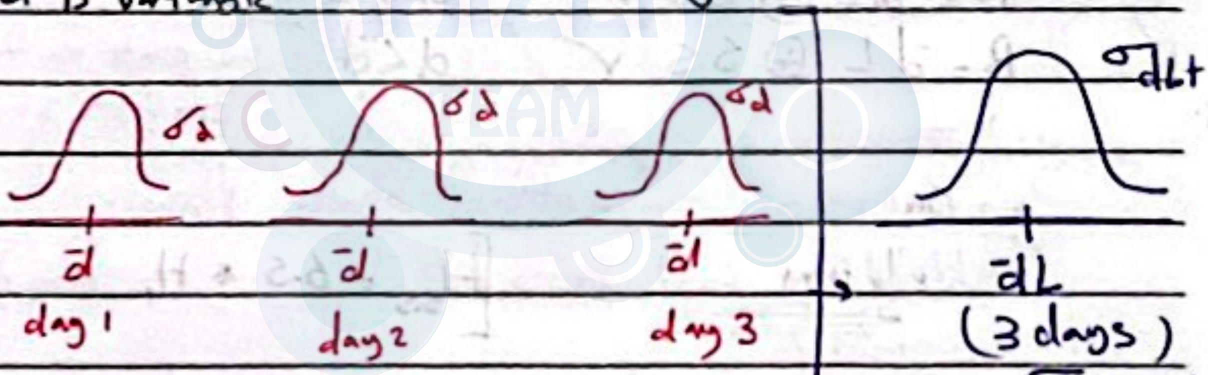
Service level = 95%

p(Stock-out) = 5% ✓

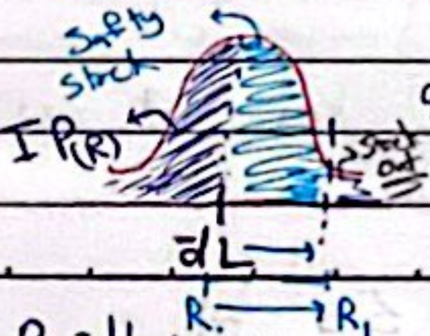
acceptable.. ✓

Lead time = 3 day (Constant)] $\rightarrow$ case 2

d is variable



$\sigma_{dLT} = \sqrt{3} * \sigma_d$



$R = \bar{d}L + S.S$

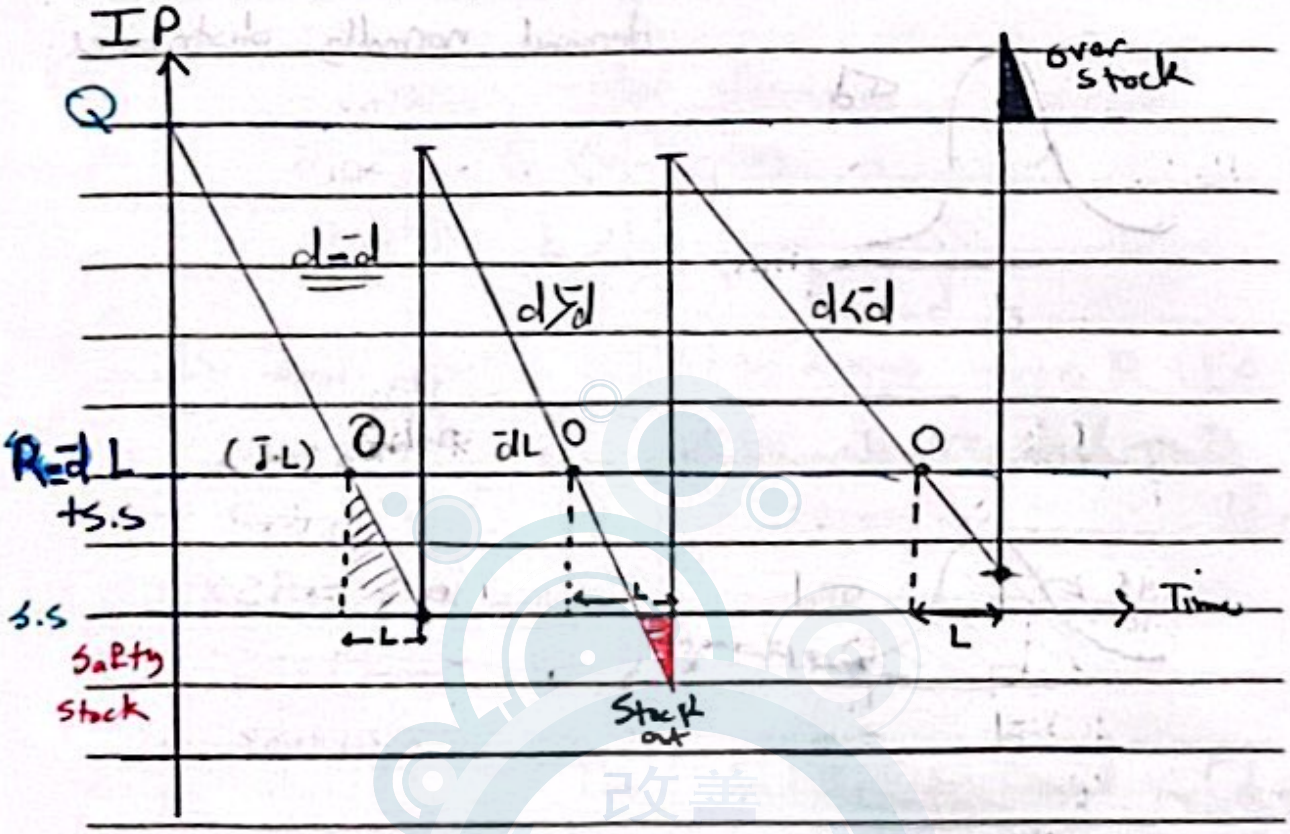
95% of service level

$R = R_1$ ✓ service level

$R > R_1$ X zero-stock situation

$\hookrightarrow$ 0.05 propability of occurrance

$$(R = (\bar{d} L) + S.S)$$



$R = \bar{d}L$, $R = dL$ ✓ $\quad d = \bar{d}$

$R = \bar{d}L + S.S$ ✓ $\quad d > \bar{d}$ we take from S.S

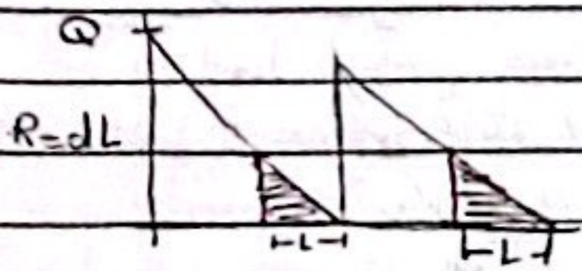
$R = \bar{d}L + S.S$ ✓ $\quad d < \bar{d}$ we put on the saftey stock

↳ Saftey stock is fixed during time..

↳ Holding cost only $[H_{S.S} = S.S * H$, \$/unit/year$]$

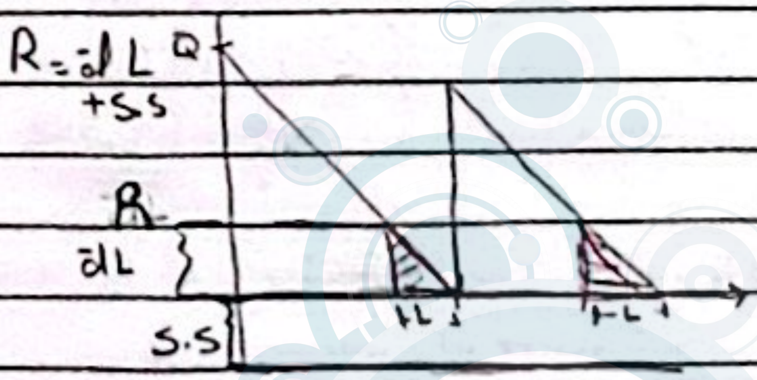
Service level → indicates how much we can take from the S.S (95%) → we will avoid zero stock by 95%. but it could be occured by 5% only ;

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



d constant

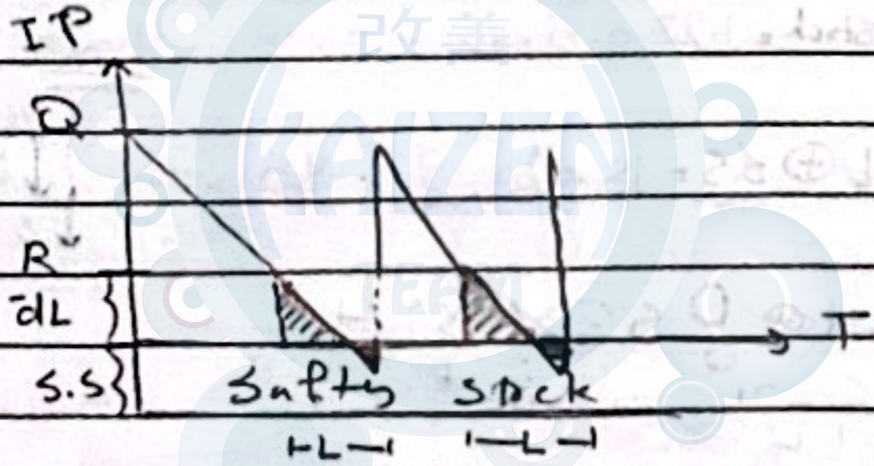
L costant



d variable

L constant

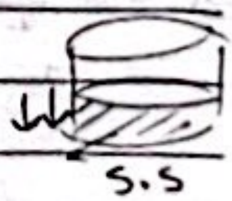
($d = \bar{d}$)

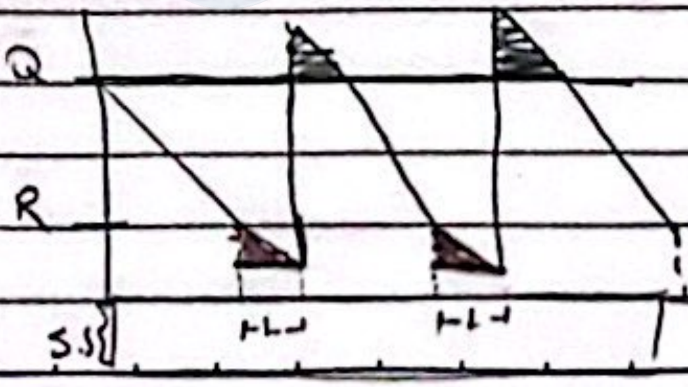


d var

L costant

$d > \bar{d}$





$d < \bar{d}$

L constant

Ex:- operates 52weeks ($D \frac{unit}{year}$, year = 52week)

