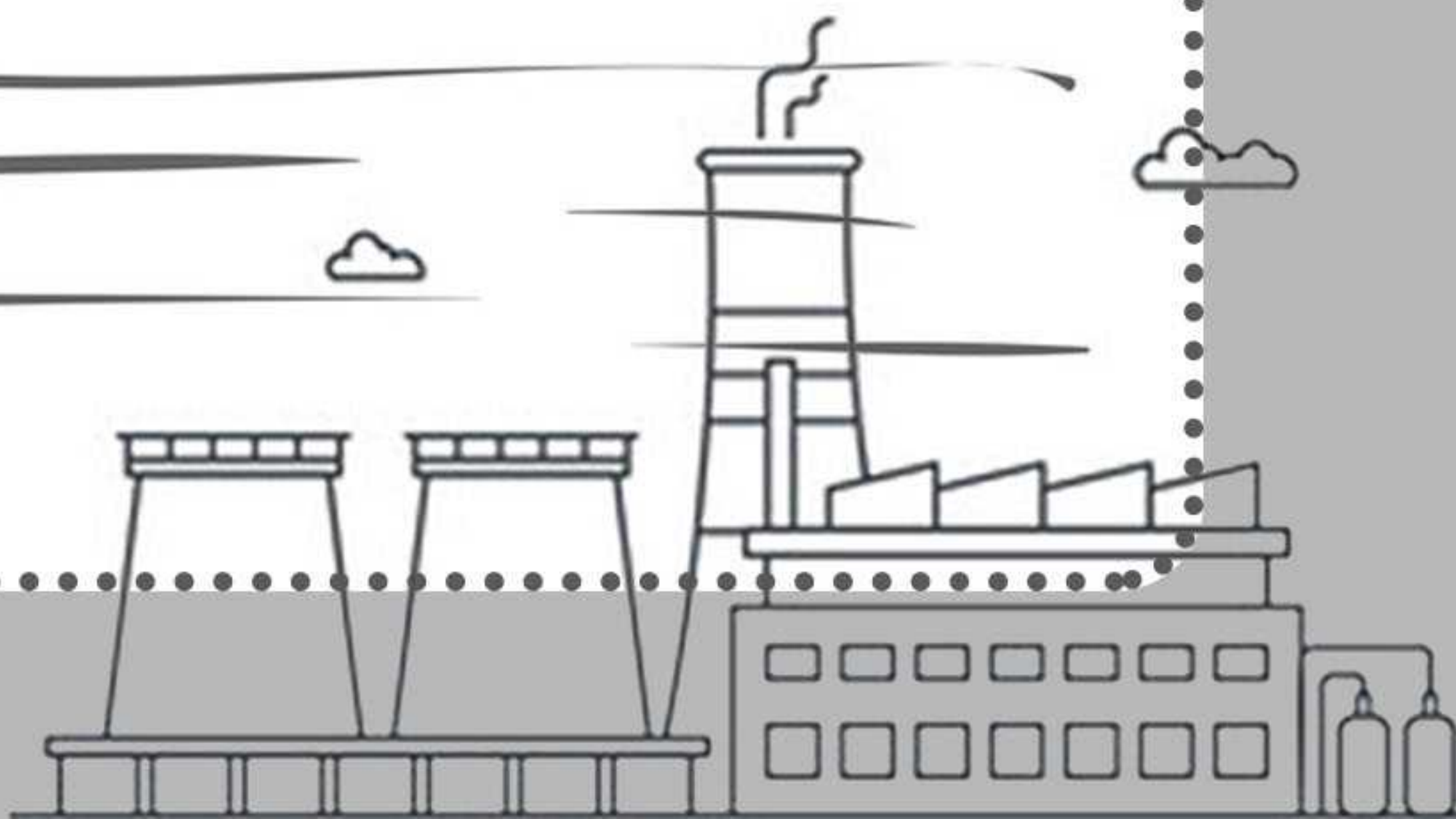


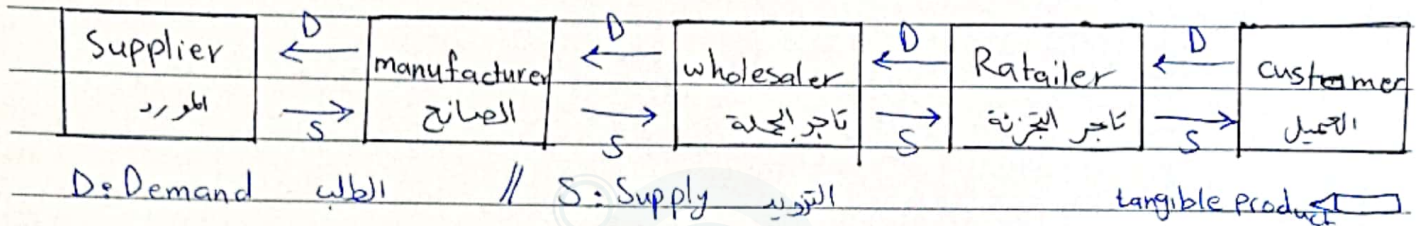
WEEKLY NOTEBOOK

PPC

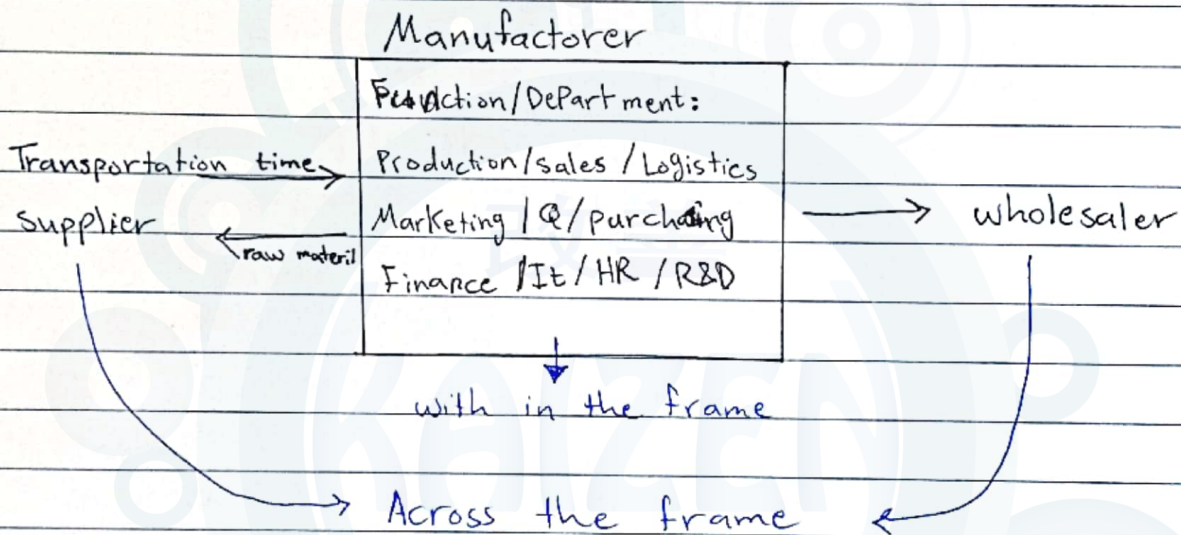
second semester
2021



Lec 2



→ supply chain: the interrelated processes within the frame and across the frame that it needed to produce a product or service according the need of customers



Example of interrelated process (within the frame):

Marketing → زيادة مبيعات → increase sales

Production → it able to increasing in production ??

Logistics → Raw material inventory

Finance → cash flow

HR → overtime/parttime / shift

purchasing → dealing with supplier for raw material

→ supply chain management:

* what happen if:

→ the demand from wholesaler is more than capacity of manufacturer to supply?

Less in quality / defect in products ⇒ return the products /
change the manufacturer / Losing customers and retailer /
increases the cost

→ the manufacturer can supply more than the demand of wholesaler?
decrease the price to increase the demand / expiry the product /
Loss of time and money when manufacturer stop manufacturing

∴ supply chain management: To ^{synchronize} ~~synchronize~~ and coordinate all interrelated
Process with in the frame and across the frame to
match the (information / cash / materials) flow with demand

→ How to take decisions related to activities of the function:

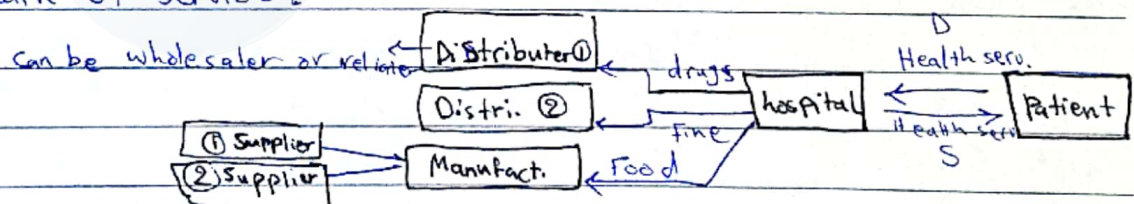
→ Logistics function:

The activities of it are:

- 1- Forecasting
- 2- Inventory management
- 3- Aggregate planning
- 4- scheduling
- 5- Material requirements planning

* Logistics is part of supply chain management

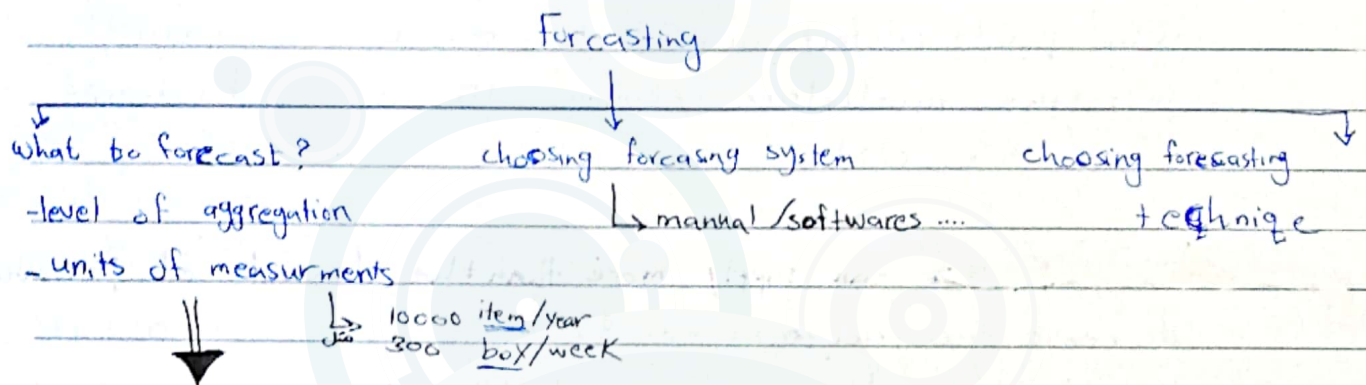
■ Supply chain of service:



Another example: Airports / schools / Banks / Hotels / UNV.

→ Forecasting: An activity done by organization to know and understand what the coming demand in the future

• The decisions that needed to do forecasting:



- highest level of aggregation (long term planning) (Per year) جميع المنتجات	حليب كامل الدسم 1L حليب خالي الدسم 1L حليب 250ml خافضة } g₁
- Medium level of aggregation (medium term planning) (Per Quarter or month) تقسيم المنتجات إلى مجموعات (g ₁ /g ₂ /g ₃)	حليب 250ml شوكولاتة عصير تفاح 2L عصير برتقال 1L } g₂ } g₃
- Lowest level of aggregation (short term planning) (Per shift/hour/week/day) كل منتج على حدة	

Forecasting

what to forecast?

- level of aggregation
- units of measurements

choosing forecasting system

choosing forecasting technique

data about previous actual demand not available

data about previous actual demand is available

بداية 2010

نهاية

(new market) Iraq ← 2021

حليب كامل الدسم 1L	→ 2010
حليب خالي 1L	
حليب فريز 1L	
حليب شوكولاتة	
عصير تفاح	
عصير برتقال	

→ Present (Jordan market)

Demand → sales = available

Jordan market ← new Product 2021

حليب بقم القوية 1L

= not available

↓ we used

طريقة الحكم

Judgmental method

- market research
- executive opinion
- Delphi method
- Salesforce estimates

quantitative methods

causal methods

→ Independent variable → Affects demand

model relationship

- simple linear regression
- multiple linear regression

Time-series analysis

- repeated observation of demand services product in their order of
- simple moving average
- waiting

simple linear regression

related by linear equations

dependent variable

Independent variable

Demand (sales, no. of patient, no. of customers)

- weather

- time during day

- culture of market

- competitors market

- competing product market

- location

- marketing expenditures

- Price

- quality

at least 5 period

Period	Independent Variable X	dependent variable 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	$X_2 Y_2$	X_2^2	Y_2^2
3	X_3	Y_3	$X_3 Y_3$	X_3^2	Y_3^2
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
n	X_n	Y_n	$X_n Y_n$	X_n^2	Y_n^2
	ΣX	ΣY	ΣXY	ΣX^2	ΣY^2

$$\bar{X} = \frac{\Sigma X}{n}$$

$$\bar{Y} = \frac{\Sigma Y}{n}$$

Y dependent (demand) variable

$$Y = a + bX$$

$$b = \frac{\Sigma XY - n \bar{X} \bar{Y}}{\Sigma X^2 - n \bar{X}^2}$$

b: slope

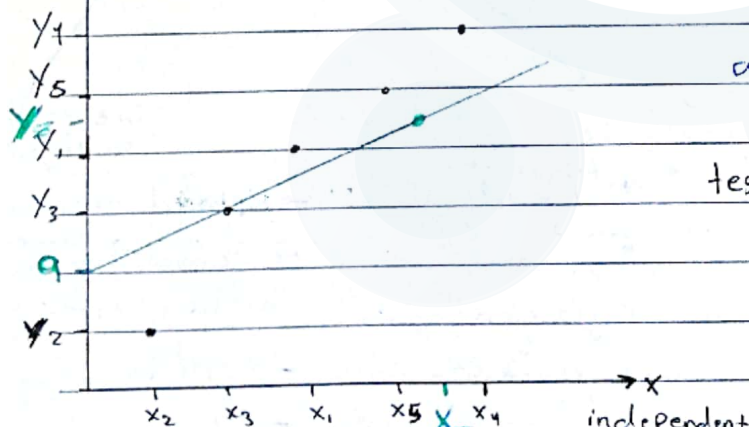
a: intercept

$$a = \bar{Y} - b \bar{X}$$

testing measure: correlation coefficient r

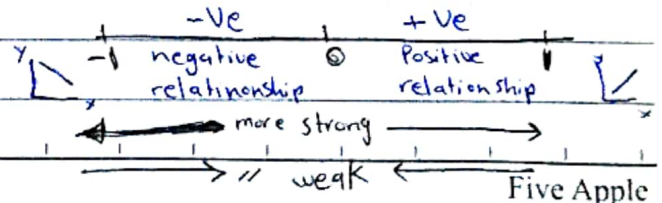
$$r = \frac{n \Sigma XY - \Sigma X \Sigma Y}{\sqrt{[n \Sigma X^2 - (\Sigma X)^2] [n \Sigma Y^2 - (\Sigma Y)^2]}}$$

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



$$\bar{X} = \frac{\Sigma X}{n}$$

$$\bar{Y} = \frac{\Sigma Y}{n}$$



Lec 4

model 1	model 2
$r = -0.4$	-0.6 ✓ more strong
$r = -0.6$ نفس القوة	$+0.6$

→ when $r=1$: the model is perfect represents the relationship ^{في الواقع}
 $r=0$: There maybe a relation, their maybe not, but we are sure that the relationship is not a line 

② coefficient of determination r^2

→ which give ^{إشارة/أشياء} indications about amount of change in y caused by change in x as represented by the model

ex. : $r = 0.6$

$r^2 = 0.36 \Rightarrow 36\%$ of the changes in y is caused by the changes in x...