EOQ = 75 unit

H = 15 \$ /unit/year

S = 45 \$ /order

$\bar{d}$ = 18 unit/week

σ_d = 5 units

L = 2 week

90% of service level

Find: Safty Stock, R, C

[1] $S.S = Z_{0.9} \times \sigma_{dLT}$

90% S.L

0.9

$\bar{d}L$ $Z_{0.9} = 1.28$

$\sigma_{dLT} = \sqrt{2} \times 5 = 7.07$

[1] Safty stock = $1.28 \times 5 \times \sqrt{2} = 9.05 \simeq$ 9unit

[2] $R = \bar{d}L + S.S = 18 * 2 + 9 = 45$ unit

R , 36 + 9 = 45

$\bar{d}L = 36$

S.S = 9

[3] $C = \frac{Q}{2} H + \frac{D}{Q} S + (S.S)\, H$

cost Q = 75 unit

cost holding S.S

$= \frac{75}{2}(15) + \frac{18 \times 52}{75}(45) + 9(15) = 1259.1$ \$

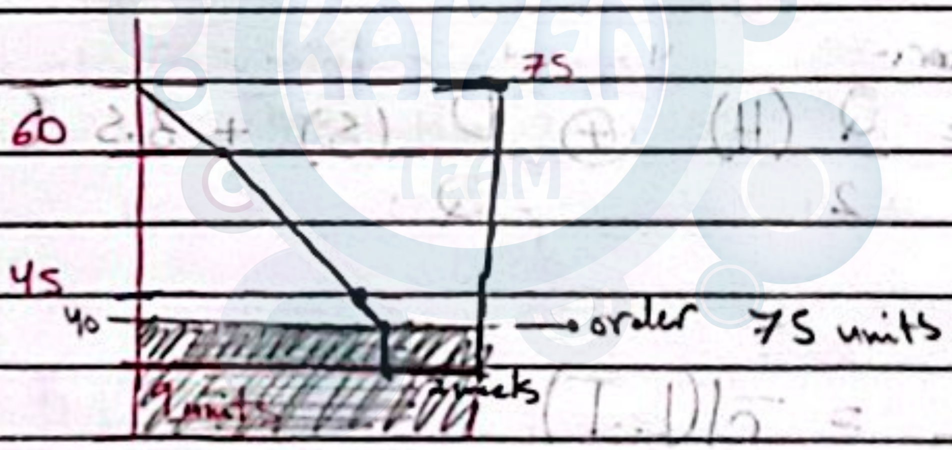
The on-hand Inventory equals 60 units. There is no Scheduled receipts & no back orders. Now, we make a withdrawal of 20 units. Is it time to order? and How much?

OH = 60
SR = 0
BO = zero

IP = 60 + 0 + 0 = 60 units
R = 45 units

60 - 20 = 40 unit are left

So, we have to order 75 units.



Ex:

$\bar{d}$ = 12000 pens

σ_d = 3000 pens

The current Inventory policy for replenishment

Q = 156000 pens

$\bar{L}$ = 5 ~~days~~ weeks , σ_{LT} = 2 weeks , 95% of S.L

Find R:- $R = \bar{L} \cdot \bar{d} \oplus Z_{0.95} * \sqrt{\bar{L}\,\sigma_d^2 + \bar{d}^2\,\sigma_{LT}^2}$

$= 5 * 12000 \oplus 1.65 * \sqrt{5(3000)^2 + 12000^2(2^2)}$

$= 101117.7 \approx$ 101118 pens

Remember:-

$$\boxed{C = \frac{Q}{2}(H) \oplus \frac{D}{Q}(S) + S.S\,(H)}$$

Pipeline Inventory $= \bar{d}(L.T)$

IP

Manually | Technology | Visual

$IP = OH + SR + BO$

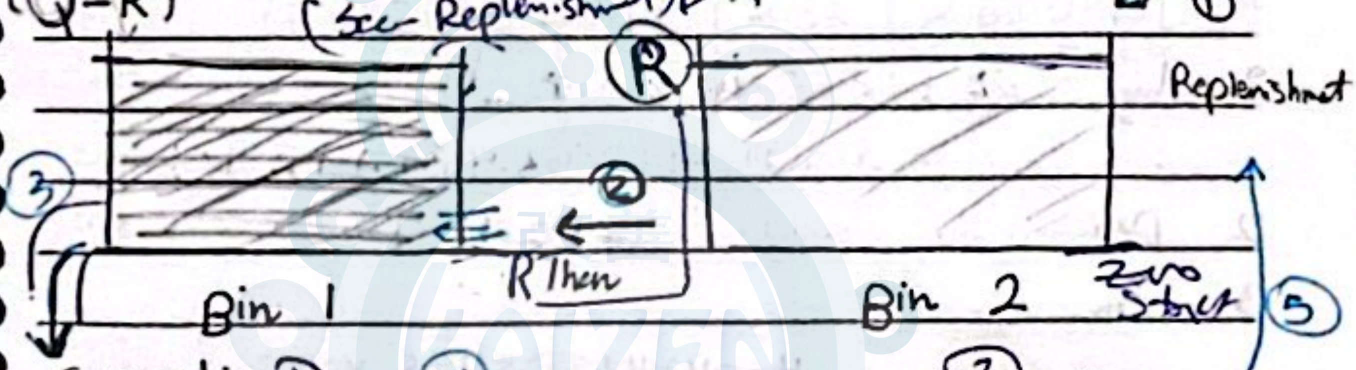
- Scanners -
- barcodes -
- Software -

(OH)

"Visual Q System" Two bin system

(Q-R)

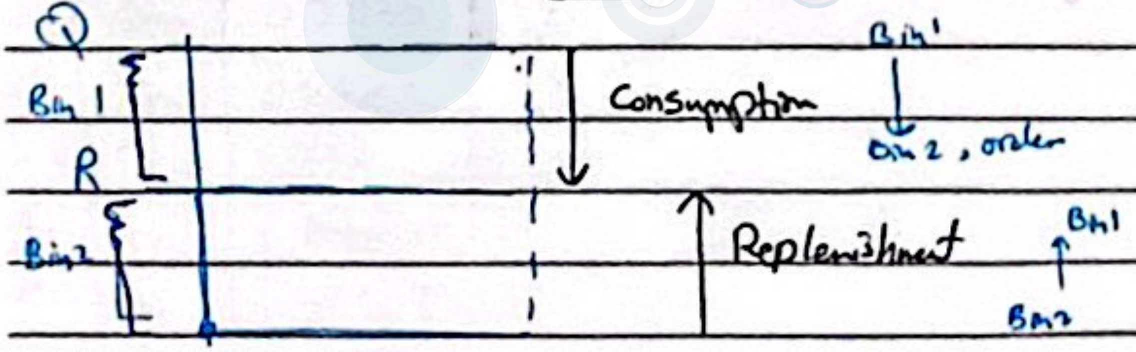
(See Replenishment then)



Consuption ① ④ Then Bin 2 Consumption ② from R

- R -

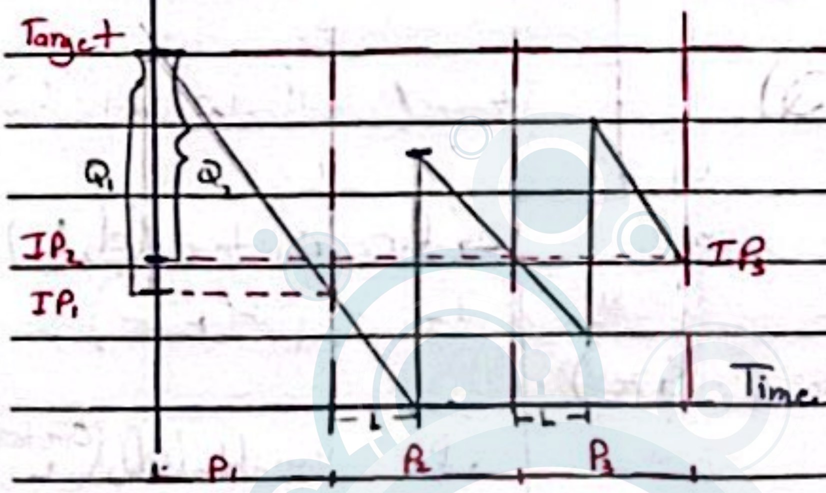
order



"Periodic Review Sys"

{Fixed-Interval, Re-order-sys, P-sys, Periodic Re-order-sys}

IP (IP = OH + SR - BO)



→ we check the IP each period (P)

→ The protection interval (P+L)

ord1	ord2	ord3
Q_1	Q_2	Q_3
$Q_1 = T - IP_1$	$Q_2 = T - IP_2$	$Q_3 = T - IP_3$

How often to renew (IP)?!	when to order?!	How ~~many~~ much to order?!
Periodically at the end of the review period (P)	at the end of each review period (P)	$Q = (T - IP)$

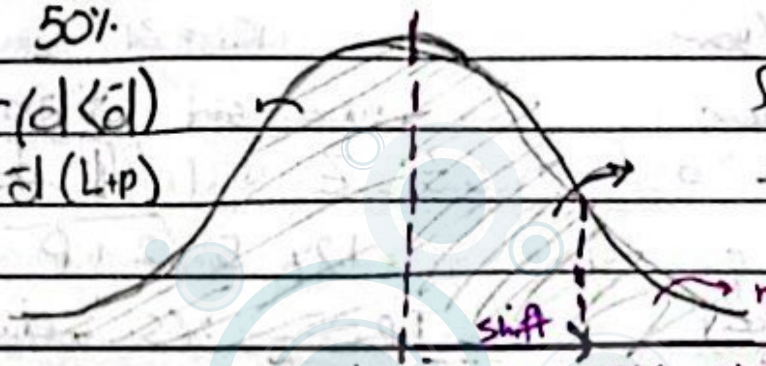
How to determine the value of P & T?!

How to Determein ? : P & T

Perical "P"	"Target" "T"
$\boxed{P}$ (Time between order)	
$TBO = \frac{Q}{D} = \frac{P}{D}$	protection Interval $PL = (P + L.T)$ → possibility to have (stock-out-sitivation)
① → for the (EOQ) $P = \frac{EOQ}{D}$	→ for constant (d, L) $T = d(P+L)$
② → for the (container size) $P = \frac{Q\ (\text{con-size})}{D}$	→ for variable (d), (Constant L) $(\bar{d}, \sigma d)$ ~ (Normal dist)
③ → for (Price-break-Q) $P = \frac{Q\ (\text{Price-break})}{D}$	$T = \bar{d}(P+L) + S.S$ $S.S = (Z)\ \sigma_{(P+L)}$ $\sigma_{(P+L)} = \sigma d \sqrt{P+L}$
④ → for a (Selected Q) $P = \frac{Q\ \text{selected}}{D}$	Z: number of Standard diviation needed to achive Service level
Selected by :- Supplier, productive line, expery date, budget.	

T (Variable demand, Constant Lead time)

$(\bar{d}, \sigma_d)$ (L)



$T = \bar{d}(L+P)$ achives 50% of the (Service level)

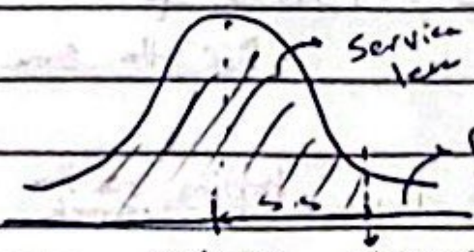
to get a higher Service level (we shift the T to the right from $T = \bar{d}(L+P)$)

$$T = \bar{d}\,(L+P) + S.S$$

$$S.S = Z\ \sigma_{(AD)}$$

$\hookrightarrow \sigma_{(P+L)} = \sigma_d \sqrt{P+L}$

Z: number of Standard-div to achieve the service level



Z (Service level)

Bird feeder:- useing P-System

operates 52 weeks

$\bar{d} = 18$ Units/week

$\sigma_d = 5$ units

H = 15 \$/unit/year

S = 45 \$/order

EOQ = 75 unit

L = 2 weeks

90% of (Service Level)

$Z = Z_{(0.9)} = 1.28$

Find:- S.S = ?!