→ which measure the amount of variation in dependent variable about the mean that is explained by the regression line.

$\therefore 36\%$ of y changed ^{بسبب} x ^{في} model $\Rightarrow$ this model weakly represent actual relationship

ex. : $r = 0.9$

$r^2 = 0.81 \Rightarrow 81\%$ // // $\therefore$ it's strong relationship

$$0 \leq r^2 \leq 1$$

③ Standard error of estimate S

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

→ which measure the amount of variation of y about the regression line, not as r^2 about the mean of the regression line.

To describe any data, we need two types of measures:

- 1- The measures of central tendency ($\bar{x}$) ^{التشبع}
- 2- The measures of dispersion (s)

actual points $\leftarrow$ أكبر Variation $\leftarrow$ أكبر S
further from the line

fee

→ It is better if (S) is small because the difference between the actual and predicted points in the model will be so small
 that mean ⇒ The error is small
 in the forecast

Example

	Y → dependent	X → independent			
Month	Sales (thousands of units)	Advertising (thousands of \$)	X ²	y ²	XY
1	264	2.5			
2	116	1.3			
3	165	1.4			
4	101	1.0			
5	209	2.0			
	Σy =	ΣX =	ΣX ² =	Σy ² =	ΣXY =

next month ⇒ \$1750 → the demand for next month??

$$\bar{X} = \frac{\sum X}{n}$$

1- $Y = a + bX$

$b = 109.229 / a = -8.135$

$$\bar{Y} = \frac{\sum Y}{n}$$

$y = -8.135 + 109.229 X$ Linear regression model

2- $r = 0.98$ ⇒ +ve (advertising ↑ ⇒ Sales ↑)
 $r^2 = 0.96$ ⇒ very strong

96% → very strong

$S = 15.6$

→ The company will spend \$1750 on advertising next month.

sales next month?? $x = 1.75$

$Y = -8.135 + 109.229 \times 1.75 = 183.01575$



sales = 183015.7 ≈ 183016 units

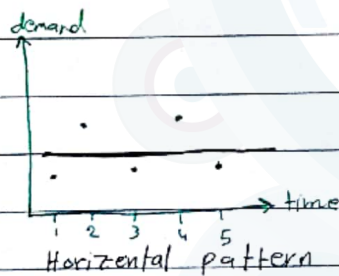
Time-series analysis

- Naive approach
 - simple moving average
 - weighted moving average
 - exponential smoothing
 - Trend
 - multiplicative seasonal method
- technique of time-series

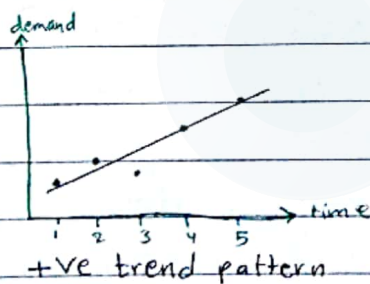
Time-series analysis : It is repeated observation of demand for a product or service in their order of occurrence.
(The behavior of demand overtime)

→ 5-Basic Patterns of the demand over time:

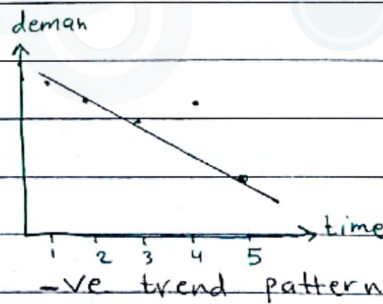
- ① Horizontal
- ② Trend
- ③ seasonal
- ④ cyclical
- ⑤ Random



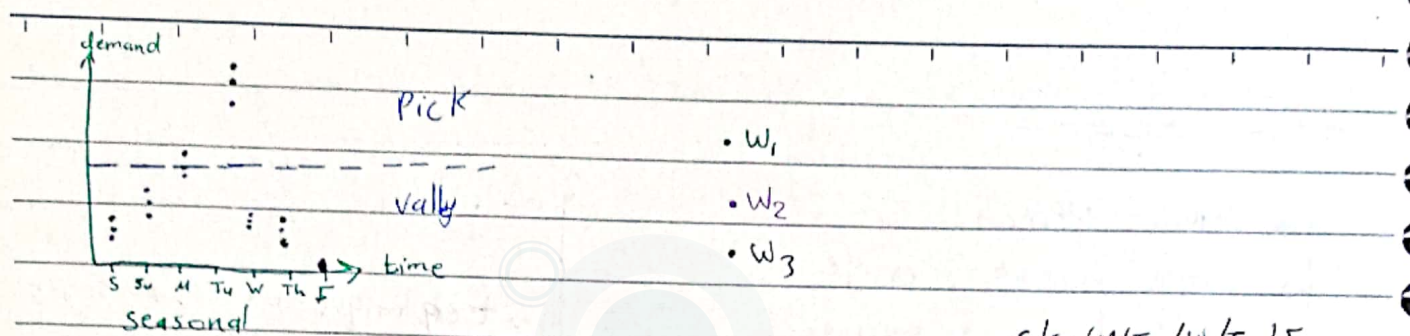
→ no increase or decrease with time



→ consistent increase in demand overtime



→ consistent decrease in demand overtime



Tu → the highest demand (pick)

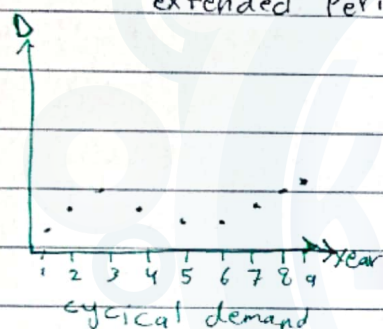
F → The lowest demand (Valley)

S/Su/M/Tu/W/Th/F
→ season

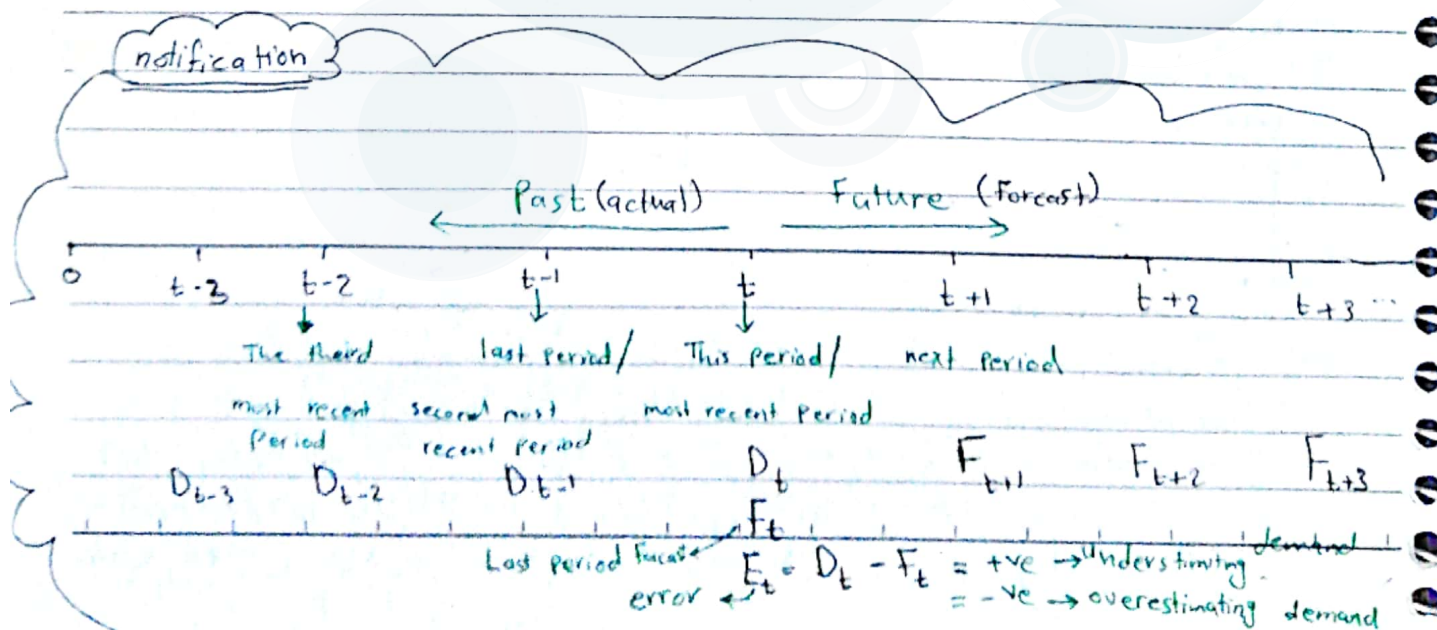
∴ recurrence for the Picks and valleys the same season, for different periods.
→ This is seasonality

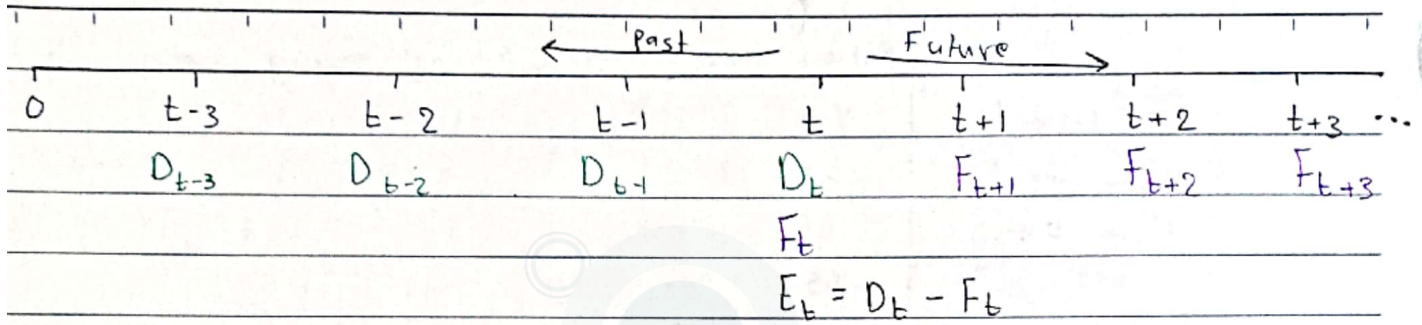
→ then we use multiplicative seasonal method

cyclical: the gradual increase followed by gradual decrease over extended periods.



Random: When cannot recognize any previous patterns





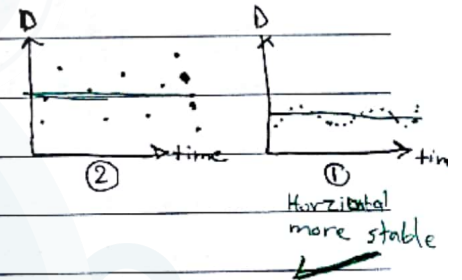
* Time Series Technique:

1) Naive approach:

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

→ It's very simple, but it's effective (It produced very small error in forecast process)

→ Used in Horizontal and the more stable demand



2) Simple moving average:

→ calculating the average demand for n most recent period

n : عدد الفترات التي نأخذها
average
لأحدث Forecast للفترة
التي نرسم

$$F_{t+1} = \frac{D_t + D_{t-1} + \dots + D_{t-n+1}}{n}$$

ex. 3 periods simple moving average

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

ex. 2 periods simple moving average

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

Example (8.3)	Week	Patient arrivals	3 week moving average
<u>moving</u> $t-3 \leftarrow t-2 \leftarrow 1$		400	
$t-2 \leftarrow t-1 \leftarrow 2$		380	
$t-1 \leftarrow t \leftarrow 3$		411	
$t \leftarrow 4$		415	

b) $F_{w4} ??$ $F_{w4} = \frac{D_t + D_{t-1} + D_{t-2}}{3} = \frac{411 + 380 + 400}{3} = 397 \text{ patient}$

$E_{w4} = D_{w4} - F_{w4} = 415 - 397 = 18 \text{ patient}$

c) $F_{w5} ??$ $F_{w5} = \frac{415 + 411 + 380}{3} = 402 \text{ patient}$

✖ moving → When new period ended, it be the most recent one (∴ The avg. moves from

✖ simple → we give the same weight for each period. Period to Period)

(لا نعطى الأهمية على العدد بل نأخذ نفس weight لكل فترة)

Simple moving average $\xrightarrow{\text{by default}}$ moving average : $\frac{415}{3} > 40$

[3] Weighted moving averages

→ each demand can have its own weight in the average

$$F_{t+1} = W_1 D_t + W_2 D_{t-1} + \dots + W_n D_{t-n+1}$$

$$W_1 + W_2 + W_3 + \dots + W_n = 1$$

$$W_1 > W_2 > \dots > W_n$$

ex. 3-periods weighted moving average

$$F_{t+1} = W_1 D_t + W_2 D_{t-1} + W_3 D_{t-2}$$

$$W_1 + W_2 + W_3 = 1$$

$$W_1 > W_2 > W_3$$

Example	Month	customer arrival	3 periods weighted average
	1	800	
	t-2 ← 2	740	$w_1 = 0.5 / w_2 = 0.3 / w_3 = 0.2$
	t-2 ← t-1 ← 3	810	
	t-1 ← t ← 4	790	
	t ← 5	805	

a) $F_{m5} ??$

$$F_{m5} = (0.5)(790) + (0.3)(810) + (0.2)(740) = 780 \text{ customer}$$

$$E_{m5} = 805 - 780 = 25 \text{ customer}$$

b) $F_{m6} ??$

$$F_{m6} = (0.5)(805) + (0.3)(790) + (0.2)(810) = 801.667 \approx 802 \text{ customer}$$

→ usually in weighted moving average we don't have more than 3 period weighted avg

لأنه كلما زاد عدد الـ period أصبح قيم الـ W قريبة من 0

→ because the advantage from w.m.a that we emphasize for the most recent

$F_3, F_4, F_5, F_6, F_7, \dots$ ← (Forecast for ^{Period} 3 through 7) إذا كان السؤال

[4] Exponential smoothing:

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

α : smoothing parameter, $0 \leq \alpha \leq 1$

0.3/0.5/0.7/0.9 ← α

→ α → determined the emphasis of the most recent demand period ($\alpha \uparrow$, emphasis for $\uparrow$ actual D_t compared with F_t)

Example (8.1)

week | Patient arrivals | $\alpha = 0.1$

1 | 400

2 | 380

t ← 3 | 411



Five Apple

طريقة الكتاب مثال (8.4)

$$F_{w4} = \alpha D_t + (1 - \alpha) F_t$$

$$= (0.1)(411) + (0.9)(F_{w3})$$

$$= 0.1 \times 411 + 0.9(390) = 392.1 \approx 392 \text{ patients}$$

$$F_{w3} = \frac{380 + 400}{2} = 390 \text{ (simple moving average)}$$

الكل الأصح مثال (8.4)

$$F_{w4} = \alpha D_{w3} + (1 - \alpha) F_{w3}$$

Default
↓
(F_{w1} = D_{w1})