T = ?!

C = ?!

$S.S = Z \, \sigma_d \sqrt{L+P}$

$= 1.28 \; 5 \sqrt{2+P}$

$P\text{-}TBO = \frac{75}{18(52)} = 0.08$ year

$= 4.16 \approx 4$ weeks

① $S.S = 1.28 * 5 * \sqrt{6}$

$= 15.677 \approx 16$ units

② $T = 18(6) + 16$

$= 124$ units

$$C = \frac{\bar{d}P}{2}(H) + \frac{D}{\bar{d}P}(S) + S.S(H)$$

$$C = \frac{18(4)}{2}(15) + \frac{18(52)}{18(4)}(45) + 16(15)$$

C = 1365 \$

For the same service level

Q-sys | P-sys

C = 1259 \$ | Holding on the S.stock < | C = 1365 \$

S.s = 9 units | longer Protection Interval | S.s 16 units

Protection Interval = L | P. Interval = (L+ P)

Recently, the OH equals 60 units (No S.R, No BO)

Now; it's the end of review period (P) and OH is 45)

is it the time to order? and How much

(1) it's the end of the review period P .. yes, it's the time to order

(2) $Q = T - IP_{(at\ P)}$

$= 124 - 45 = \underline{79 \text{ units}}$ close to the economic order quantity

Target (T)

Demand d (constant)	Demand ($\bar{d}, \sigma_d$) variable	Demand variable ($\bar{d}, \sigma_d$)
lead time L (constant)	lead time (L) constant	L.T variable ($\bar{L}, \sigma_L$)
$T = d(P+L)$	$T = \bar{d}(P+L) + S.S$	variability on both demand and protection interval → not normally distributed
	$S.S = Z_{SL}\,\sigma_d(\sqrt{L+P})$	
	normal-distribution	

We use simulation to estimate the demand during the protection interval to use it to select (T) under the desired service level.

data must be selected (to determine the distribution)

C.R.Sys
FOQ   P.R.Sys
Q-system   P_system

	C.R.Sys / FOQ / Q-system	P.R.Sys / P_system
Cost :-	less cost	higher cost
Q :-	Fixed Q	not-fixed Q
TBO :-	not fixed (P)	fixed (P)
IP :-	Continuously	Periodically

Factory → Same supplier (one order for both X_2, X_3) → P-system

X_1	X_2	X_3
X_4	X_5	X_6
X_7	X_8	X_9

(worker) for checking
Q-system ✓ IP
Continuously

hospital

Function:- (not for checking only)

nursing staff
→ P-system ✓

x-ray X_1 X_2 X_3	OR X_4 X_5 X_6
emergency X_7, X_2	MRI X_9 / X_{10}

X_{10} → discount for Q = 1000
→ Q-system

Inventory Management

Classification of SKUs ?!

ABC
(Classification)

Choosing inventory control approach ?!

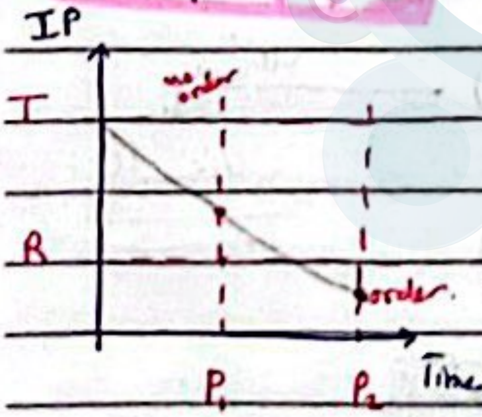
- How much to order ?!
- when to order ?!
- How often to review IP ?!

Independent demand SKUs

- Continuous Review Sys
- Periodic Review Sys
- hybrid System
  - optional Replenishment
  - base-stock System

dependent demand SKUs

- Material Requirements Planning (MRP)



$Q = T - IP_{(P_2)}$

- we check the IP at P
- we put an order if $\boxed{IP \leq R}$

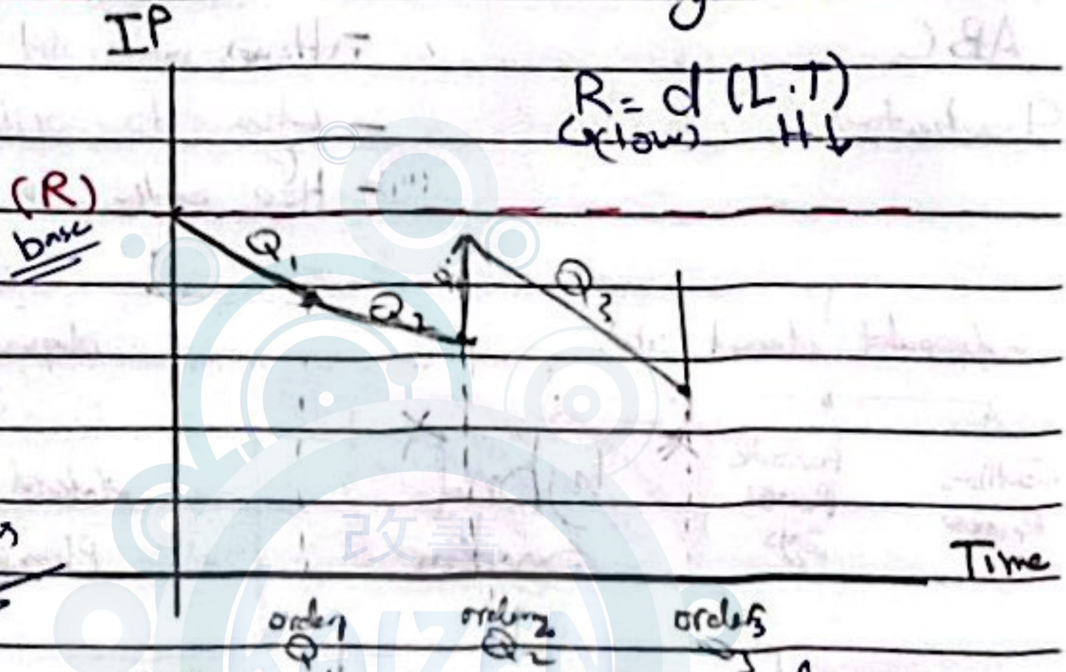
for cheap items (Holding cost ↑)

The (Max - Min) system
The (S - s) system

hybrid system

optional Replenishment

* Base Stock * System



for expensive items (holding cost)

* with each withdrawal we put an order

* Q = ~~[illegible]~~ (withdrawal Q)

IP (P-system)

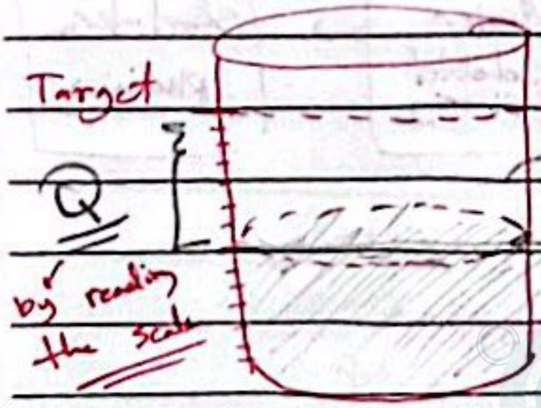
manually
- OH
- S.R
- BO

Technology
- softwares
- OH: sensors, barcode

Visually

$IP = OH + S.R - BO$

Visual (P- System) [one-bin-system]



withdrawal at period P (IP)

$Q = T - IP$

↳ visually by reading the scale

→ for liquids (compulsory)

① optional Replenishment	② base-stock-system
How much to order?:	How much to order?:
$Q = T - IP$	Q = withdrawal (Q)
when to order?:	when to order?:
at P if and only if $(IP \leq R)$	with each withdrawal
How often to review?:	How often to review?!
at end of P	Continously with each withdrawal. $(IP \leq R)$ always
(minimize ordering cost)	(minimize Holding Cost)
Holding ↑ Cheap	ordering ↑ (expensive)

(p1) $D = 5000$ unit

$S = 15\$/\text{order}$ Find EOQ?

$H = 4\$/\text{unit}/\text{year}$ C?

① $EOQ = \sqrt{\dfrac{2(5000)(15)}{4}} = 193.6 = 194$ unit drills

② $C = \dfrac{5000}{194}(15) + \dfrac{194}{2}(4)$

$= 774.6\$$

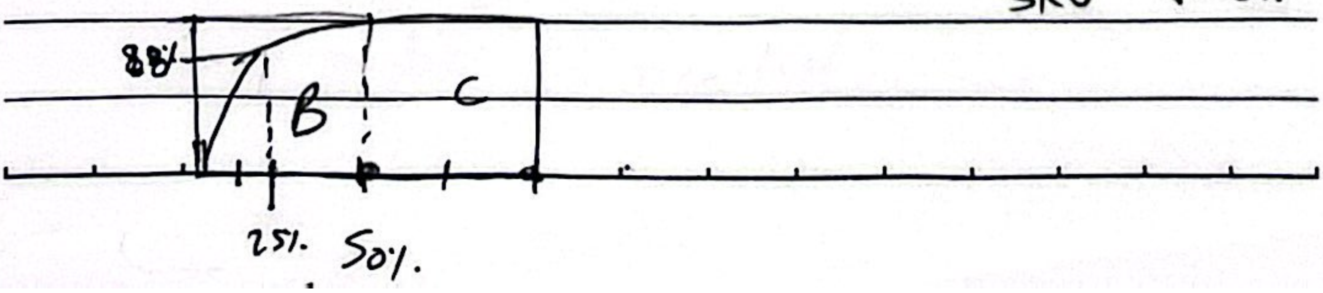
#SKU	Dollar	Annual Usage	A.U.V
1	0.01 $	1200	12 (8)
2	0.03 $	120 000	3600 (4)
3	0.45 $	100	45 (7)
4	1 $	44000	44000 (1)
5	4.5 $	900	4050 (3)
6	0.9 $	350	315 (5)
7	0.3 $	70 000	21000 (2)
8	1.5 $	200	300 (6)
Sum			73322

4, 7 class A

2, 5 class B

1, 3, 6, 8 class C

A.U.V	Cumulative A.U.V%	Cumulative SKU%	
44 000	60.00%	12.5%	Class A
21000	88.65%	25%	A.U.V 25% SKU, 88.65%
4050	94.17%	37.5%	Class B
3600	99.08%	50%	50% SKU → 99.08% AUV
315	99.5%	62.5%	
300	99.92%	75%	Class C
45	99.98%	87.5%	
12	100%	100%	100% SKU → 100% A.U.V