1	400	F _{w1}
2	380	F _{w2}
3	411	F _{w3}
4	415	

← حيث الأصح نطرح F_{w3} على Exponential smoothing

والمستخدم technique T

$$F_{w5} = (0.1)(415) + (0.9)(392.1)$$

$$= 394.4 \approx 394 \text{ patients}$$

ملاحظة: عند استخدام قيمة ال Forecast ما يستخدم القيمة بعد التقريب (to less error)

** (naive approach / simple moving avg. / weighted moving avg. / exp. smoothing)

we use them for any time series patterns??

usually when we have horizontal time series demand

1) Naive approach

2) simple moving average $\rightarrow n=??$

3) weighted moving average $\rightarrow n=??$

4) exponential smoothing $\rightarrow \alpha=??$

horizontal time series

random, cyclic, trend & technique

other technique error رج تزيد ذلك

less error

Simple moving average $\rightarrow n=2$

(n small $\Rightarrow$ emphasis to the most two recent

responsive behavior forecast)

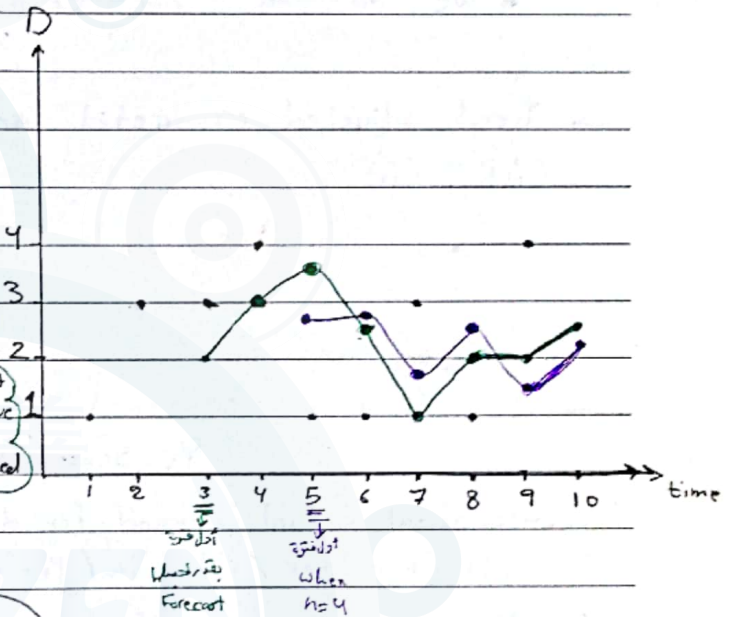
Simple moving average $\rightarrow n=4$

(n large $\Rightarrow$ Variations $\downarrow$, more smooth $\rightarrow n$ كبير)

(بقر بـ Forecast لـبات)

simple moving average n smaller $\rightarrow$ more responsive

weighted moving average n larger $\rightarrow$ more smooth



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

α larger $\rightarrow$ more responsive forecast

α smaller $\rightarrow$ more smoothed forecast

emphasis $\uparrow$ for the most recent period $\leftarrow \alpha$ كبير

Supplier رج يورد supplier بـ رقم ثابت هو حاجته لزود كل اسبوع / more smooth / كبير n

منع خط الانتاج عن Flexibel مع اختلاف الحاجات لا ياتي / more responsive / كبير n

عند اختيار التقنية من هناك الكثير من العوامل (التي تؤثر على الاختيار service, product, ... supplier)

supply chain management $\rightarrow$ It's about coordinating all activities or processes (interrelated process)

Trend time series

→ simple linear regression

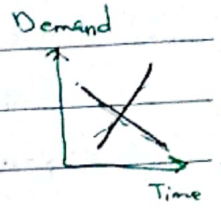
dependent variable

↳ Demand

The technique which we use

independent variable

↳ Time



* we developing $Y = a + bX$
 ↳ strong → can use it
 ↳ not strong → we need another techn

→ Trend adjusted exponential smoothing

→ previous to

→ (ARIMA)

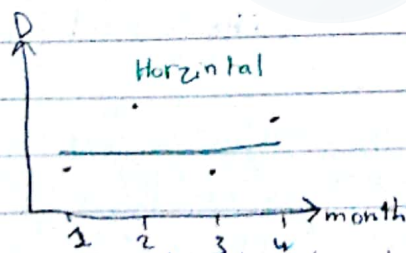
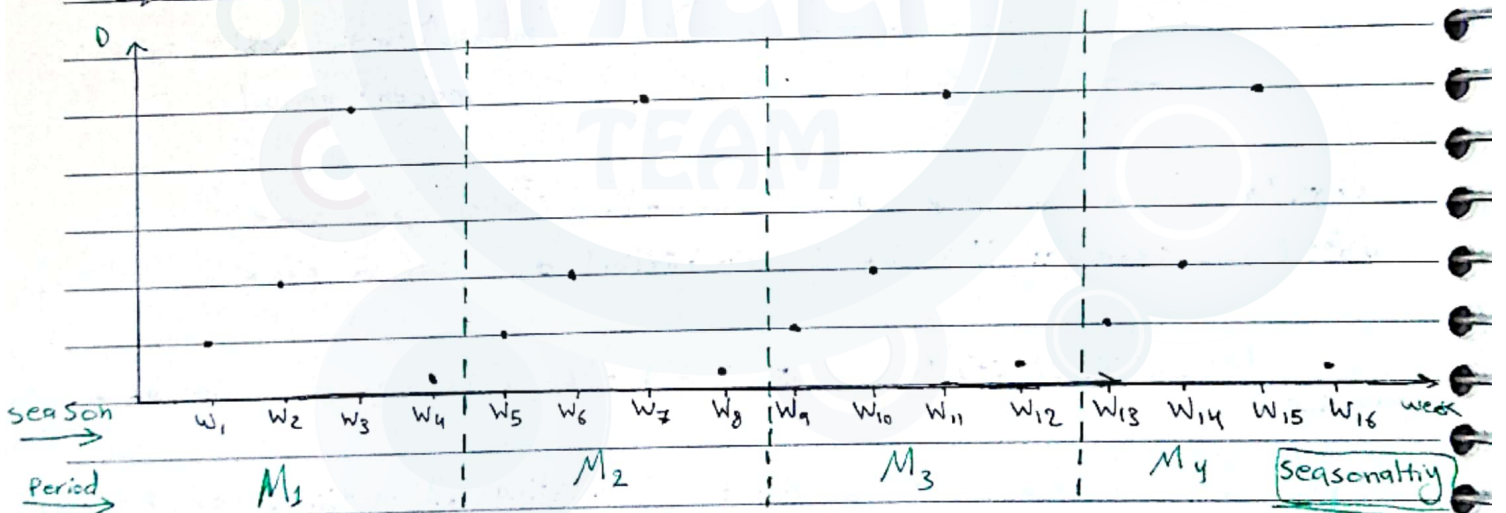
Seasonal Time Series

→ multiplicative seasonal method (Technique ^{الطريقة})

SS: Seasonality axis (Product/service) of ^{كيف نكتشف} $\leftarrow$

The data about actual demand for different time units $\leftarrow$ collect a lot of data
 (Per shift / Per week / Per month / Per quarter / Per year)

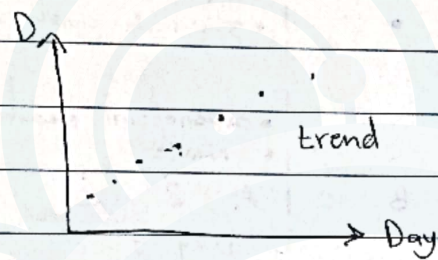
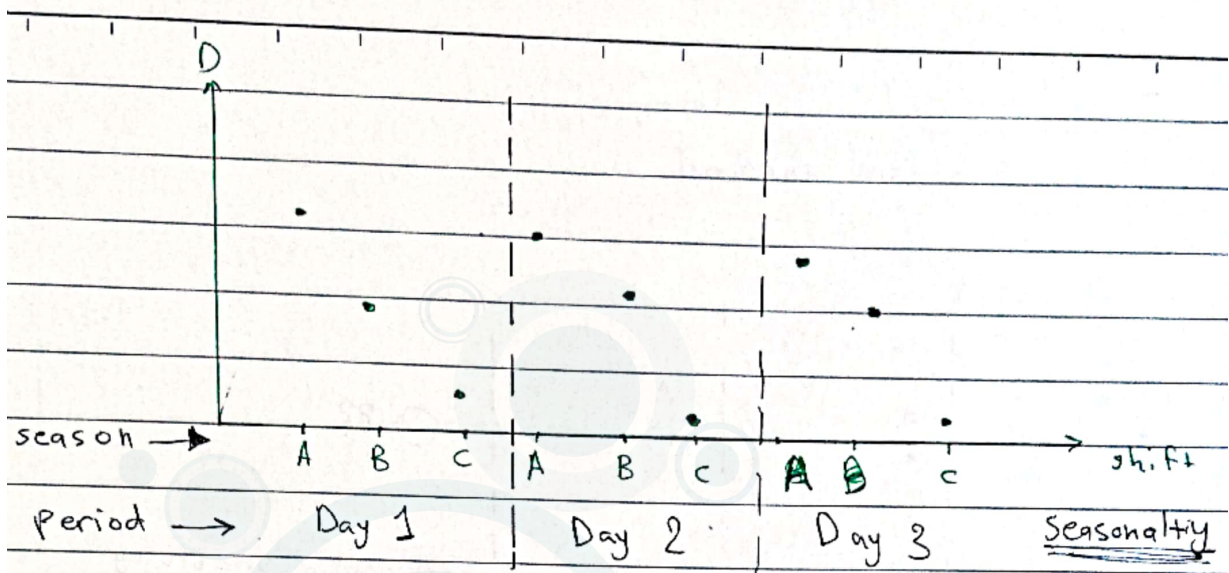
↳ for a lot of periods (at least 3 periods) $\Rightarrow$ Plotting to discover seasonality



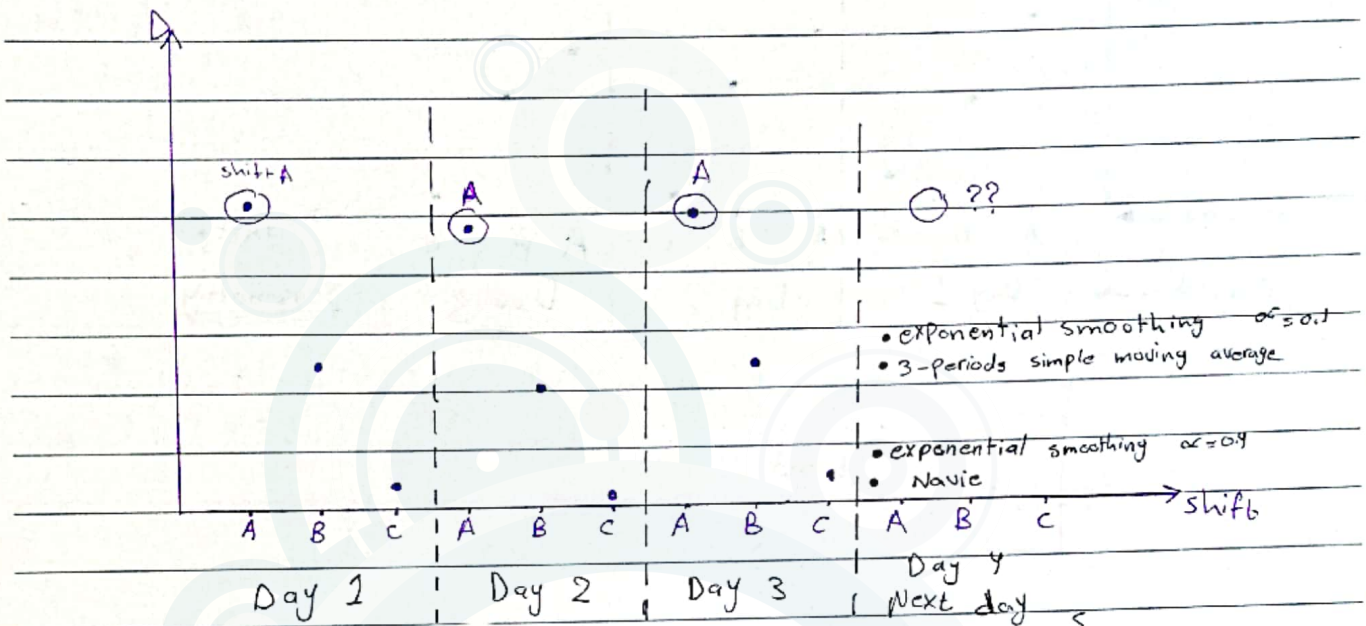
reoccurrence behavior $\leftarrow$ $\frac{y}{x}$ $\leftarrow$ behavior (سلوك)

reoccurrence behavior

seasonality تظهر وتختفي في الـ plot باختلاف توزيع demand $\leftarrow$
 Time $\leftarrow$



Lec 7

Seasonal Time series→ Multiplicative seasonal method

البيانات السابقة هي التي نستخدمها في التنبؤ
 * To Forecast A in the next day with multiplicative method:
 (d1,2,3) in pervious periods * shift A Demand in pervious

shift A → peak value
 shift B → an average
 shift C → the lowest demand

Case (2 periods, 3 seasons)

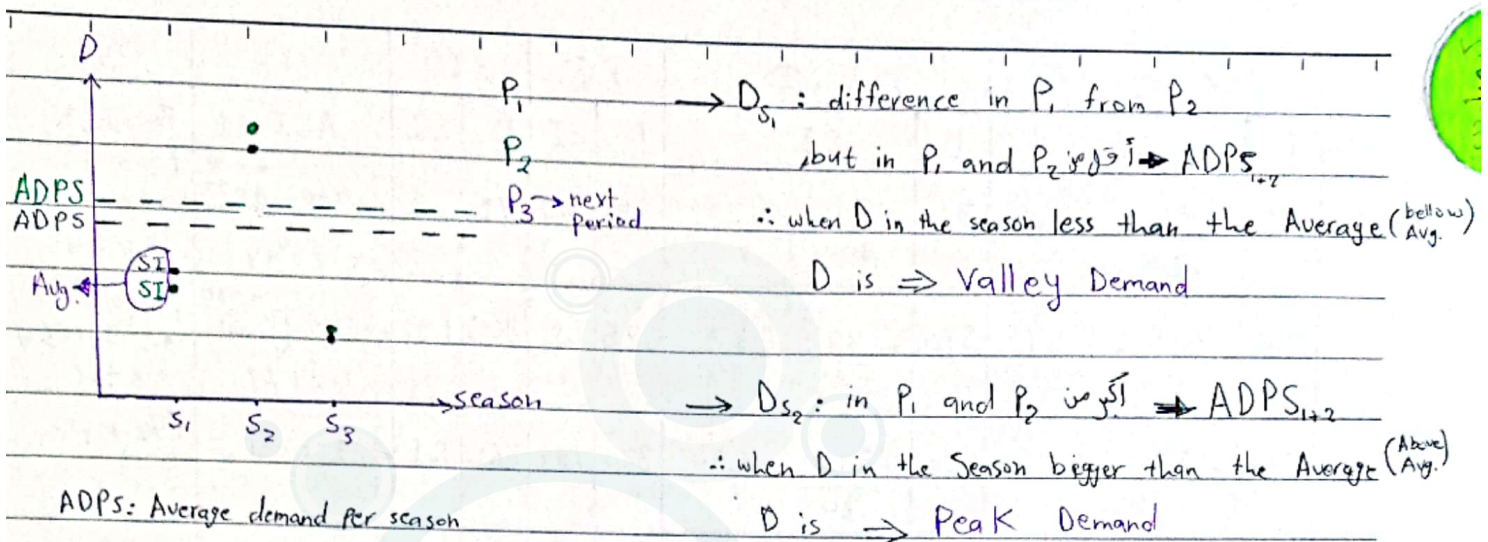
(ASI)

Forecast

season	D	Period ① Seasonal Index (SI)	D	Period ② SI	Average Seasonal Index	Period ③ (next Period)
S_1	$D_{P_1 S_1}$	$SI_{P_1 S_1} = \frac{D_{P_1 S_1}}{ADPS_{P_1}}$	$D_{P_2 S_1}$	$SI_{P_2 S_1} = \frac{D_{P_2 S_1}}{ADPS_{P_2}}$	$ASI_{S_1} = \frac{SI_{P_1 S_1} + SI_{P_2 S_1}}{\text{no. of Periods}}$	$F_{P_3 S_1} = ASI_{S_1} \times EADPS_{P_3}$
S_2	$D_{P_1 S_2}$	$SI_{P_1 S_2} = \frac{D_{P_1 S_2}}{ADPS_{P_1}}$	$D_{P_2 S_2}$	$SI_{P_2 S_2} = \frac{D_{P_2 S_2}}{ADPS_{P_2}}$	$ASI_{S_2} = \frac{SI_{P_1 S_2} + SI_{P_2 S_2}}{\text{no. of Period}}$	$F_{P_3 S_2} = ASI_{S_2} \times EADPS_{P_3}$
S_3	$D_{P_1 S_3}$	$SI_{P_1 S_3} = \frac{D_{P_1 S_3}}{ADPS_{P_1}}$	$D_{P_2 S_3}$	$SI_{P_2 S_3} = \frac{D_{P_2 S_3}}{ADPS_{P_2}}$	$ASI_{S_3} = \frac{SI_{P_1 S_3} + SI_{P_2 S_3}}{\text{no. of periods}}$	$F_{P_3 S_3} = ASI_{S_3} \times EADPS_{P_3}$
Total Demand = $D_{P_1 S_1} + D_{P_1 S_2} + D_{P_1 S_3}$ (TD_{P_1})		$TD_{P_2} = D_{P_2 S_1} + D_{P_2 S_2} + D_{P_2 S_3}$		$SI_{P_3} = \frac{D_{P_3}}{ADPS_{P_3}}$ average SI		Estimated total Demand (ETD_{P_3}) (by using appropriate technique)
Average Demand per season ($ADPS_{P_1}$) = $\frac{TD_{P_1}}{\text{no. of seasons}}$		$ADPS_{P_2} = \frac{TD_{P_2}}{\text{no. of seasons}}$				Estimated Average demand per season ($EADPS_{P_3}$)

Five Apple

تم شرح الجداول



$\rightarrow$ Seasonal Index (SI) = $\frac{D}{ADPS}$

$SI \geq 1 \Rightarrow$ Peak

$SI \leq 1 \Rightarrow$ Valley

$\rightarrow D_{S_3}$: lower demand (below Avg.) valley

$\rightarrow$ The minimum period in this technique is 3

بشكل المفروض كان 2 لتسهيل الشرح فقط

* To Forecast the next period (Period 3): $\rightarrow$ ETD_{P_3} Estimated total demand (ETD_{P₃})

* behavior for (TD_{P_1} , TD_{P_2})

* trend / Horizontal

* to forecast appropriate technique point

total demand for next period (P_3)

$\rightarrow$ $EADPS_{P_3}$ Estimated Average demand per season (EADPS_{P₃})

$$EADPS_{P_3} = \frac{ETD_{P_3}}{\text{no. of seasons}}$$

$\rightarrow$ SI Average seasonal Index (season SI)

8.6 مثال

Example: The manager of the Stanley steamer ... in the first quarter.

Following are the quarterly demand data from the past 4 years:

Quarter	Year 1	Year 2	Year 3	Year 4
1	45	70	100	100
2	335	370	585	725
3	520	590	830	1160
4	100	170	285	215
Total	1000	1200	1800	2200

Five Apple

	Year ①		Year ②		Y ③		Y ④			
Q	D	SI	D	SI	D	SI	D	SI	ASI	
1	45	$= \frac{45}{250} = 0.18$	70	$= \frac{70}{300} = 0.23$	100	0.22	100	0.18	$= \frac{0.18 + 0.23 + 0.22}{4} = 0.2075$	
2	385	$= \frac{385}{250} = 1.34$	370	$= \frac{370}{300} = 1.23$	585	1.3	725	1.32	$= \frac{1.34 + 1.23 + 1.3}{4} = 1.2975$	
3	520	$= \frac{520}{250} = 2.08$	590	$= \frac{590}{300} = 1.96$	830	1.84	1160	2.1	$= 2.0001$	
4	100	$= \frac{100}{250} = 0.4$	170	$= \frac{170}{300} = 0.56$	285	0.63	215	0.39	$= 0.4977$	
$TD_{y_1} = 1000$		$TD_{y_2} = 1200$		$TD_{y_3} = 1800$		$TD_{y_4} = 2200$				① ET
$ADPS_{y_1} = \frac{1000}{4(\text{season})} = 250$		$ADPS_{y_2} = \frac{1200}{4} = 300$		$ADPS_{y_3} = 450$		$ADPS_{y_4} = 550$				② EP

Lec 8Measures of Error: (Helps to decide the appropriate techniques of the Forecasting)

Product →		method ①			method ②		
Forecast (next period)	Period	F	D	E	F	D	E
	10	15	17	2	13	17	4
	11	14	9	-5	11	9	-2

$$E = D - F$$

→ نحتاج إلى جمع بيانات عن الأخطاء الناتجة عن الطريقة: we need to collect data about the error produced by the method for several period in order to know the appropriateness for this technique

(Is there a method produced less error) هل هناك طريقة تنتج أخطاء أقل من الطريقة الأخرى لمعظم الفترات، أم لا؟
for most of the periods, or not??

Period	D	F	E
1	D ₁	F ₁	E ₁
2	D ₂	F ₂	E ₂
3	D ₃	F ₃	E ₃
⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮
n	D _n	F _n	E _n

* at least we need 5 periods

(statistically $n \geq 5$ to use measures of error)

← data about the error

Ex Data: height of student in the class (describe it ??)

179

* To describe any data, we have to types of measures:

175

① measures of central tendency

166

(mean / mode / medium)

169

164

② measures of dispersion (variability)

172

(σ / σ^2 / range)

170

169

→ To understand the error produced by the method we need to use certain measures (تدابير tendency or dispersion)

→ then we take conclusion about the appropriateness of Five Apple technique

measures : (6 measures) → 5 measure give me certien information

① Cumulative sum of forecast errors

$$CFE = \sum_{t=1}^{t=n} E_t$$

$$E = D - F$$

+ve → $D > F$ (underestimated demand)

-ve → $D < F$ (overestimated demand)

Ex	Period	M1 E	M2 E
	1	-1	+1
	2	(+1)	(-1)
+ve (underestimated)	3	(+1)	(-1)
	4	(+1)	(-1)
	CFE	± 2	$\equiv 2$

→ That (M1) have bias to underestimated demand

(-ve) That (M2) has a bias to overestimated demand

Let say we have Method ③

+2

→ M_1, M_2 → have the same magnitude of the bias

-2

-2

-2

(difference in the direction of the bias)

It have bias to overestimate
M2 bias أكبر bias M1

→ M_2, M_3 → bias $M_3 > \text{bias } M_2$

∴ $M_2 \Rightarrow$ أضعف / أيسر

$$CFE = \sum_{t=1}^{t=n} E_t$$

+ve (bias to underestimate demand)
-ve (bias to overestimate demand)

so, we use the method that have less CFE

② The Mean bias ($\bar{E}$)

$$\bar{E} = \frac{CFE}{n}$$

+ve (bias to underestimate demand)

-ve (bias to overestimate demand)

3] Mean absolute deviation (MAD)

	M_1	M_2
Period	E	E
1	-1	-2
2	+1	+2
3	-1	-2
4	+1	+2
CFE	0	0
MAD	$\frac{4}{4} = 1$	$\frac{8}{4} = 2$

→ In terms of the bias: (M_1, M_2) is the same
but It doesn't give me indication about magnitude
of error and magnitude of deviation from actual

→ If we check the error as an absolute value

$M_1 \rightarrow$ أحسن

so we need a measure to take the absolute value.
(MAD)

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

⇒ MAD give me the average deviation from actual

يعني انظر الى انحراف كل فترة وخذ القيمة

$MAD_{M_1} < MAD_{M_2}$ so, M_1 is best

4] Mean squared Error (MSE)

	method ①		method ②	
Period	E	E^2	E	E^2
1	1	1	4	16
2	1	1	0	0
3	1	1	0	0
4	1	1	0	0
MAD	$\frac{4}{4} = 1$		$\frac{4}{4} = 1$	
MSE		$\frac{4}{4} = 1$		$\frac{16}{4} = 4$

→ M_1 same as M_2 ($MAD_1 = MAD_2$)

∴ average deviation from actual same

but in error produced

$M_1 \rightarrow$ repetition for small deviation → avg. small

$M_2 \rightarrow$ one large error and very small small deviation
avg. small

Forecast 1 في خطأ كبير large error

So, we need another method to decide

which method is best
MSE

Large error

→ when we have large error (MSE كبير)

في خطأ كبير MSE كبير

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

⇒ gives me an indication about a periods that
have a large error

5 Mean absolute percent error (MAPE)

same method

	E	D	$\frac{ E }{D} \times 100\%$
Product X	1	10	10 %
Product Y	1	1000	0.1 %

نفس قيمة error لكن بنسبة مختلفة بالنسبة لـ demand

فالقيمة لأصغر لـ Product Y لأن Demand لـ Product X أكبر

$$MAPE = \frac{\sum_{t=1}^{t=n} \left[\frac{|E_t|}{D_t} \times 100 \right]}{n}$$

⇒ give me indication about on average how much we have deviation from actual as a percent of the actual

* القانون بالكتاب في غلط

← الأنفة والى جتالها (MAPE آخر)

* (CFE, $\bar{E}$, MAD, MSE, MAPE) → 2 method فينا، القيمة الأصغر

* The measures (From 2-5) → Mean, is measures of central tendency

* To describe any data we should use two types (tendency / variability)

↓
6

6 Standard deviation of error (σ_E)

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

⇒ give me indication about the variability of the data around the mean value

Ex: Month	D	F	E	E	E^2	$\frac{ E }{D} \times 100$
-----------	---	---	---	---	-------	----------------------------

← الأنفة لـ σ_E أصغر

1	200	225	-25	25	625	$\frac{25}{200} \times 100 = 12.5$
2	240	220	20	20	400	$\frac{20}{240} \times 100 = 8.3$
3	300	285	15	15		= 5
4	270	290	-20	20		= 7.4
5	230	250	-20	20		= 8.7
6	260	240	20	20		= 7.7
7	210	250	-40	40		= 19
8	275	240	35	35		12.7
			-15	195	5275	81.8

$$[1] CFE = \frac{\sum E_t}{n} = -15$$

$$[2] MAD = \frac{\sum |E_t|}{n} = \frac{195}{8} = 24.4$$

$$[3] MSE = \frac{\sum E_t^2}{n} = \frac{5275}{8} = 659.3$$

$$[4] MAPE = \frac{\sum \left[\frac{|E_t|}{D_t} \times 100 \right]}{n} = \frac{81.8}{8} = 10.2\%$$

Assignment (1)

* exponential smoothing : ($\alpha = 0.7$, $F_y = 15$)

Year	D	F	E	E^2
3	18	19	-1.2	1.44
4	12	18	-6.36	40.449
5	25	14	11.092	123.032
				164.921

$$\rightarrow F_{y_1} = 15$$

$$\begin{aligned} \rightarrow F_{y_2} &= \alpha D_1 + (1-\alpha) F_1 \\ &= 0.7 \times 15 + 0.3 \times 15 \\ &= 15 \end{aligned}$$

$$\begin{aligned} \rightarrow F_{y_3} &= \alpha D_2 + (1-\alpha) F_2 \\ &= 0.7 \times 18 + 0.3 \times 15 \\ &= 19.2 = 19 \end{aligned}$$

$$\rightarrow E_{y_2} = 18 - 19 = -1.2 \quad \boxed{E = D - F}$$

$$E_{y_4} = 12 - 18.36 = -6.36$$

$$E_{y_5} = 25 - 13.92 = 11.092$$

$$\begin{aligned} \rightarrow F_{y_4} &= \alpha D_3 + (1-\alpha) F_3 \\ &= 0.7 \times 18 + 0.3 \times 19.2 \\ &= 18.36 = 18 \end{aligned}$$

$$\rightarrow MSE = \frac{\sum E^2}{n} = \frac{164.92}{3} = 54.974$$

$$\begin{aligned} \rightarrow F_{y_5} &= \alpha D_4 + (1-\alpha) F_4 \\ &= 0.7 \times 12 + 0.3 \times 18.36 \\ &= 13.908 = 14 \end{aligned}$$

* 2 year simple moving average : ($n=2$)

Year	D	F	E	E^2
3	18	18	0	0
4	12	20	-8.5	72.25
5	25	15	10	100
				172.25

$$\rightarrow F_{y_3} = \frac{D_2 + D_1}{2} = \frac{21 + 15}{2} = 18$$

$$\rightarrow F_{y_4} = \frac{D_3 + D_2}{2} = \frac{21 + 18}{2} = 19.5$$

$$\rightarrow F_{y_5} = \frac{D_4 + D_3}{2} = \frac{12 + 18}{2} = 15$$

$$\rightarrow MSE = \frac{\sum E^2}{n} = \frac{172.25}{3} = 57.083$$

$$\rightarrow E = D - F$$

$$E_3 = 18 - 18 = 0$$

$$E_4 = 12 - 19.5 = -7.5 = -8$$

$$E_5 = 25 - 15 = 10$$

* 2-year weighted moving average... ($n=2$, $w_1=0.6$, $w_2=0.4$)