$\bar{d} = 300$ unit / week , $\sigma_d = 15$ unit

$L = 9$ weeks

Find ① $\sigma_{dLT} = \sqrt{9} * 15 = 45$ unit

② The avg d during $L = 300 \times 9 = 2700$ unit

③ 0.99 service level , $S.S = 2.33 \times 45 = 105$ unit

$R = 2700 + 105 = 2805$ unit

$\bar{d} = 50 \frac{unit}{week}$

Unit cost $= 650\$/unit$

$Q = 350$ unit

$L = 2$ weeks

$S.S = $ 1-week supply

$= 50$ units

$R = \bar{d}L + S.S$

$= (50 \times 2) + S.S$

$= 100 + 50 = 150$ unit

(S.P. 4) $\bar{d} = 100$ (unit/day), $\sigma_d = 30$ unit

$L = 3$ days

$H = 9.4\$ / unit / year$

$S = 35\$ / order$

Service level $= 92\%$

a) $Q = 440$ unit

$OH = 40$, $SR = 440$, $BO = $ zero

$IP = 480$ unit

$R = (100 \times 3) + \underbrace{1.41 (30\sqrt{3})} = 373$ unit

→ no order is needed

$S.S = 1.41 * (\sqrt{3} \cdot 30) = 73$ unit

$\cancel{C = \frac{(100*365)35}{440}}$ it operats $\underline{5 \text{ day}}$
(a week)

$$EOQ = \sqrt{\frac{2(D)35}{9.4}}$$

$$D \frac{unit}{year} = \frac{100 \, unit}{\cancel{day}} * \frac{5 \cancel{day}}{1 \cancel{week}} * \frac{52 \cancel{week}}{1 year}$$

$$D = 100 * 5 * 52 \frac{unit}{year}$$

$D = 26000$

$$EOQ = \sqrt{\frac{2(2600)35}{9.4}} = 440 \text{ unit (mixture)}$$

$$C = \frac{(26000)}{440} 35 + \frac{(440)}{2} 9.4 + 9.4 (\cancel{7}3)$$

$$C = 4822.4 \$$$

52 weeks / year

7 days / week

$\bar{d} = 95$ unit/week $\rightarrow D = 4940$ unit/year

$S = 58$ \$/order

$H = 2.69$ \$ /unit/year

Service level = 0.9 (90%)

$L = 4$ weeks

$\sigma_d = 16$ unit

$$EOQ = \sqrt{\frac{2(4940)\,58}{2.69}} = 461.5 \approx 462 \text{ unit}$$

$$TBO = \frac{Q}{D} = \frac{462}{4940} = 0.09 \text{ year} \approx 5 \text{ weeks} \approx 1 \text{ month}$$

$$R = (95 \times 4) + 1.28(16\sqrt{4}) = 421 \text{ unit}$$

S.S = 41 unit

$$\frac{17 * 10^{-4}}{1 \quad * 10^{-4}}$$

((Solved problem 5))

operates 365 day / year

$\bar{d} = 275$ bars/day , $\sigma_d = 30$ bars

$S = 10\$$ / order , $H = 0.3$ \$/bar/year

$\bar{L} = 5$ days , $\sigma_{LT} = 1$ day

① $EOQ = \sqrt{\frac{2(100375)10}{0.3}} = 2587$ bars

② R with 99% of service level $Z_{0.99} = 2.33$

$S.S = 2.33\sqrt{5(30)^2 + (275^2)} = 660$ unit

$R = (275 * 5) + S.S$

$= 2035$ bars

$C = \left(\frac{100375}{2587}\right)10 + 0.3(660) + 0.3\left(\frac{2587}{2}\right)$

$= 974.05\ \$$

problems

Ex 9.7 a:-

BO = 5 sets

OH = zero , SR = zero

T = 400

$IP = 0 + 0 - 5 = -5$ sets

$Q = T - IP = 400 + 5 = 405$ sets will bring IP up to T

"Solved problem 5"

① EOQ :-

$\bar{d} = 275$ bars/day $D = 275 * 365 = 100375$ item

$\sigma_d = 30$ bars

$S = 10$ \$

$H = 0.3$ \$/unit/year

$\bar{L} = 5$ days

$\sigma_L = 1$ day

① EOQ :-

$$EOQ = \sqrt{\frac{2(100375)(10)}{0.3}} = 2587 \text{ bars}$$

" Solved 6"

1. operates 5 days/week for 52 weeks
2. Q = 440 mixers
3. $\bar{d}$ = 100 mixer/day , σ_d = 30 mixer
4. L = 3 days
5. H = 9.4 \$/unit/year , S = 35 \$/order
6. S.L = 92% → $Z_{0.92}$ = 1.41

→ D = 100 * (52 * 5) = 26000 mixers

→ protection Interval = P + L ✓

$P = TBO = \frac{440}{26000} = 4$ days

Protection Interval = 4 + 3 = 7 days

→ $Target(T) = 100(7) + 1.41(30)\sqrt{7} = 812$ bars

S.S = 112 bars

a) Find C :-

$$C = \frac{100 * 4}{2}(9.4) + \frac{26000}{100(4)}(35) + 112(9.4)$$

C = 5207.8 \$

"Ch16" planning Sufficient Resources

"Inventory Management"

↓

choosing Inventory control approach

- Independent SKUs
- "Dependent" SKUs → MRP: The material requirements planning

* Enterprise resource planning :- (Information Sys)

ERP Sys → HR, Sales & Marketing, Manufacturing, logistics, Accounting & finance, Customer Service, data analysis

* it's an information system links all these activities (function)

MRP: it's a computerized information system ((used to manage the Inventory for dependent (SKUs) demand))

↳ to take a decision about: How much to order? When to order? How often to Review --)

For each dependent demand SKU.

MRP Explosion

↓

Dependent (SKU) ← Material

How much?! ← Requirement

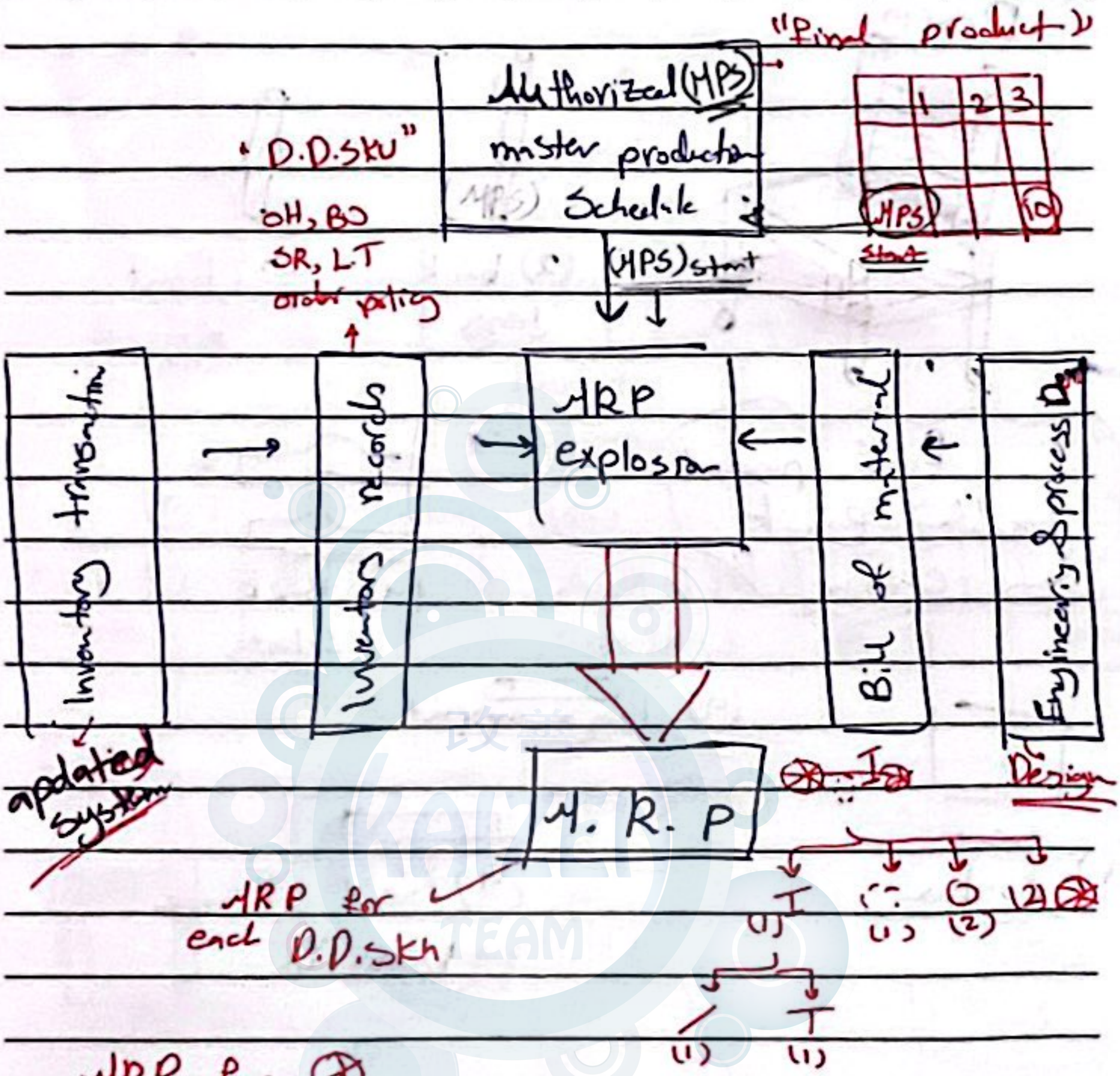
when ?! ← Plan

How often ↵

(continuously) by an updated system

	1	2	3	4	5
requirments ←					
How much to order ←					
when to order ←					

MRP for Dep. SKU

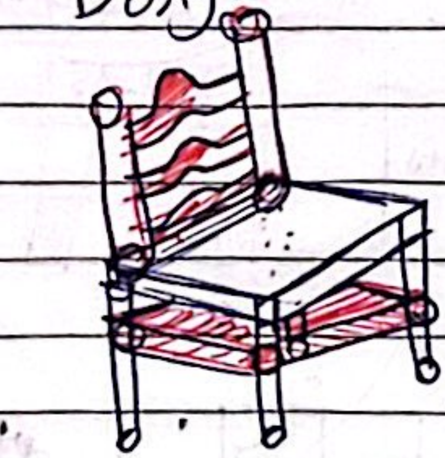


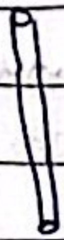
MRP for ⊗

	1	2	3
Gross Required			20
when to order?			