Year	D	F	E	E^2
3	18	19	-0.6	0.36
4	12	19	-7.2	51.84
5	25	14	10.6	112.36
				164.56

$$\begin{aligned} \rightarrow F_{y_3} &= w_1 D_{y_2} + w_2 D_{y_1} \\ &= 0.6 \times 21 + 0.4 \times 15 \\ &= 18.6 = 19 \end{aligned}$$

$$\begin{aligned} \rightarrow F_{y_4} &= w_1 D_{y_3} + w_2 D_{y_2} \\ &= 0.6 \times 18 + 0.4 \times 21 \\ &= 19.2 = 19 \end{aligned}$$

$$\begin{aligned} \rightarrow F_{y_5} &= w_1 D_{y_4} + w_2 D_{y_3} \\ &= 0.6 \times 12 + 0.4 \times 18 \\ &= 14.4 = 14 \end{aligned}$$

$$\rightarrow E = D - F$$

$$E_3 = 18 - 18.6 = -0.6$$

$$E_4 = 12 - 19.2 = -7.2$$

$$E_5 = 25 - 14.4 = 10.6$$

$$\rightarrow MSE = \frac{\sum E^2}{n} = \frac{164.56}{3} = 54.853$$

$$MSE_1 = 54.974$$

$$MSE_2 = 52.083$$

$$MSE_3 = 54.853$$

$\Rightarrow$ ~~just~~ // The exponential smoothing is the best

lec 9

→ We used the previous measures to compare between more than one method and we need to choose the appropriate method

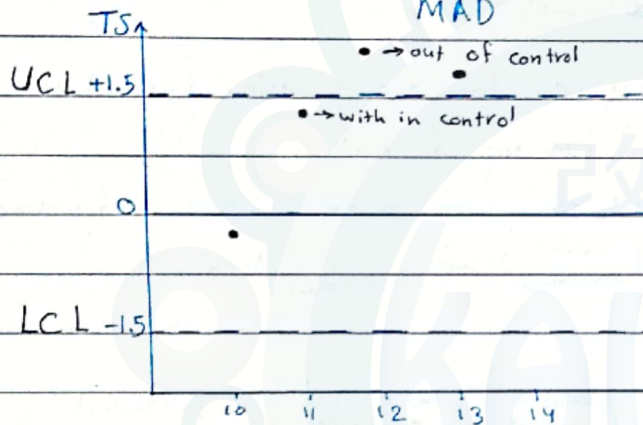


we have another technique ⇒ we use it after choosing the method

↳ to check if the forecasting process using this method is within control or out of control

Tracking signal (TS)

→ Tracking signal = $\frac{CFE}{MAD}$ ← within control chart



→ Within limits ($-1.5 < TS < 1.5$)

∴ Process of forecasting using this specific method is within control

→ Upper or less control limits

∴ " " " " out of control
 ↳ (demand, ...) the method of fore.
 ∴ we need to look for another technique

How to choose the appropriate technique:

[1] Availability of data about actual demand for previous periods

data → not available → Judgemental methods

→ available → quantitative methods (causal method / time series)

[2] Assumption that the demand is related to one or more independent variables

→ causal methods → simple linear regression
 → multiple linear regression

[3] Assumption that demand behavior in the past will continue in the future

→ time series analysis

④ Time series Pattern → - horizontal (naive / simple moving average / weighted moving average / exponential smoothing)
 - trend (linear regression / ARIMA / trend adjusted exponential smoothing)
 - seasonal (multiplicative seasonal method / additive seasonal method / SARIMA)

⑤ Measures of error → - bias of method → CFE / $\bar{E}$
 - deviation from actual → MAD
 - large error in certain periods → MSE
 - amount of deviation as a percent of actual demand → MAPE
 - Variability of error → σ_e

↓
 criteria التي تستخدم

⑥ Tracking signal → check if the process of forecasting using the chosen technique is within control or not

xx when we have more than one method are close to each other Performance

↳ we use new 2 strategies (more methods / one method)

⑦ Combination forecasting

→ Time series (horizontal) → Naive / simple moving average / weighted moving average / exponential smoothing
 ① $n=2$ $n=4$ $n=2$ $n=4$ $\alpha=0.3$ ⑥
 ② ③ ④ ⑤ $\alpha=0.7$ ⑦
 $\alpha=0.9$ ⑧

- amount of deviation as a percent of actual → MAPE

→ $M_2 / M_4 / M_8$ (Performance (2/4/8) about MAPE)

Period	M_2	M_4	M_8	Forecast decision
q	$F_{M_2(q)}$	$F_{M_4(q)}$	$F_{M_8(q)}$	$\frac{F_{M_2(q)} + F_{M_4(q)} + F_{M_8(q)}}{3}$

بالتالي
 combined

→ It proved to be less error for the forecast than the error in (2/4/8)

8 Focus Forecasting

Period	M_2	M_4	M_8	Forecast decision	→ MAPE till Period ⑧
9	$F_{M_2} ⑨$	$F_{M_4} ⑨$	$F_{M_8} ⑨$	$F_{M_4} ⑨$	M_2
					✓ M_4
10	$F_{M_2} ⑩$	$F_{M_4} ⑩$	$F_{M_8} ⑩$	$F_{M_2} ⑩$	M_8
					MAPE أقل

→ we are going to focus on the method that

produced the least error of the past periods.

→ MAPE till Period ⑨

M_2 ✓ أقل خطأ
 M_4
 M_8

End-of-chapter

new chapter

Inventory Management

inventory (stock)

material stocked المخزون

warehouse

المكان الذي نخزن فيه المخزون

two terminologies are related

Inventory في warehouse هي

inventory management

decisions

How much to order

When to order

How often to review

:

warehouse management

decisions

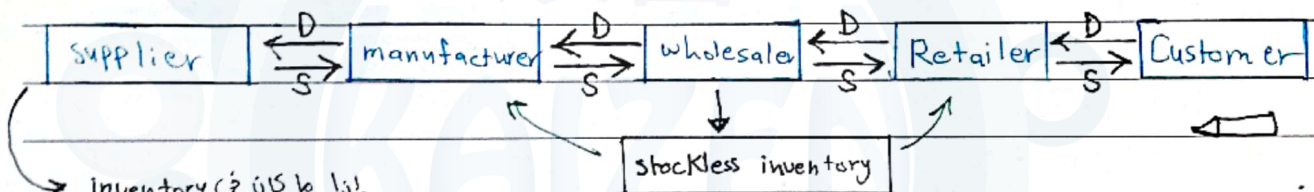
number of warehouse

location of the warehouse

Size of " "

number of the shelves " "

:



very long delivery time في سلسلة التوريد

→ Now a day, customer are demanding:

- shorter delivery time

- highest quality

- lowest cost

(to be succeed between)
competitors → العميل/customer

→ To ensure the shortest delivery time:

we need to have inventory

→ - warehouse (مخزن) Inventory like

- Enablers (ممكنات) في سلسلة التوريد

① reliable information system
(manufacturer/wholesaler/retailer) (معلومات)

② reliable transportation system

- immediately the informations
arrive manufacturer

→ immediately the manufacturer
wholesaler (مخزن)

→ immediately wholesaler
The retailer (مخزن)

- supply chain system (نظام سلسلة التوريد)

- in general, in most cases
the stockless inventory

one supplier chain (سلسلة موردين) → لا يمكن تطبيقها في كل ال echelons (مستويات) Five Apple

* Stock-Keeping-unit (SKU)

↳ any item stocked somewhere in the supply chain have a unified code (SKU ← رمز فني item)

→ We can categorize inventory using different criteria:

- Raw material inventory
- finish good inventory
- work in process inventory

	مخزون
① خط انتاج	Work in Process inventory (WIP)
② خط انتاج	

← خط انتاج ① امرغ من ②
فني للنتج الناتج من ①
بين فترة موجود ليقول ②

↳ The quantity of tubes that waiting until use it in Production line ② ③ ④ ⑤

Lean (eliminate waste)

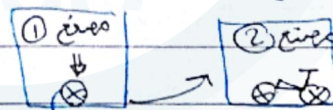
↳ we need to eliminate WIP inventory because it doesn't give me added value
↳ anything doesn't give value

raw material inventory	finished goods inventory
------------------------	--------------------------

The inventory of SKU we will make on it further processing to transform it into finished goods

الاسك
crom rod

↳ The inventory of SKU in its final form as it will go to the next customer



finished good inventory

dependent demand SKU

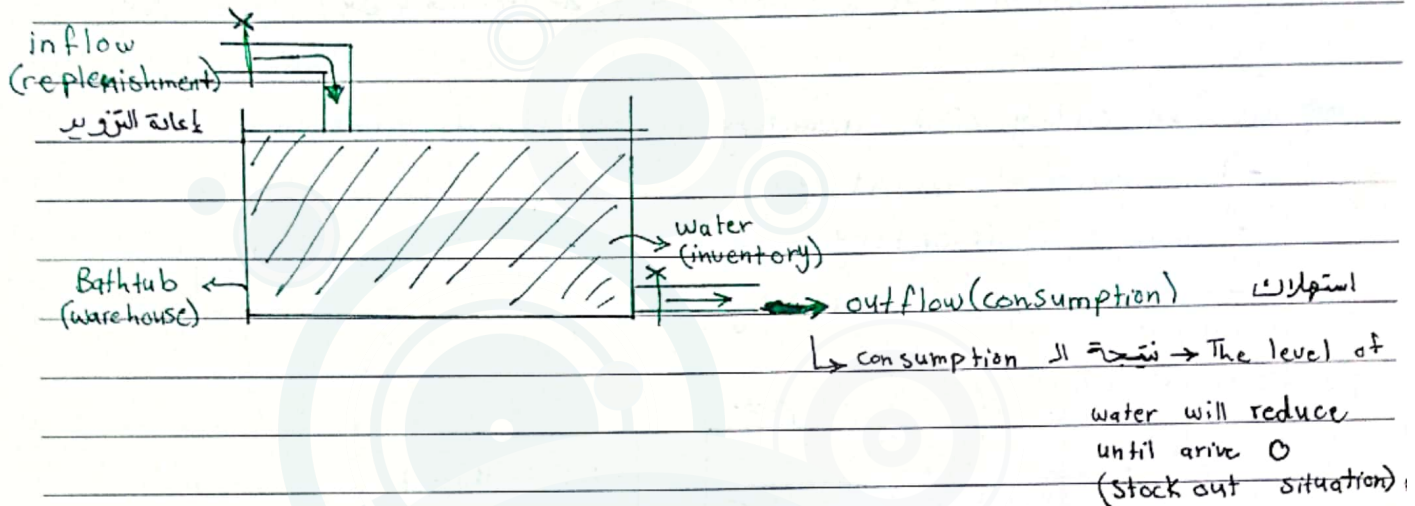
↳ Independent demand SKU

depend on demand of other SKU

↳ depend. in market condition

→ why its important to know if SKUs is dependent demand SKU or independent?
because the method that use for manage the independent SKUs is different from the dependent SKUs

Lec 10

Managing the inventory: (the purpose: supply the demand)

→ The Decisions (to manage inventory):

So need replenishment

- How much to order?
- When to order?
- How often to review inventory position?

Inventory management

classification of SKUs

→ help to make control

- ABC classification method

choosing inventory control approach

How to answer 3 decisions:1 how much to order?2 when to order?3 how often to review IP?

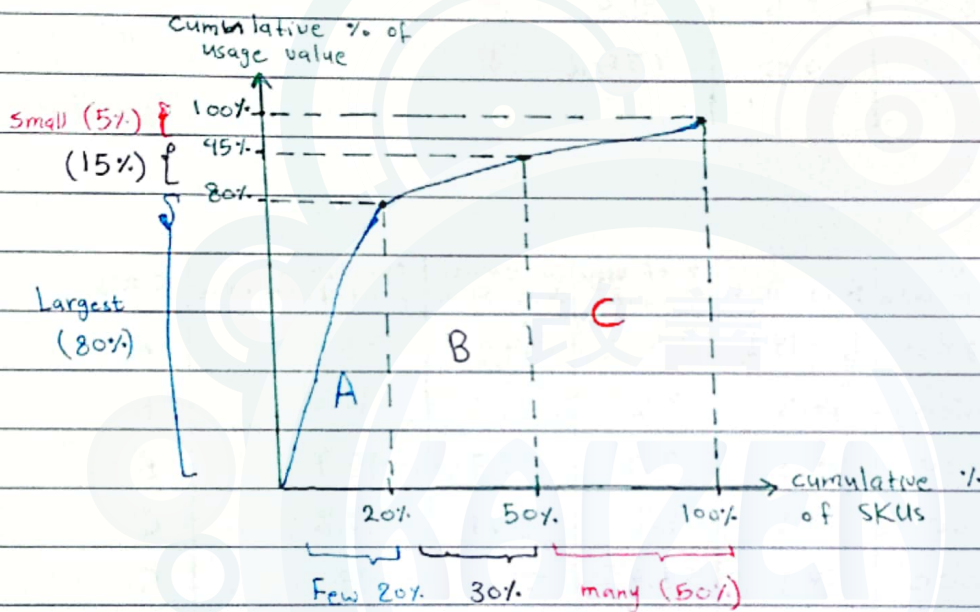
* ABC classification method

→ It will classify the stock keeping unit into class A/class B/class C in terms of annual usage value (dollar usage)

	cost	Annual Demand	Annual usage value = Cost X Annual demand
Product X	\$1	1000 000	1000 000 \$/year
Product Y	\$1000	1	1000 \$/year

← we will give more attention for Product X

↓
I will make the details of inventory control give more attention for Product X



* Ranking for all SKUs in term of usage value descending order (ترتيب تنازلي)

* As a general rule from the graph

- The few percent from SKUs (20%) → The largest percent of usage value (80%) (A)
- many percent (80%) → 30% → 15% (B)
- 30% → 15% (C)

⇒ (80-20) Rule / Pareto

- few → Largest effect (more focus)
- larger → small effect

⇒ In Inventory

- (A) few → critical → more attention in terms of managing
- (C) many → trivial/Useful → less frequent managing

Another classification method

Criticality to the patient (in Hospital)

- critical + medium + low criticality

Example of ABC classification

SKU #	Description	Quantity used Per year	Unit value (\$)	Annual usage value (\$/year)	
1	Boxes	500	3	1500	(4)
2	cardboard	18000	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)

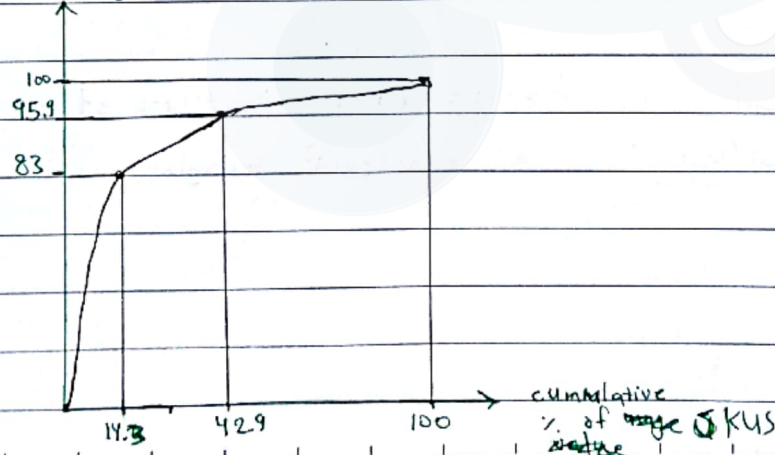
SKU #	Description	Annual usage value	% of SKUs	% of usage value	Cumulative % of SKUs	Cumulative % of usage value	class
7	signature	67500	$\frac{1}{7} = 14.3$	83	14.3	83	A
3	cover	7500	14.3	9.2	28.6	92.2	B
4	glue	3000	14.3	3.7	42.9	95.9	B
1	Boxes	1500	14.3	1.8	57.1	97.8	C
5	inside cover	1000	14.3	1.2	71.4	99	C
6	tape	450	14.3	0.6	85.7	99.6	C
2	cardboard	360	14.3	0.4	100	100	C
		81310					

مع النسبة

مع النسبة



Cumulative % of usage value



Lec II

Inventory cost

① inventory holding cost

② ordering / setup cost

cost of capital

Storage and handling cost

Taxes, insurance, shrinkage

→ losing Profit is cost
 , so losing opportunity
 to invest (the holding
 amount of money in
 the form of inventory)
 to having more Profit
 ↳ is cost of capital

→ Storage cost :

obtaining, warehouse
 temperature, etc.,
 controlling, shelves

unit of cost →

shrinkage

→ handling cost :

a way of handling
 inventory
 جلب و نقل البضائع

Pilferage (theft)

the inventory
 البضائع المفقودة

obsolescence

the value
 less than
 the original
 due to being
 outdated

deterioration

damage or
 expired

↓
 The value of
 it will be less
 than the original

losing profit
 ↓
 cost

→ cost of capital

unit of cost

(unit of cost ↑ cost of capital ↑)

→ unit of cost

H : unit holding cost : \$/unit/year (Finance Department يقرر)

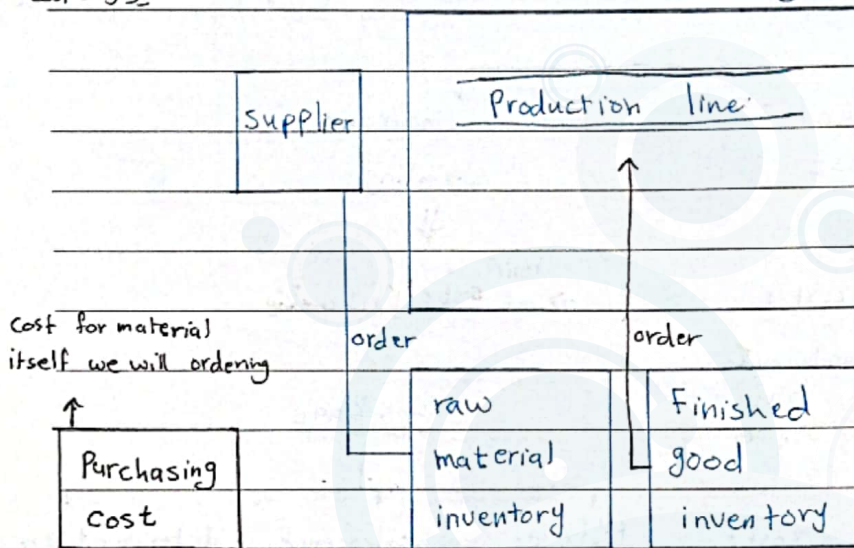
↳ as a percent of unit cost (15% / 20% / 25%)

2] Ordering / setup cost : replenishment / making order

S: setup cost (\$/order)

cost of order

time



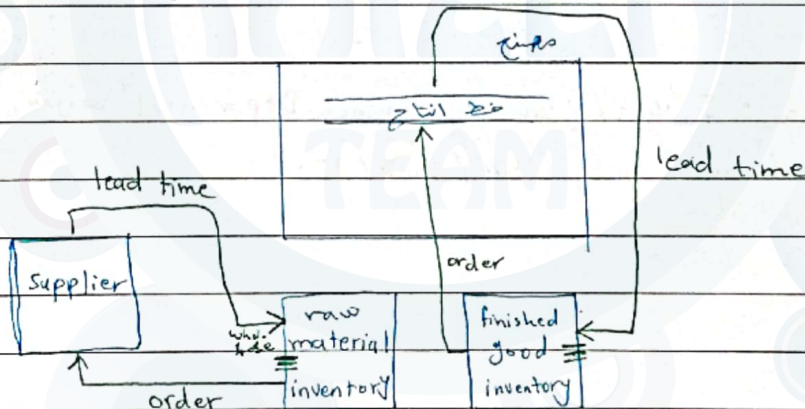
: ordering cost

setup cost : replenishment (order)

the cost of replenishment and order (cost of phone / Email / sms / time)

(Person cleaning / schedule / setting up for machine)

*Lead time: the time from the moment the quantity was ordered until the quantity is received (checked, put on shelves in warehouse)

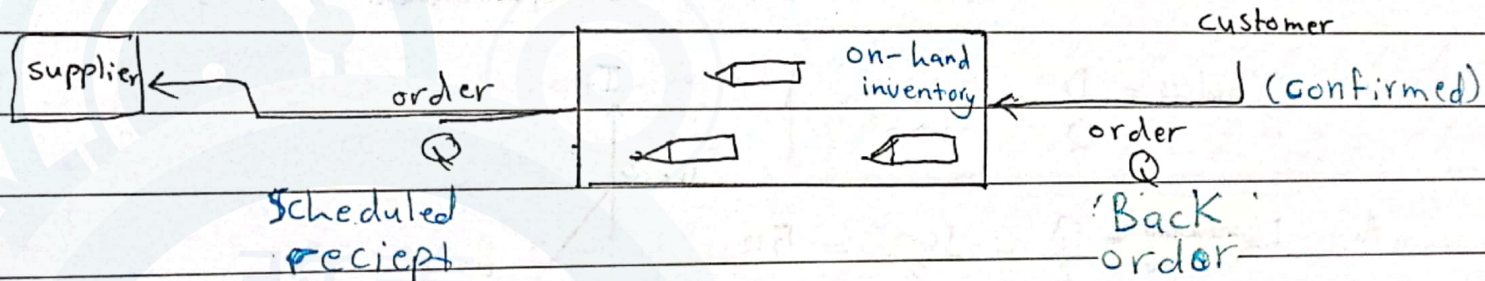


* Inventory Position :

Inventory position = on-hand Inventory $+$ scheduled Receipt $-$ Back order

موجود على الرف ordered but not recieved yet ز ايجاز customer

$$IP = OH + SR - BO$$



* method to calculate IP $\rightarrow$ Manually $\rightarrow$ عدد القطع على الرف / عدد orders

$\rightarrow$ Technology $\rightarrow$ barcodes

scanners (scan to barcodes)

software (مربوط بالscanner $\Rightarrow$ جداول البيانات)

* The Relationship between Quantity that we order each time with # of orders Per year with average inventory Per year

Product X

Annual Demand $D = 100$ unit/year

D : unit/year
 d : unit/month
 unit/week
 unit/day

Case ① $Q = 100$ unit (quantity that we order each time we need to put an order or to replenishment inventory)

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

$$\text{Avg. inventory} = \frac{Q}{2} = \frac{100}{2} = 50$$

Case ② $Q = 50$

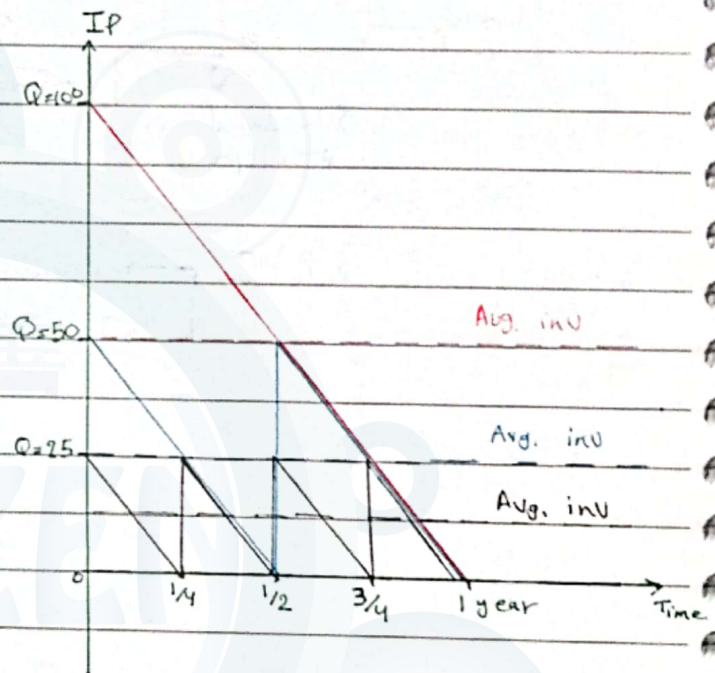
$$\text{no. of orders} = \frac{100}{50} = 2$$

$$\text{Avg. inventory} = \frac{Q}{2} = \frac{50}{2} = 25$$

Case ③ $Q = 25$

$$\text{no. of orders} = \frac{100}{25} = 4$$

$$\text{Avg. inventory} = \frac{25}{2} = 12.5$$



Holding Cost

H : unit holding cost
 \$/unit/year

$Q \uparrow \Rightarrow$ $\leftarrow$ no. of order $\leftarrow$ Avg. inventory
 $\text{Avg.} \uparrow \rightarrow$ holding cost
 $\text{no. order} \downarrow \rightarrow$ ordering cost

$Q \rightarrow$ How much to order

ordering Cost

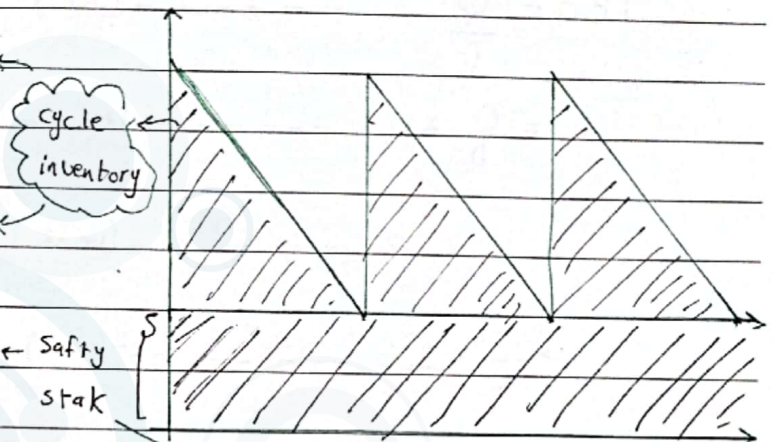
S : order cost
 \$/order

xx cycle inventory cost

the quantity of inventory that is caused by replenishment and consumption

because we used traditional methods for managing inventory (traditional methods to replenish and consume inventory)

Saw-tooth pattern: $\frac{D}{Q}$



due to cycle inventory (due to variability in demand or lead time cost) → Safety stock

pipeline inventory → another way to classify the inventory

xx Total annual cycle inventory cost:

Total annual cycle inventory cost = Annual holding cost + Annual ordering cost

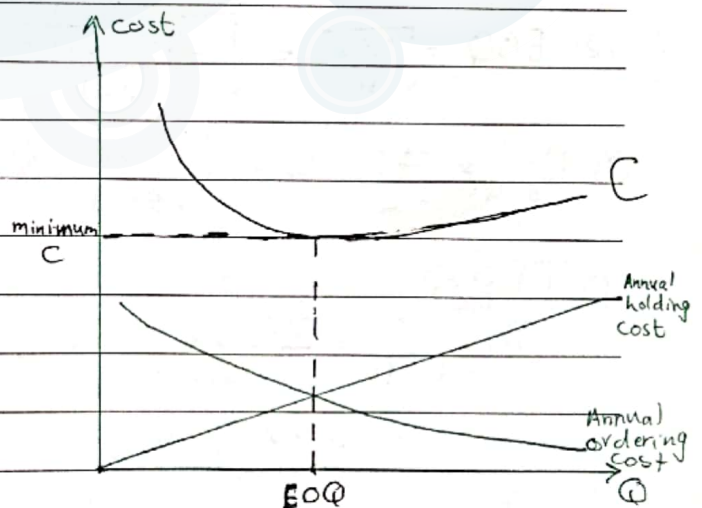
$$C = \frac{Q}{2} H + \frac{D}{Q} S$$

→ Annual holding cost = Average cycle inventory × unit holding cost
 $= \frac{Q}{2} H$

→ Annual ordering cost = Number of order Per year × ordering/setup cost
 $= \frac{D}{Q} S$

⇒ economic order = the total quantity (EOQ)

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



Five Apple

Time between orders (TBO)

$$TBO = \frac{Q}{D} \text{ --- (year)}$$

$$= \frac{Q}{D} \times 12 \text{ --- (month)}$$

$$= \frac{Q}{D} \times 52 \text{ --- (weeks)}$$

$$= \frac{Q}{D} \times 365 \text{ --- (days)}$$

Example 52 weeks

SKU: bird feeder

$d = 18$ unit/week

$S = \$45$ /order

unit cost = \$60 unit

$H: 25\%$ of unit cost = $0.25(60)$

$Q_{\text{current}} = 390$ unit = \$15/unit/year

Find $C_{\text{current}} = ??$

$EOQ = ??$

$C = ??$
 EOQ

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

$$\textcircled{1} C_{\text{current}} = \frac{390}{2} (15) + \frac{(18)(52)}{390} (45) = \$3033$$

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

$$\textcircled{3} C_{EOQ} = \frac{75}{2} (15) + \frac{(18)(52)}{75} (45) = \$1124$$

④ $TBO_{EOQ} = ??$

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

$$= \frac{75}{(18)(52)} \times 12 = 0.96 \text{ month} \approx 1 \text{ month}$$

$$= \frac{75}{(18)(52)} \times 52 = 4.17 \text{ month} = \frac{75}{(18)(52)} \times 365 = 29.25 \text{ days} \approx 30 \text{ days}$$

lec 13

Inventory management

classification of SKUs

- ABC classification method

choosing inventory control approach

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

independent demand
SKU
market & supply conditions

dependent demand
SKU
demand for another SKU

(1/2/3)

these methods are traditional inventory control methods

① Continuous Review system

② Periodic Review system

③ hybrid system

Material Requirements Planning (MRP)

optional Replenishment

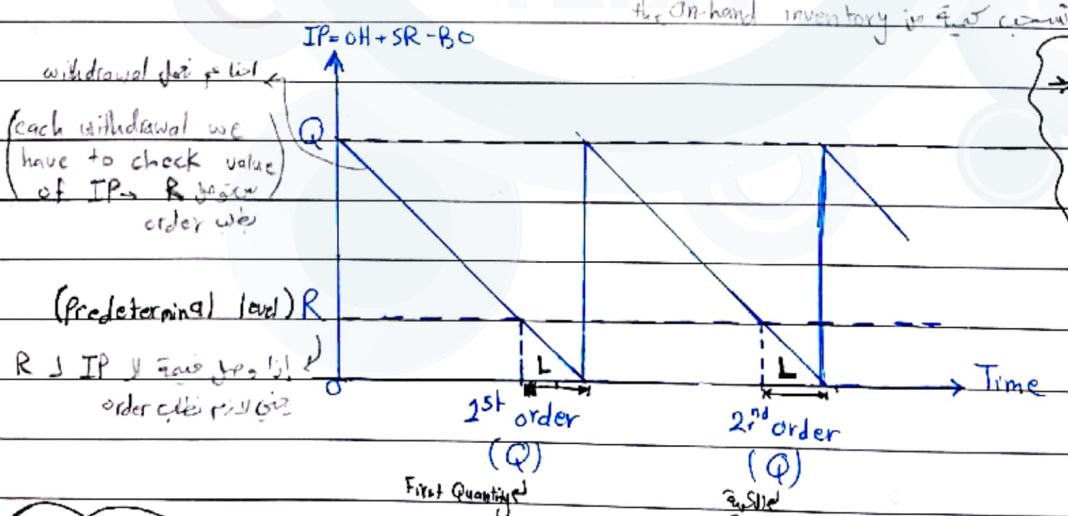
base-stock system

another chapter

** Continuous Review system / ROP / fixed quantity / Q system

⇒ Description how this method is used for managing inventory:

We check the inventory position at each withdrawal, if the inventory position reaches a predetermined level (R) → we put an order of a fixed quantity (Q)



→ lead time & demand rate is constant

→ at time zero the value of quantity is (Q)

Lead time

at the lead time we use from quantity (R) → $R = \text{average demand rate} \times \text{lead time}$

Five Apple

Questions about continuous review system

How often to review IP?