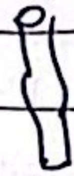
if (L.T = 2 weeks)

"Design"





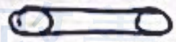
(2) back legs



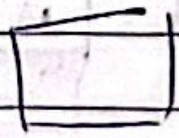
(2) front legs

final product
Ladder-Back-Chair

(4) Back slats



(4) legs support

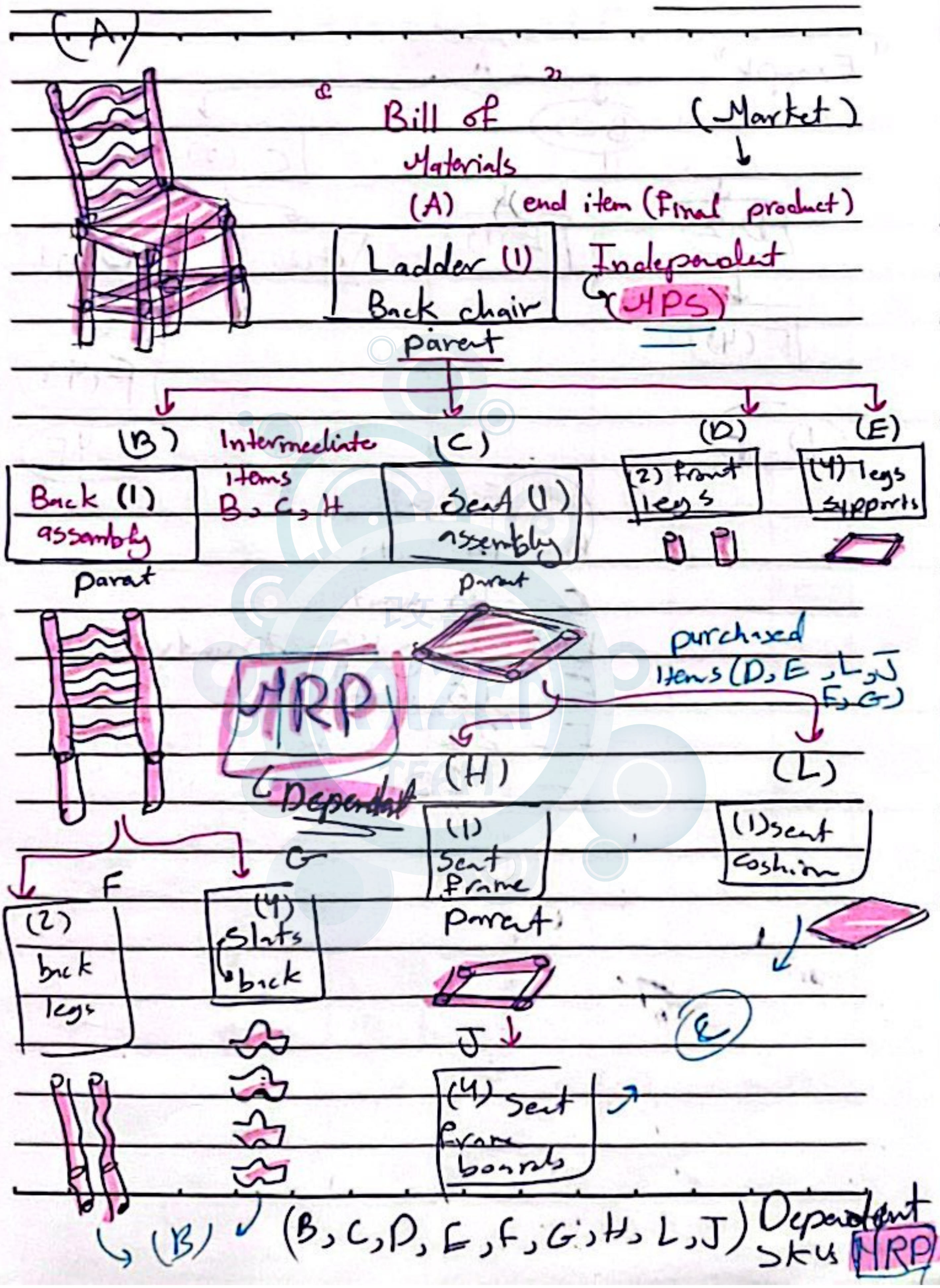


(1) seat coshin

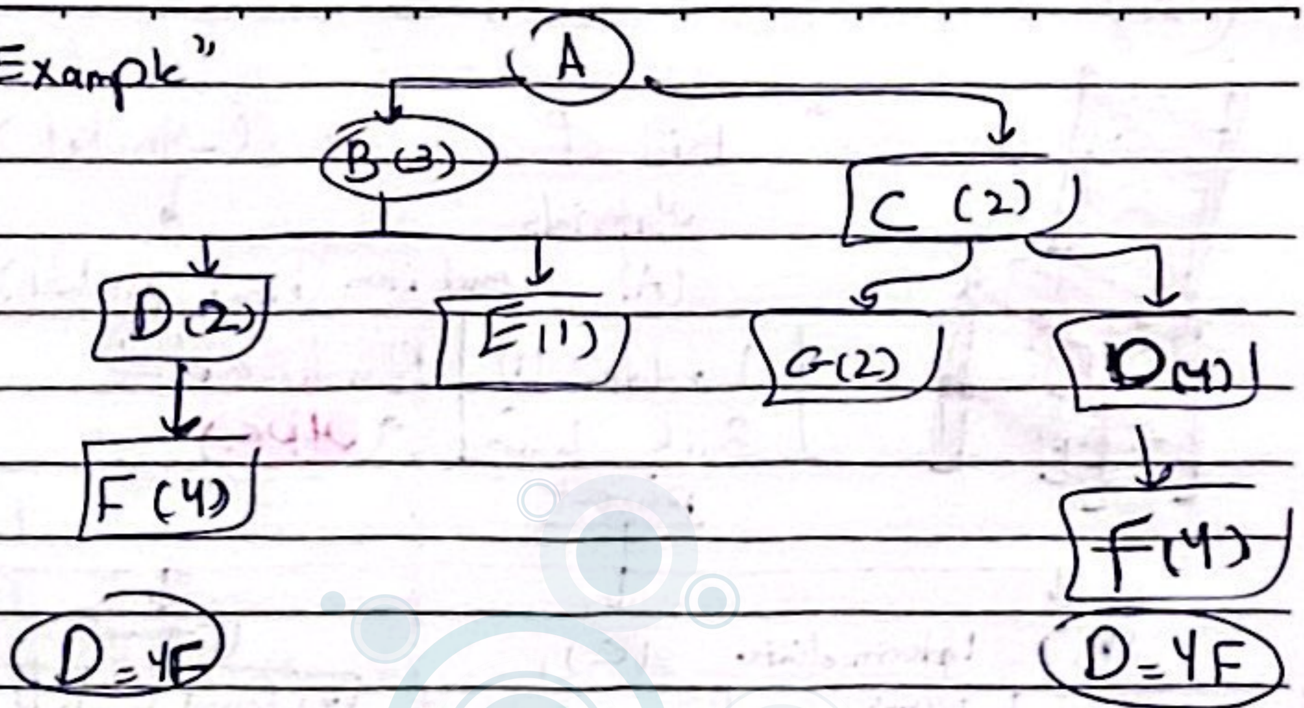
(4) seat frame boards

Company

- Ladder Back chair
- Kitchen Chair
- desk Chair


(A)
Bill of Materials
(Market)
(A) (end item (final product)
Ladder (1) Back chair
parent
Independent
MPS
(B)
Back (1) assembly
parent
Intermediate items B, C, H
(C)
Seat (1) assembly
parent
(D)
(2) front legs
(E)
(4) legs supports
purchased items (D, E, L, J F, G)
MRP
Dependent
(H)
(1) Seat frame
parent
(L)
(1) seat coshion
F
(2) back legs
G
(4) Slats back
J
(4) Seat frame boards
(B)
(B, C, D, E, F, G, H, L, J) Dependent SKUs MRP

"Example"



A = 5 units

B = 15 units

C = 10 units

D = 30 + 40 = 70 units

E = 15 units

F = 280 units

G = 20 units

MPS (master production schedule)

↳ for (final product)

MPS

Item:- Ladder-Back Chair

Order policy:- 150 units

Lead time:- 1 week

Quantity On Hand: 55	April 1	April 2	April 3	April 4	May 5	May 6	May 7	May 8
Forcast (Demand)	30	30	30	30	35	35	35	35
Customer orders booked	38	27	24	8	0	0	0	0
("expected") projected OH Inventory (shortage / OH (qua))	(55-38) 17	(17-30) ① shortage; ② 150+17-30 = 137	107	77	42	7	① shortage; ② 122	87
MPS (quantity) Recieved quantity at the begining of the period	Zero	150	zero	Zero	Zero	zero	150	Zero
MPS (start)* *when do we start to Manufacture (final product)	150 (1 week)					150 (1 week)		
available-to-promise (ATP) Inventory	(55-38) 17	2nd week → 6th week (150-27-24-8) 91					(150-0-0) 150	

① Forecast (for April, and May)

Demand

② C.O. Booked → we choose the greater to expect the OH Inventory.

MPS start → MRP explosion

ATP	1	2	3	4	5	6	7	8
	~~17~~	~~91~~					150	
	8	~~71~~						
(updated)		0						

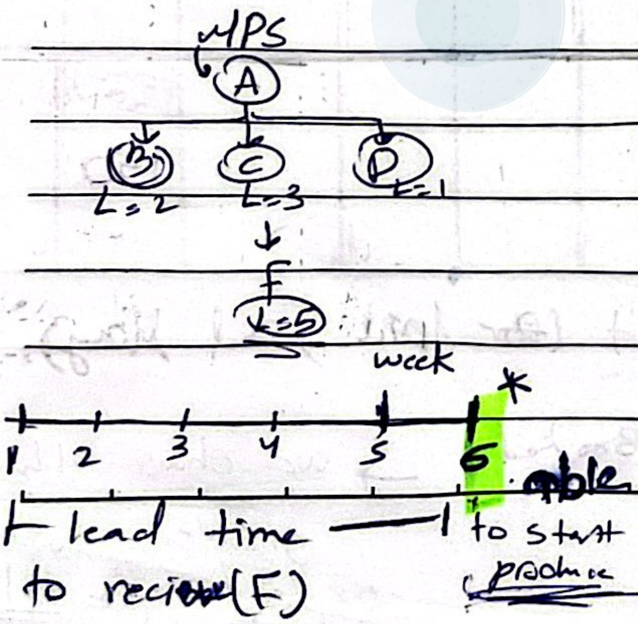
ATP	Customer #	Q	week	Dec
(17+91)	1	20	3	✓
(17+71)	2	100	5	✗
(8+0)	3	80	4	✓

~~17 + 71~~
8 0

updated

Demand

- Customer order Booked (Freezed)
- Forcasted demand → A.T. promise = OH − (C.O.B)



→ by the forcasted demand we can accept an orders without Booking them in the (MPS) → Freezed

but (ATP) → updated

Item: Product (A)

MPS for A

Order Policy : 50 unit
Lead time : 1 week

Quantity / OH $\boxed{5}$	1	2	3	4	5	6	7	8	9	10
Forcast	20	10	40*	10*	0	0	30*	20*	40*	20*
Customer order (booked)	30*	20*	5	8	0	2	0	0	0	0
Projected OH Inventory	25	5	15	5	5	3	23	3	13	43
MPS Q	50	0	50	0	0	0	50	50	50	50
MPS (50 start)		50				50		50	50	
ATP.I	5		35				50		50	50
available to promise = (MPS)Q − (C.O.B)	(55-20 -30)		(50-5 -8-0-2)				(50-0 -0)		(50-0)	(50-0

Customer#	Q	w		Dec	ATP
1	50	5	(40)	X	5 35
2	17	3	(40)	✓	5 ~~35~~ -17
					5 18

MPS → MRP

"MPS (Start)" "Gross requirment"