→ continuously, each time we make a withdrawal

when to order?

→ When IP reaches the predetermined level (R)

How we choose??

How much to order?

→ A fixed Quantity

How we choose?

↳ to choose Q ?

EOQ

- First option

usually we think of

- It minimize the total cycle inventory cost

- Sometimes we have constraints which limit EOQ

container size Quantity

ex EOQ = 100

shelves → 50

→ shelf

* transportation system

Price-break Quantity

C

Purchasing cost

EOQ ↓
120 ↑

إذا كان الفرق بين C و EOQ كبيراً

إذا كان الفرق بين C و EOQ صغيراً

convenient Quantity

كمية مناسبة

for supplier/المنتج

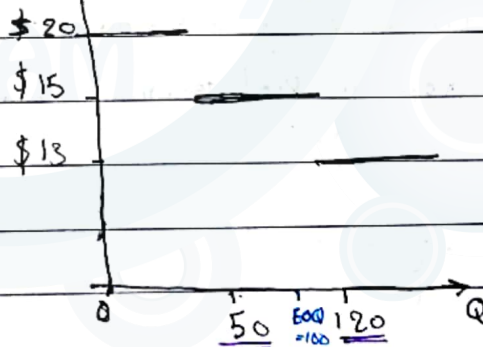
→ selected quantity by management

Factor Expiry

تاريخ انتهاء الصلاحية

Expiry

* It must be balance between all Factors



50/120 = Price break Quantity

الكمية التي يتغير فيها السعر

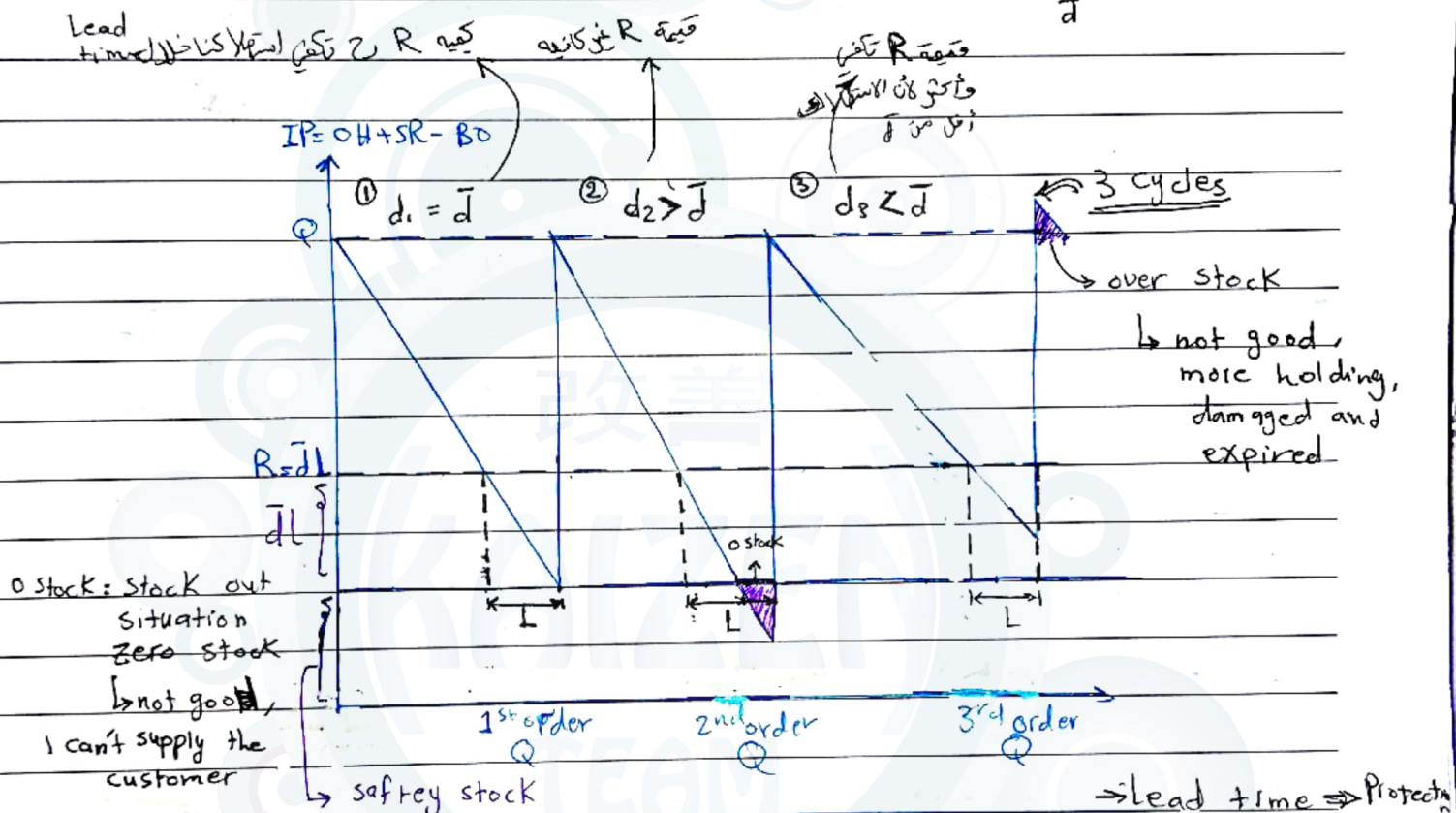
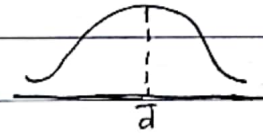
→ To Determine R

Demand Constant (d)
Lead time Constant (L)

Have normal distribution
Demand Variable ($\bar{d}$)
lead time Constant (L)

$$R = dL$$

$$R = \bar{d}L$$



$$R = \bar{d}L + \text{Safety stock}$$

→ Lead time → Protection interval
protecting from having a 0 stock situation

safety stock: protect the inventory position during this interval (lead time) from having this amount of safety

* Service level

100% → 0% stock out

95% → 5% stock out

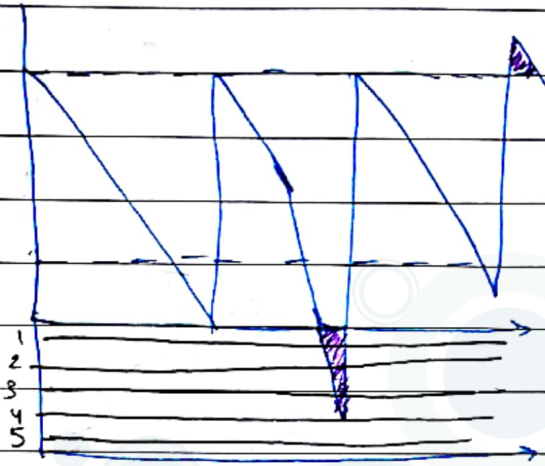
by safety stock

(service level ↑ holding cost ↑)

→ disadvantage of safety stock:

increases the holding cost

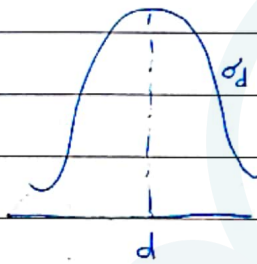
(safety stock ↑ holding cost ↑)



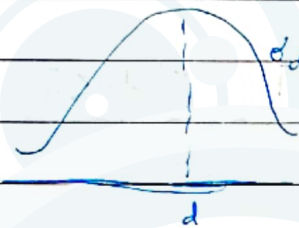
→ safety stock → risk of stockout

سafety stock

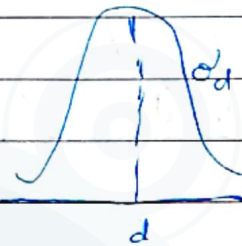
$$R = \bar{d}L + \text{safety stock}$$



day ①

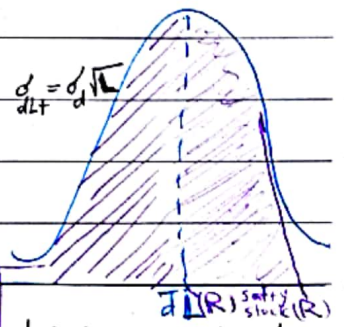


day ②



day ③

$L = 3 \text{ days}$



distribution of demand during protection interval (L)

area → service level 50%

safety stock

→ If Demand Variable (σ_d)

lead time constant (L)

$$R = \bar{d}L + \text{Safety stock}$$

$$SS = Z \sigma_{dLT}$$

Z: number of standard deviation needed to achieve service level

$$\sigma_{dLT} = \sigma_d \sqrt{L}$$

Lec 14

Example Birdfeeder

52 weeks

safety stock = ??

 $R = ??$

EOQ = 75 unit (assume this the best value)

 $C = ??$ $H = \$15/\text{unit}/\text{year}$ $S = \$45/\text{order}$ Q system بمقدورها $\bar{d} = 18 \text{ unit}/\text{week}$ $\sigma_d = 5 \text{ units}$ $L = 2 \text{ weeks (constant)}$

90% service level

$$S.S = Z \sigma_{dLT} = Z \sigma_d \sqrt{L} = (1.28)(5)(\sqrt{2}) = 9.05 \approx 9 \text{ units}$$

شرح كيف طلع
في الصفحة
التالية

$$R = \bar{d}L + S.S = (18)(2) + 9 = 45 \text{ units} \rightarrow \text{Make order when reach } \underline{R} \text{ or less}$$

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

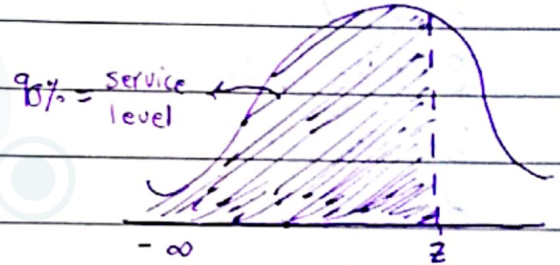
$$= \frac{75}{2} (15) + \frac{(18)(52)}{75} (45) + (9)(15) = \$1259$$

* Recently, the on-hand inventory equals 60 units. There is no scheduled receipt and no back orders. Now, we make a withdrawal of 20 units. Is time to order? and if yes, how much?

$$IP_{\text{now}} = OH + SR - BO = (60 - 20) + 0 - 0 = 40$$

$IP_{\text{now}} < R$, yes we order $Q = 75 \text{ unit}$

Z : area under curve from minus infinity to the quantity of Z that equal the same area of service level



Z	0.60	0.01	0.02	0.08	0.09
0.0					
0.1					
0.2					
:					
:					
:					
1.2				0.8997	0.9015
3.4					

بدرج على أقرب رقم 0.9
90%

$Z=1.28 \leftarrow$ قيمة Z التي تحقق 90% service level

↳ to determine R

↓ Demand Constant (d)	↓ Demand variable ($\bar{d}$)	↓ Demand variable ($\bar{d}$)
lead time constant (L)	lead time constant (L)	lead time variable ($\bar{L}$)

$$R = dL$$

$$R = \bar{d}L + \text{Safety stock} \quad \checkmark$$

$$R = \bar{d}\bar{L} + \text{Safety stock}$$

$$S.S. = Z \sigma_{dLT}$$

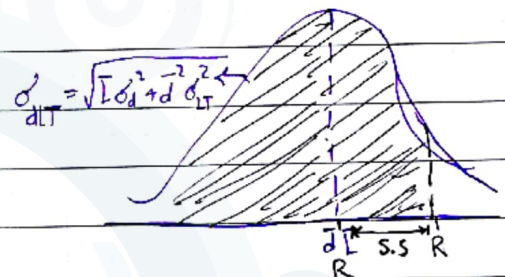
$$S.S. = Z \sigma_{dLT}$$

Z: number of standard deviation needed to achieve required service level

Z: number of standard deviation needed to achieve required service level

$$\sigma_{dLT} = \sigma_d \sqrt{L}$$

$$\sigma_{dLT} = \sqrt{\bar{L} \sigma_d^2 + \bar{d}^2 \sigma_{LT}^2}$$



Example Pen

$$\bar{d} = 12000 \text{ Pens}$$

95% service level

$$\sigma_d = 3000 \text{ Pens}$$

R = ?

distribution of demand during Protection level (L)

$$Q = 156000 \text{ Pens} \quad \left(\begin{array}{l} \text{from: call for an order} \\ \text{of } 156000 \rightarrow Q \text{ is } 156000 \end{array} \right)$$

$$L = 5 \text{ weeks}$$

$$\sigma_{LT} = 2 \text{ weeks}$$

Q system

$$Z = 1.65 \rightarrow 95\% \text{ service level area (0.95)}$$

$$S.S. = Z \sigma_{dLT} = Z \sqrt{\bar{L} \sigma_d^2 + \bar{d}^2 \sigma_{LT}^2} = (1.65) \sqrt{(5)(3000)^2 + (12000)^2 (2)^2} = 41117.79 \approx 41118 \text{ Pens}$$

$$R = \bar{d}\bar{L} + S.S. = (12000)(5) + 41118 = 101118 \text{ Pens}$$

Variable $\leftarrow$ standard dev + avg. (left)

Variable L $\leftarrow$ standard + avg. lead time (left)