Bill of materials

Company

- ladder Back Chair (A)
- Kitchen Chair (Z)
- Desk chair

(A) Back Chair → (C) (1) Seat Sub assembly → H, L

(Z) Kitchen Chair → (C) (1) Seat Sub-assembly → H, L

from *MPS Start*

MPS (A)

Period	1	6
MPS Start	150	150

MPS (Z)

Week	4	7
MPS Start	120	120

Item: C (Seat Subassembly)
Description: //

lot size: - FOQ = 230 units
L.T.: - 1 week
safty stock = zero

MRP

GC (Dependent)

week	1	2	3	4	5	6	7	8
Gross Requirment for Prod. line	150			120		150	120	
Scheduled receipts	230							
Projected OH. Inventory [37]	117	117	117	227	227	77	187	187
Planned receipts	0 117>0	0	0	230	0	0 77>0	230	0
* Planned order releases			230			230		

When and How much ?!

lot sizing Rules

1 (FOQ) Fixed order Quantity

2 (POQ) Periodic order Quantity

3 (Lot 4 Lot)

Item (A)

Lot Size:- FOQ = 80 Units

S.S = Zero

L.T = 1 week

week	31	32	33	34	35	36	37	38	39	40
Gross Requirments		60		25		35		45		60
Sch-eduled Receipts										
		reminant		20225			Reminat			
Projected OHI $\boxed{0}$	0	20	20	75	75	40	40	75	75	15
				not reminat						
Planned order rec	0	80	0	80	0	0	0	80	0	0
P.O release	80		80				80			

Shortage → OH < S.S → ordering

(P) the period from the shortage to the next (P) Periods ..

Item A	MRP	Lot size = POQ
S.S = zero	L.T = 1 week	P = 4

week	31	32	33	34	35	36	37	38	39	40
Gross Req		60		25		35		45		60
Sched.Rec										
P.O.H.I $\boxed{0}$	0	25	25	0	0	45	45	0	0	0
Planned Rec	0	85	0	0	0	80	0	0	0	60
Planned Rel	85				80				60	

60 + zero + 25 + zero = 85 for 4 periods (32-35)

(35 + 0 + 45 + 0) for (36 - 39)

special case for POQ $\boxed{P=1}$

(Item A) Lot size = Lot 4 lot

S.S = zero. L.T = 1 week

week	31	32	33	34	35	36	37	38	39	40
Gross Requirments		60		25		35		45		60
Sheduled Rec										
POHI $\boxed{0}$	0	0	0	0	0	0	0	0	0	0
Planned Rec	0	60	0	25	0	35	0	45	0	60
Planned Rel	60		25		35		45		60	

→ only S.S on the OH Inventory

P = 1

G.R = 60

Q = 60

$\boxed{OH = S.S}$

Scanned with CamScanner

$$P = TBO = \frac{Q}{D} = \frac{\text{avg order Quantity}}{\text{annual demand}}$$

(Q) in avg = 80 units
- EOQ ← container
- avg Q ← convenient

$$D = \frac{60+25+35+45+60}{10}$$

D = 22.5 avg weekly demand

Avg Annual Demand = 22.5 × 52 yearly

$$P = \frac{80}{(22.5 \times 52)} \text{ year}$$

$$P \text{ in (weeks)} = \left(\frac{80}{22.5\,(\cancel{52})}\right)_{TBO(y)} \times \cancel{52}\text{ week} = 3.55 \text{ week} \simeq 4 \text{ week}$$

$\boxed{P = 4 \text{ weeks}}$

FOQ week
- Reminant : Holding Cost (disadv), works as Safty.S (adv)
- larger (Q) less ordering Cost
- cheap SKUs (H.C = avg(OH) * H)

POQ
- No Reminant (No Holding for reminant)
- $H.C_{POQ} < H.C_{FOQ}$ (" ")

L4L → (expensive Items).
- No Holding Cost for the OH. (least H.C)
- highest ordering Cost (num of orders ↑↑)

Item A — Lot size: POQ (P=4)

S.S = 80 units — L.T = 1 week

week	31	32	33	34	35	36	37	38	39	40
Gross-Req		60		25		35		45		60
Sheduled Rec										
POHI $\boxed{80}$	80	105	105	80	80	125	125	80	80	80
Planned Rec	0	85	0	0	0	80	0	0	0	60
Planned Rel	85				80				60	

20 < S.S → Shortage — 45 < 80 → Shortage — 20 < 80 → Shortage

→ S.S = 80 units → Fixed

→ OH < 80 → order (planned order Rel)

→ P.O.Receipts for (P Periods) P=4
after 4-periods OH = S.S = 80 units

→ after (4 periods) new order.

Item:- C (Seat subassembly) lot size:- FOQ = 230 units

S.S :- Zero L.T :- 2 weeks

week	1	2	3	4	5	6	7	8
Gross Req	150			120		150	120	
S.R	230							
POHI $\boxed{37}$	117	117	117	227	227	77	187	187
P (Rec)	0	0	0	230	0	0	230	0
P (Rel)		230	~~230~~		230			

L.T = 2 w L.T = 2 w

Item:- C (Seat subassembly) | Lotsize :- POQ P=3 | L.T = 2 weeks | S.S = Zero

week	1	2	3	4	5	6	7	8
Gross Req	150			120		150	120	
S R	230							
POHI $\boxed{37}$	117	117	117	150	150	0	0	0
P (Rec)	0	0	0	153	0	0	120	0
P (Rel)		153			120			

S.S

Shortage

-3 < zero

OH = SS after 3 periods

Q = 120 + 0 + 150 = 270 U

+ 117 U

270 - 117

= 153 U

Item :- C (Seat subassembly) Lot size :- Lot 4 lot

S.S = Zero L.T :- 2 weeks

week	1	2	3	4	5	6	7	8
Gross Req	150			120		150	120	
S.R	230							
POHI 37	117	117	117	0	0	0	0	0
P (Rec)	0	0	0	3	0	150	120	0
P (Rel)		3		150	120	~~150~~		

S.S S.S S.S

Shortage Shortage Shortage

Item :- C (seat subassembly) Lot size :- POQ (P = 3 weeks)

S.S = 20 units L.T :- 2 weeks

week	1	2	3	4	5	6	7	8
Gross Req	150			120		150	120	
SR	230							
POHI 37	117	117	117	170	170	20	20	20
P (Rec)	0	0	0	173	0	0	120	
P (Rel)		173			120			

S.S

Sh Sh

120 − 20 + 20

$(120 + 0 + 150) = 270$

117 153 for S.S = Zero

S.S = 20

$(270 - 117) + 20$ maintinance

OH ≥ S.S

C (1)
Seat subassembly
"dependent"

Parent

Intermediate

H (1)
Seat frame
"dependent"

I (1)
Seat Cushion

purchased
"dependent"

Parent

J (4)
Seat-frame
boards

purchased
"dependent"

MRP

Bill of Material → MRP exp ← MPS (MPS Start) for the end item demand

parent child

Inventory records

(lot sizing) (L.T) (S.S.)

Item:- C (MRP) Lot size:- FOQ = 230 Unit

Des:- Seat subassembly L.T:- 2 weeks S.S = 0

week	1	2	3	4	5	6	7	8
Gross Req	150			120		150	120	
S R	230							
POHI $\boxed{37}$	117	117	117	227	227	77	187	187
P (Rec)	0	0	0	230	0	0	230	0
P (Rel) *		230			230			

parent ① → ladder Back chair ② → kitchen chair

week	1	6
MPS start	150	150

week	4	7
MPS start	120	120

Item:- H Lot size:- FOQ = 300 U

Des:- Seat frame L.T:- 1 week S.s:- Zero

week	1	2	3	4	5	6	7	8
Gross Req		230			230			
POHI $\boxed{40}$	40	110	110	110	180	180	180	180
P (Rec)	0	0	0	0	300	0	0	0
P (Rel) *				300				
S.R		300						

C (1)

H (1)

week	2	5
P(Rel)	230	230

230 (C) = 230 (H)

Item :- I Lot size :- L4L

Des :- Seat Cushion L.T :- 1 week S.S :- Zero

week	1	2	3	4	5	6	7	8
Gross Req		230			230			
S R								
POH I $\boxed{0}$	0	0	0	0	0	0	0	0
P (Rec)	0	230	0	0	230	0	0	0
P (Rel)	230			230				

parent → Seat Sub assembly (C)

C (1)
I (1)

↳ MPR :-

week	2	5
P (Rel)	230	230

Item :- J Lot size :- FOQ = 1500 U

Des :- Seat frame boards L.T :- 1 week S.S :- Zero

week	1	2	3	4	5	6	7	8
Gross Req				1200				
S.R								
POH I $\boxed{200}$	200	200	200	500	500	500	500	500
P (Rec)	0	0	0	1500	0	0	0	0
P (Rel)			1500					

H (1) Seat frame MRP "(H)"

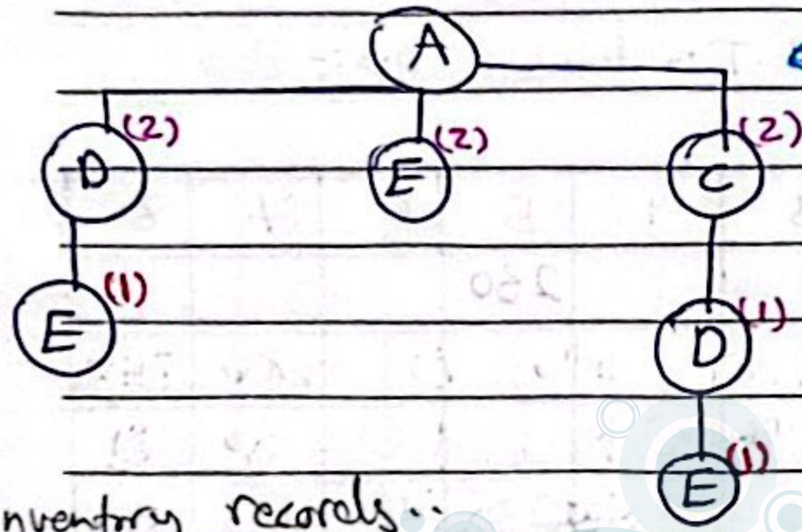
↓

J (4) Seat frame boards

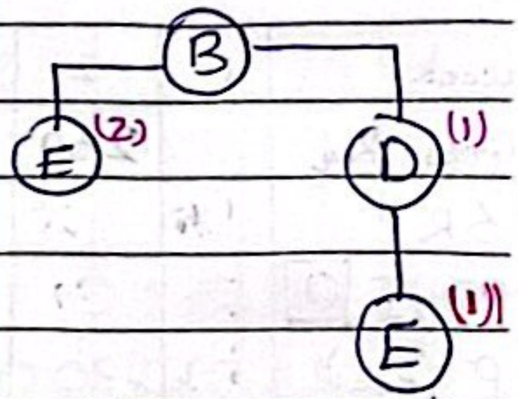
weeks	4
Q	300

→ $300 \times 4 = 1200$ Seat frame boards

at period (3) we ~~purchase~~ ordered 1500 seat frame boards → we reciept them at week 4.



⟸ Bill of Materials ⇓



Inventory records..

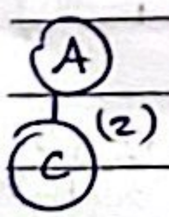
Item	Lot sizing	L.T	S.R	Beginning Inventory	
C	L4L	3 W	200 U W=2	85	S.S=0
D	POQ(P=3)	2 W	None	625	S.S=0
E	FOQ(800)	1 W	800U W=1	350	S.S=0

Item \ week	2	3	4	6	8
A	125	·	95	150	130
B		80		70	

↳ from (MPS) start

Item:- C Lot-size:- L4L L.T:- 3 weeks S.S:- zero

week	1	2	3	4	5	6	7	8
Gross Req		250		190		300		260
S.R		200						
POHI $\boxed{85}$	85	35	35	0	0	0	0	0
P (Rec)	0	0	0	155	0	300	0	260
P (Rel)	$\boxed{155}$		300		260			



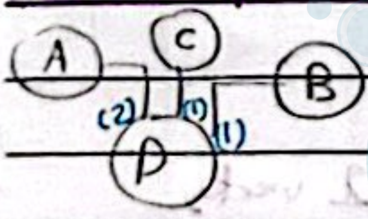
A (MPS)

week	2	4	6	8
MPS start	125	95	150	130
$G.R_{(C)}$	250	190	300	260

$MPS_{(A)}(\text{Start}) \times 2 = G.R_{(C)}$

Item :- D   lot-size :- POQ (P=3)   L.T = 2 weeks   S.S = zero

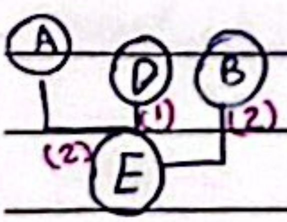
week	1	2	3	4	5	6	7	8
Gross Req	155	250	80 300	190	260	300 70		260
S.R					s.s			s.s
POHI $\boxed{525}$	470	220	450	260	0	260	260	0
P (Rec)	0	0	610	0	0	630	0	0
P (Rel)	610			630				



week	1	2	3	4	5	6	8
A (2)		125		95		150	130
B (1)			80			70	
C (1)	155		300		260		

Item :- E   lot-size :- FOQ = 800   LT = 1 week   S.S = zero

week	1	2	3	4	5	6	7	8
Gross Req	610	250	160	190 630		300 140		260
S.R	800							
POHI $\boxed{350}$	540	290	130	110	110	470	470	210
P (Rec)	0	0	0	800	0	800	0	0
P (Rel)			800		800			



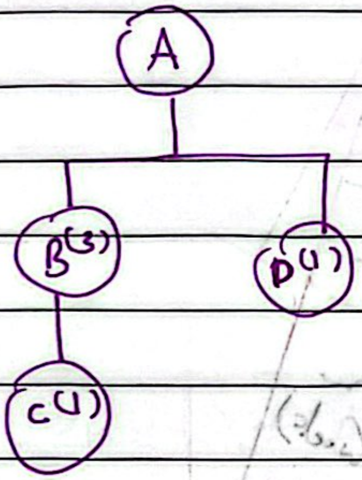
week	1	2	3	4	6	8	
A (2)		125		95	150	130	→ MPS start
B (2)			80		70		→ MPS start
D (1)	610			630			→ P(Rel)

Item (A) lot size :- 95 Units L.T = 1 week
MPS

Q OH $\boxed{55}$	1	2	3	4	5	6	7	8	9	10
Forcast	45	45	45	45	45	50	50	150	50	50
C.O.B	10	0	50	48	7	0	0	0	0	0
POHI	10	60	10	57	12	57	7	52	2	47
MPS (Q)	0	95	0	95	0	95	0	95	0	95
MPS (Start)	95		95		95		95		95	
ATP	45	45		40		95		95		95

Item (A) lot size :- POQ L.T = 2 weeks
MRP (P = 3 weeks) S.S = 100

week	1	2	3	4	5	6	7	8	9	10
Gross Req			70		50			55	80	
SR										
POHI $\boxed{100}$	100	100	150	150	100	100	100	180	100	100
P (Rec)	0	0	120	0	0	0	0	135	0	0
P (Rel)	120					135				



Item	Lot sizing Rule	L.T	S.R	OH	S.S
B	POQ P=4	1	—	40	40
C	FOQ=500	2	—	200	100
D	L4L	1	1000 week (1)	50	50

L.T = 1 week

MPS for A :-

Lot size = 200

OH $\boxed{190}$	1	2	3	4	5	6	7	8	9	10
Forcast	70	70	70	70	70	80	80	80	80	80
C.O.B	75	80	60	0	13	0	0	0	6	0
POHI	115	35	165	95	25	145	65	185	105	25
MPS Q			200			200		200		
MPS (S)		200			200		200			
ATP	35		127			200		200		

MRP (B) POQ (P=4) $\boxed{40}$

A → B(3) L.T = 1 week S.S = 40

200 × 3 = 600

Week	1	2	3	4	5	6	7	8	9	10
G.R		600			600		600			
S.R										
OH $\boxed{40}$	40	640	640	640	40	40	40	40	40	40
P.Rec		1200					600			
R.Rel	1200					600				

MRP (C) B → C(1) FOQ = 500 L.T = 2 weeks

S.S = 100 B.IP = 200

week	1	2	3	4	5	6	7	8	9	10
G.R	1200					600				
S.R										
OH $\boxed{200}$	500	500	500	500	500	400	400	400	400	400
P Rec	1500					500				
P Rel				500						

2 weeks before, Released order = 3 FOQ = 3 × 500 = 1500 unit

A

↓

MRP (D) D (1)

LYL   L.T = 1 week $\boxed{50}$ S.S = 50

week	1	2	3	4	5	6	7	8	9	10
G.R		200			200		200			
S.R	1000	~~[illegible]~~	~~[illegible]~~	~~[illegible]~~	~~[illegible]~~	~~[illegible]~~	~~[illegible]~~	~~[illegible]~~	~~[illegible]~~	~~[illegible]~~
OH $\boxed{50}$	1050	850	850	850	650	650	450	450	450	450
Rec	0	0	6	0	0	0	0	0	0	0
Rel										

" Ch15 " Planning & Scheduling Operations

Strategic planning → Aggregate planning → Master Scheduled planning → Short-term planning

economic
political
environmental · Social factors

① Strategic planning → forcast demand (highest levels all products years)

Strategic policies

for long term (years)
- location of the facility
- size of facility
- layout
- equipments

forcast demand
(group of products) (per month, quarter)
medium level of aggregation

② Aggregate Planning

Intermediate term (monthly, quarterly)
- Facility utilization
- Personal (employment)
  - sub contract
  - over-time
  - part timers

3- Master-schedule planning

→ forcast (product/week)

→ Intermediate term (weeks)

→ MPS for each final product

→ master-schedule-planing - MPS (Start) -

Bikes	1	2	3	4
M_{22}		200		200
M_{24}	100		100	
M_{26}	100		100	

$\underbrace{\qquad\qquad}_{\text{month 1}}$

→ MPS start

→ Aggregate planing

Month	1	2
Bikes	800	

group of product / monthly

4- Short term Scheduling

→ short term: (days, shifts, hours, minutes)

* Matching specific tasks to specific people and machines *

- Job & facility scheduling
- workforce scheduling
- Sequencing Jobs at workstations

* Gantt-Chart: graphical Representation for activities against time (to monitor the progress)

Short term planning
1. days, hours, shifts
2. practical scheduling
3. matching specific task to specific people & machine

Master Schedule Planning
1. Intermediate term (Final product/week) (MPS) for each finished goods
2. shorter term than (aggregate planning)

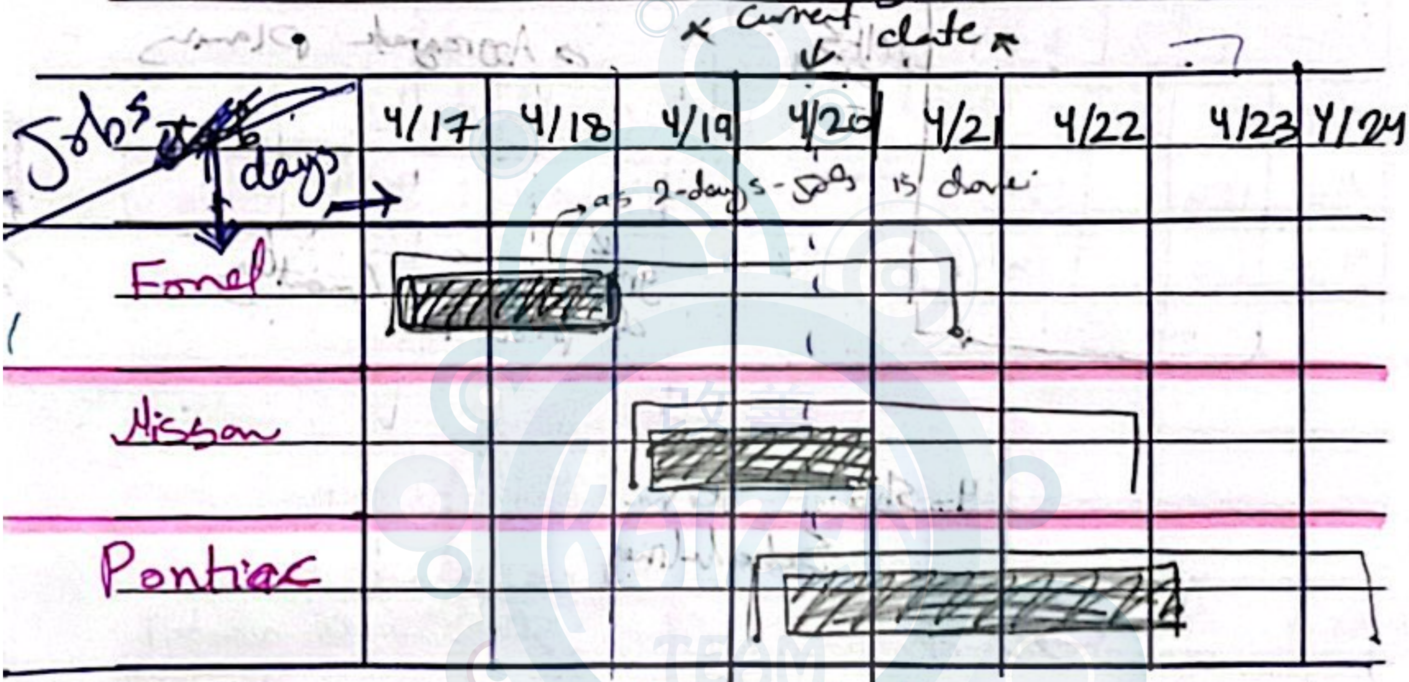
Aggregate Planning
1. Intermediate term (group of products for the coming quarter or months)
2. employment planning

Strategic Planning
1. Long term (all products/years)
2. the company's long term objectives
3. policies (Economics environments factors)

Job & facility Scheduling :-

listing for jobs & their status

* Gantt chart :- 1. Job or activity chart
2. work station chart



▭ - Job or activity chart - (progress)
(scheduled activity time)

⌐ start
⌐ finish activity

▨ actual process

⊠ Non-productive - time

- behind schedule (Ford)
- On - schedule (Nissan)
- ahead of schedule (Pontiac)

① we update the progress day by day
② easy to take decisions for new jobs

② "work-Stations-chart :-

work-stations	7am	8am	9am	10am	11am	12 pm	1pm	2pm	3pm	4pm	5pm	6pm	7pm
OR(A)	Dr. Jon		X		Dr. Aubrey				X	Dr. Alim			X
OR(B)	X	Dr. gray				X	Dr. Jeff		X	Dr. Madeline			
OR(C)	Dr. Jordan					X			Dr. Dean				

.easy decisions .updated chart
" visually "

* work force scheduling :-
- for fixed working time → we don't need schedling
like:- Teachers (5 days, 8-3) fixed ..

- for jobs 24 hours / 7 days or any long time-job, ⇒ we need scheduling for the workers
like:- hospitals and guards
(Rotating - Job - shifts)

"Work-Force-Scheduling"

- Constrains:-
1. Technical constrains } → one point
2. Requirments }
3. legal and behavioral considerations (performance of workers)
4. Psychological needs of workers (day off)

Day	M	T	W	Th	F	S	Su
Req. num. of employees	6	4	8	9	10	3	2

Ex: The manager needs a work force schedule that provides 2-consective-days-off & minimizes the amount of total slack capacity. to break ties in the selection of off-days, the scheduler gives preferance to (Sat, Sun) if it's one of the tied pairs. if not, she selects one of the tied pairs arbitrarily.

(The slack) measures the performance of the schedule.

M	T	W	Th	F	S	Su	Employee	M	T	W	Th	F	S	Su
6	4	8	9	10	3	2	1	X	X	X	X	X	off	off
5	3	7	8	9	3	2	2	X	X	X	X	X	off	off
4	2	6	7	8	3	2	3	X	X	X	X	X	off	off
3	1	5	6	7	3	2	4	off	off	X	X	X	X	X
3	1	4	5	6	2	1	5	X	X	X	X	X	off	off
2	0	3	4	5	2	1	6	off	off	X	X	X	X	X
2	0	2	3	4	1	0	7	X	X	X	X	X	off	off
1	0	1	2	3	1	0	8	X	X	X	X	X	off	off
0	0	0	1	2	1	0	9	off	X	X	X	X	X	off
0	0	0	0	1	0	0	10	X	X	X	X	X	off	off
0	0	0	0	0	0	0	Capacity (C)	7	8	10	10	10	3	2
							Req (R)	6	4	8	9	10	3	2
							Slack (C-R)	1	4	2	1	0	0	0

↳ Requirement is done

no need for 11th employee

10 is the minimum of employees

Total slack = 1+4+2+1 = 8

↳ cost

↳ useful in (underestimated demand)

If (employee 10) is a part timer then the Total slack = 0+3+1+0+0+0+0 = 4

better

	M	T	W	Th	F	S	Su	
Capacity	6	7	9	9	9+1	3	2	
Slack	0	3	1	0	0	0	0	4

* Sequencing job at workstations *

Rules :- (Rules of thumb)

① first come, first served (FCFS)

	Schedules :-	days since order	Jobs
M_1	$J_1 \to J_2 \to J_3$		
J_1, J_2, J_3	rule 2 • $J_1 \to J_3 \to J_2$		
	rule 1 • $J_2 \to J_1 \to J_3$	3 days before	J_1
	$J_2 \to J_3 \to J_1$	5 days before	J_2
	$J_3 \to J_2 \to J_1$	day before	J_3
	rule 3 • $J_3 \to J_1 \to J_2$		

by (FCFS) $J_2 \to J_1 \to J_3$

② Earliest due date

Jobs	order	due date
J_1	3	10
J_2	5	15
J_3	1	12

$J_1 \to J_3 \to J_2$

③ SPT : shortest Processing time → Reduce the work-in-process

Jobs	Processing-time
J_1	10
J_2	11
J_3	3

$J_3 \to J_1 \to J_2$

" Flow Time & Days Past due "

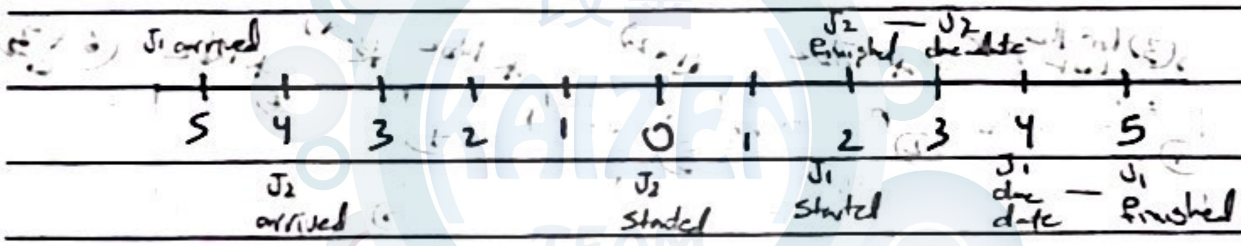
measured from the current day (0)

Days ago since order arrived	Due date	Processing Time	
5	4	3	J_1
4	3	2	J_2
1	12	5	J_3

Flow Time = Finished time (+) days ago since order arrived

days past due = Finished time (−) due date

SPT :- $J_2 \rightarrow J_1 \rightarrow J_3$



Flow Time for J_2 = 4+2 = 6

days past due for J_2 = 2 − 3 = −1 = 0

(+) delay

(−) zero-days past-due

zero days past due

Flow Time for J_1 = 5+5 = 10

days past due for J_1 = 5 − 4 = 1

(1) day past due

Customer	Time since order arrived (days) (ago) ↱ FCFS	Processing Time (days) ↱ SPT	due date (days from now)
A	15	25	29
B	12	16	27
C	5	14	68
D	10	10	48
E	0	12	80

① Determine the schedule by using the (FCFS) rule, calculate the avg. days past due & flow time ..

② How can the schedule be improved, (avg Flow Time) is the critical

① by FCFS $\boxed{A \to B \to D \to C \to E}$

Customer Sequence	① Start time (days) (3) for the last order	② Processing Time (days) * Table	③ Finished T (days) (1+2)	④ Due date * Table	⑤ days past due (3-4)	⑥ days ago since order arrival * Table	Flow Time (days) (6+3)
A	0	25	25	29	0	15	15+25=40
B	25	16	41	27	14	12	12+41 =53
D	41	10	51	48	3	10	61
C	51	14	65	68	0	5	70
E	65	12	77	80	0	0	77
		Sum = 77			3.4		60.2

Avg. Flow Time = 60.2 days

Avg. (days-past-due) = 3.4 days

② Improvment of the schedule : (Suggestion: use STP)

by (SPT):- D → E → C → B → A

(from Table)

customer sequence (SPT)	① Time since order arrival (days ago)	② processing Time (days)	③ due date (days)	④ Start Time (days)	⑤ Finished Time (days) (4+2)	Flow Time (1+5)	Days-Past-due (5−3)
D	10	10	48	0	10	20	0
E	0	12	80	10	22	22	0
C	5	14	68	22	36	41	0
B	12	16	27	36	52	64	25
A	15	25	29	52	77	92	48
					Avg by (SPT) =	47.8	14.6

Rule	FCFS	SPT
* Avg. Flow Time	60.2 days	47.8 days
Avg. Days Past due	3.4 days	14.6 days

↳ to determine the better sequence for orders

Critical (Flow Time)
SPT gives lower Flow Time. so,
we follow The SPT Sequence (D→E→C→B→A)

A restaurant operates 7 days a week. The daily Requirements:

days	M	T	W	Th	F	S	Su
Req	2	3	5	4	5	4	4

① two days off
② find the minimum num of workers needed
③ total slack capacity

M	T	W	Th	F	S	Su	Emp	M	T	W	Th	F	S	Su
2	3	5	4	5	4	4	1	off	off	X	X	X	X	X
2	3	4	3	4	3	3	2	off	off	X	X	X	X	X
2	3	3	2	3	2	2	3	X	X	X	X	X	off	off
1	2	2	1	2	2	2	4	off	X	X	off	X	X	X
1	1	1	1	1	1	1	5	off	off	X	X	X	X	X
1	1	0	0	0	0	0	6	X	X	X	X	X	off	off
0	0	0	0	0	0	0	C	2	3	6	5	6	4	4
							R	2	3	5	4	5	4	4
							S	0	0	1	1	1	0	0

$\boxed{6}$ is the minimum number of employees

$S_T = 1 + 1 + 1 = 3$ employess

FCFS :

order	Time since order arrived (h)	Machine time (h)	Due-date (h)
1	1	9	20
2	0	7	21
3	6	8	12
4	5	3	8
5	3	12	18

① use FCFS & EDD and Performance of both

① FCFS :- 3 → 4 → 5 → 1 → 2

Seq	TSOA ↓	MT (h)	D.D (h)	Starting	Finishing	Flow Time	Past due hours
3	6	8	12	0	8	14	0
4	5	3	8	8	11	16	3
5	3	12	18	11	23	26	5
1	1	9	20	23	32	33	12
2	0	7	21	32	39	39	18
		39			Sum	128	38
					avg	25.6	7.6 hours

avg Flow Time = 25.6 hours

avg ~~diff~~ past due hours = 7.6 hours

EDD :- 4 → 3 → 5 → 1 → 2

Seq	Time since order arrived	Machin time (h)	due-date (h)	S	F	Flow Time	Past due hours
4	5	3	8	0	3	8	0
3	6	8	12	3	11	17	0
5	3	12	18	11	23	26	5
1	1	9	20	23	32	33	12
2	0	7	21	32	39	39	18
		39			avg	24.6	7

avg flow Time = 24.6 hours < 25.6 (FCFS)

avg past due hours = 7 hours < 7.6 (FCFS)

by using the EDD we reduce the avg flow time and past due time but not a widely difference between the 2-rules since the sequences are very close - but changing order 3 and 4 reduces the averages (not sufficiently)

FCFS | EDD | problem

Job	Time since order arrived (D)	Processing Time (d)	Due-date -days-
A	13	8	36
B	15	4	42
C	17	4	39
D	22	3	53
E	24	10	45

1) use FCFS, EDD
2) compare them

1) FCFS :- E → D → C → B → A

Seq	Start	Processing Time	Finish	due date	days past due	Time since order arrived	Flow Time
E	0	10	10	45	0	24	34
D	10	3	13	53	0	22	35
C	13	4	17	39	0	17	34
B	17	4	21	42	0	15	36
A	21	8	29	36	0	13	42

→ Performance

1) avg Flow Time = 36.2 days

2) avg days-past-due = Zero

2) EDD :- A → C → B → E → D

Seq	Start	Processing Time	Finish	due date	days past due	Time since order arrived	Flow Time
A	0	8	8	36	0	13	21
C	8	4	12	39	0	17	29
B	12	4	16	42	0	15	31
E	16	10	26	45	0	24	50
D	26	3	29	53	0	22	51

→ Performance

1) avg flow Time = 36.4 days

2) avg day-past-due = Zero