IP (check it)

manually

Technology

Visual

OH

SR

Bo

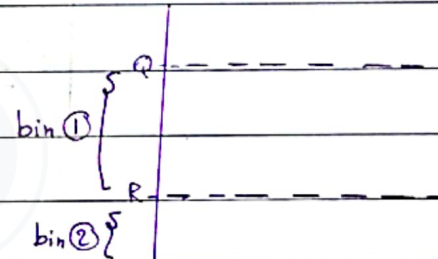
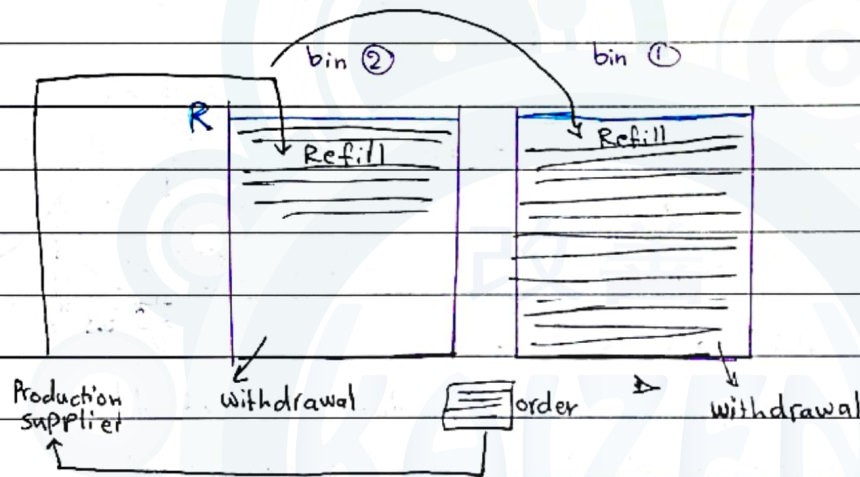
barcodes

scanners

software

OH

Visual Q system → two-bin system



نصير bin 1 و bin 2

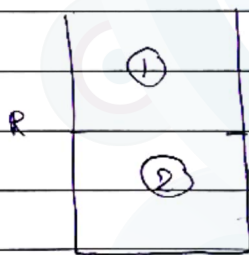
order ← R like to be

lead time

bin 2

مجرد ما انتهى وقتنا

bin 1 و bin 2



→ when we have very small items, usually uses visual Q system

non-critical items

very small items

→ can't count it manually

" have barcode for all one item

Lec 15

Periodic Review system / Fixed-interval / Periodic re-order system / P-system

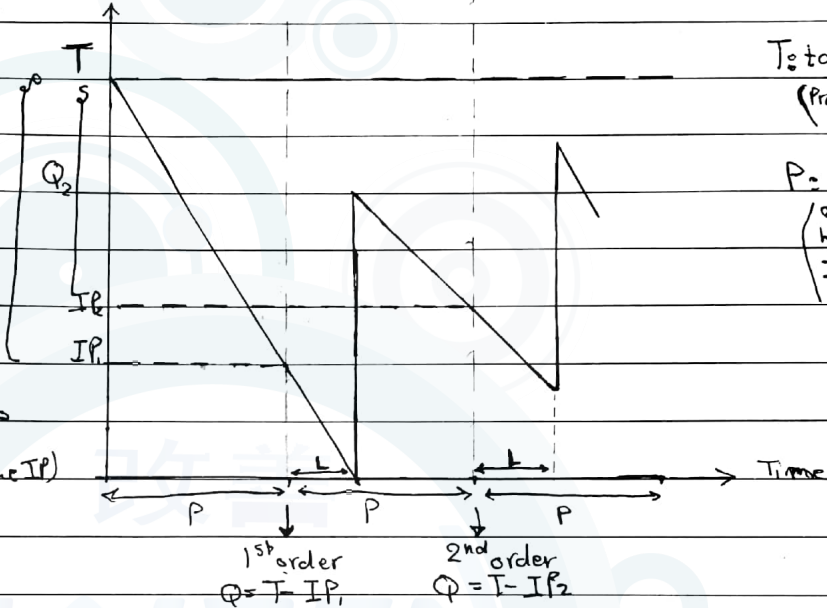
→ In periodic system, we check inventory position periodically at the end of the review period P and we put an order (this order is a quantity that brings back and interposition to a predetermined target level)

→ خلال الفترة P ما ينشك IP withdrawal Q لنظامها

→ في نهاية الفترة P ننشك IP ونطلب كمية مقدارها $(T - IP)$ الكمية التي نحتاجها لا Target

→ كمية T لا يمكن الاستهلاك خلال الفترة P والفترة L

$$IP = OH + SR - BO$$



T : target level (predetermined value)

P : Review period (at end of it we have to check Inventory position and order)

→ In P there is a possibility to happen a stock out (because we don't check the IP)

→ In Period L (because we waiting Q)

→ The protection interval if we have (variable demand and variable lead time) is P and L

Periodic Review system

How often to Review IP ?

when to order?

How much to order?

Periodically, at the end of each review period P

at the end of each review period P

order = Target - inventory quantity inventory position

$$Q = T - IP$$

P : Time between order
• TBO

How to determinand (P)

$$P = TBO = \frac{Q}{D}$$

كل ما كانت P أكبر رح تكون Q أكبر
لأنه بعدنا عن فترة T أكثر
ولا IP رح يقل أكثر

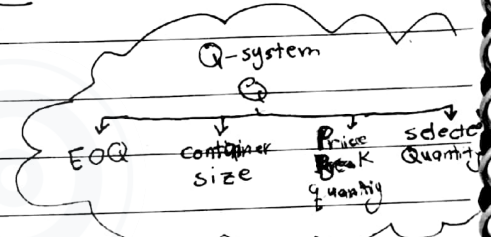
$$TBO = \frac{EOQ}{D}$$

$$TBO_{\text{container size}} = \frac{Q_{\text{container size}}}{D}$$

$$TBO_{\text{Price Break Quantity}} = \frac{Q_{\text{Price Break}}}{D}$$

$$TBO_{\text{Selected Quantity}} = \frac{Q_{\text{Selected}}}{D}$$

نختار P التي تحقق فترة زمنية متوسطة على average



How to determined (T) → L خلال فترة P Variable D constant D

Variability of Demand
← فترة T كلما جرت على
Lead Variability of time

فترة P و L Protection interval
لأنه ممكن نخلص بغير stock out

Demand constant (d)
lead time constant (L)

$$T = d(P + L)$$

→ all units measurement
for (d, P, L) should be
Same (per day / per week...)

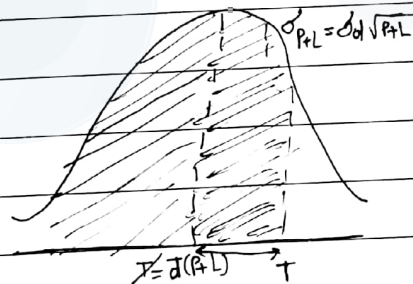
Demand variable ($\bar{d}$)
Lead time constant (L)

$$T = \bar{d}(P + L) + \text{safety stock}$$

$$S.S = Z \sigma_{P+L}$$

Z = number of standard deviation
needed to achieve required
service level

$$\sigma_{P+L} = \sigma_d \sqrt{P+L}$$



distribution of demand
during Protection interval ($P+L$)

Ex (Bird Feeder)

52 weeks

P-system

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

$$\textcircled{1} S.S = ??$$

$$\sigma_d = 5 \text{ units}$$

$$\textcircled{2} T = ??$$

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

$$\textcircled{3} C = ??$$

$$S = \$ 45/\text{order}$$

$$EOQ = 75 \text{ units} \leftarrow$$

$$L = 2 \text{ weeks}$$

$$90\% \text{ service level } (z = 1.28)$$

$$P = TBO_{EOQ} = \frac{EOQ \times 52}{D} = \frac{75 \times 52}{(18 \times 52)} = 4.2 \text{ weeks} \approx 4 \text{ weeks}$$

نفس L و $\bar{d}$ في P لأن unit measurement 52

$$\textcircled{1} S.S = Z \sigma_{P+L} = Z \sigma_d \sqrt{P+L} = (1.28)(5)\sqrt{4+2} = 15.68 \approx 16 \text{ units}$$

$$\textcircled{2} T = \bar{d}(P+L) + S.S = (18)(4+2) + 16 = 124 \text{ units}$$

$$\textcircled{3} C = \frac{\bar{d} P}{2} H + \frac{D}{\bar{d} P} S + S.S H$$

$$= \frac{(18)(4)}{2} (15) + \frac{(18)(52)}{(18)(4)} (45) + (16)(15) = \$ 1365$$

in Q-system

$$C = 1259$$

$$S.S = 9$$

$$\therefore P\text{-system} \rightarrow C \uparrow$$

	Q-system (L)	P-system (L+P)	الفرق بين النظامين
Protection interval			
S.S		larger	لنا زينا فترة ال
holding cost SS		larger	Protection
C	less cost	larger	

④ Recently, the OH equals 60 units (No scheduled receipts, no back orders). Now, it is the end of review period and the onhand inventory equals 45 units. Is it time to order? and how much?

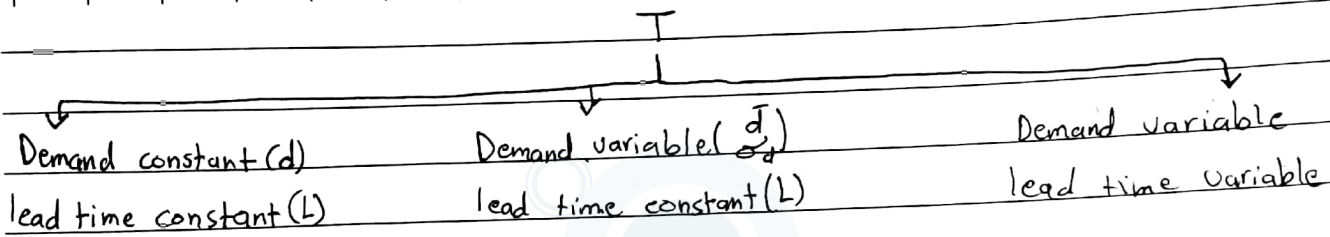
Yes, we order

$$IP = OH + SR - BO = 45 + 0 - 0 = 45$$

$$Q = T - IP = 124 - 45 = 79 \text{ units}$$

→ at the end of review period we should order

Five Apple

lec 16

$$T = d(P+L)$$

$$T = \bar{d}(P+L) + \text{safety stock}$$

$$S.S. = Z \sigma_{P+L}$$

Z : number of standard deviations needed to achieve required service level

$$\sigma_{P+L} = \sigma_d \sqrt{P+L}$$

→ due to the variability in demand and lead time during the protection interval $(P+L)$ we can't assume with certainty that the demand have normal distribution, so we need to do some kind of simulation to find out what is the distribution of demand during $(P+L)$

once we know the distribution we can use it to find amount of S.S according the service level we need



Protection interval $(P+L)$

→ use simulation to estimate the demand during protection interval $(P+L)$ so as to use it to select value of T (under-desired service level)

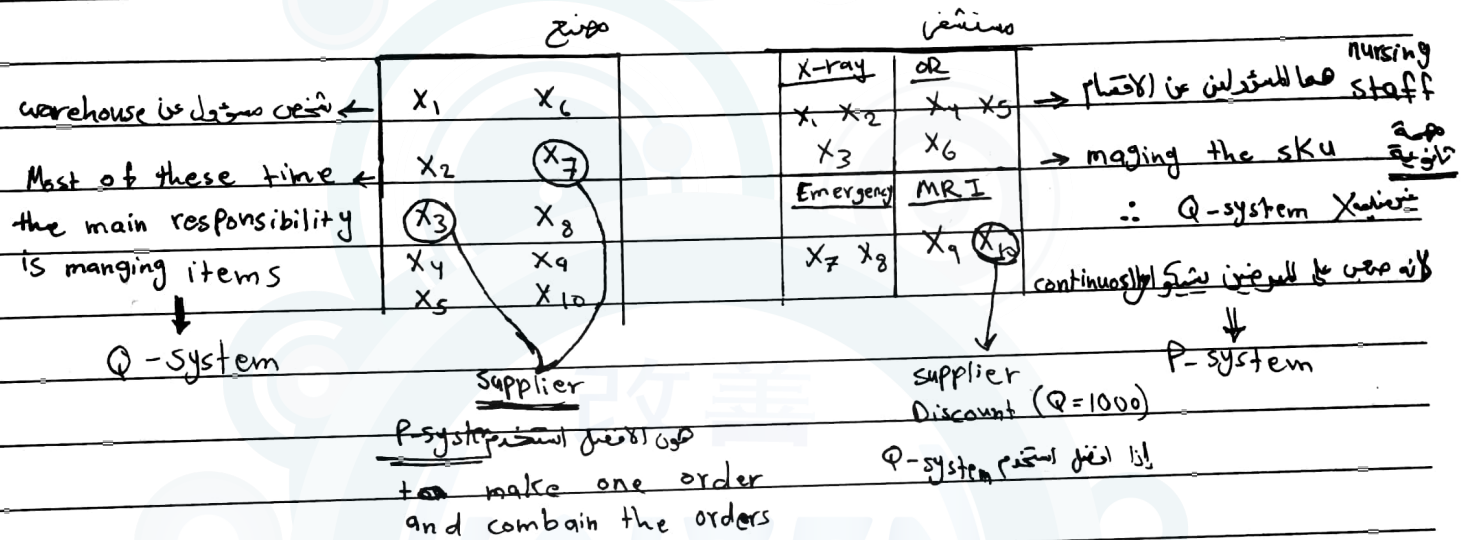
Q-system

advantage: Cost(c) less cost
fixed quantity (discount)

P-system

advantage: order → fixed intervals → IBO
* The order can be combined

I P → Periodic



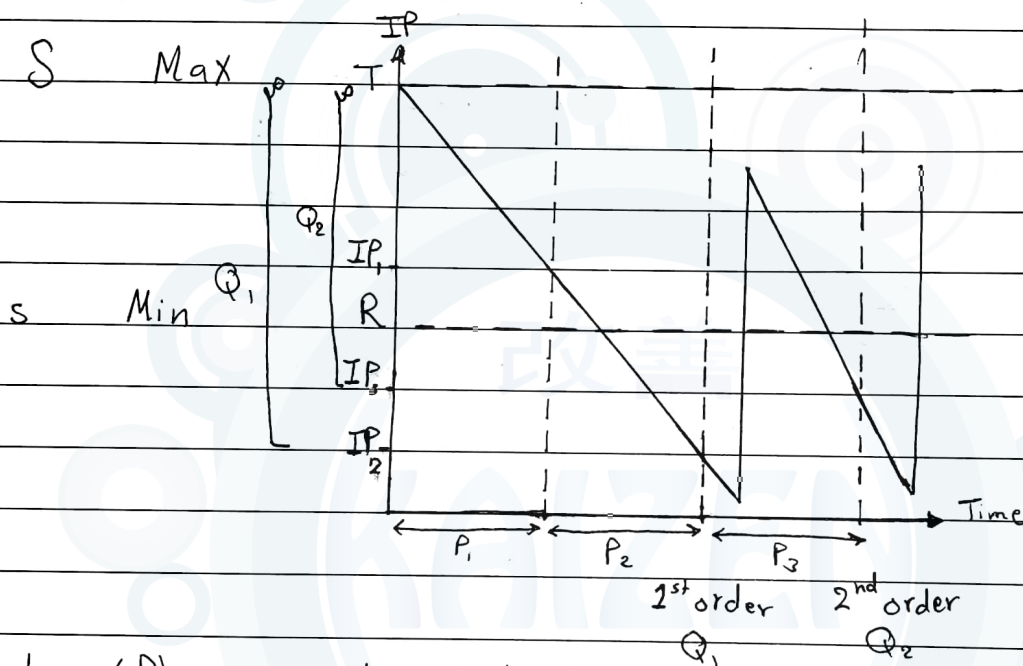
حتى اصد النظام الأنسب يجب أن أقارن بين عدة أمور وبناء عليها أقرر من الأنسب

** Hybrid system

optional Replenishment base-stock system

Optional Replenishment / (Max-Min) system / (S-s) system

→ We check the inventory position only at the end of the review period P .
 If the inventory position reaches R we put an order of a quantity that brings back the inventory position to a predetermined target level.
 If not, we wait for the next Review period to end and we check the inventory position.



during $(P) \Rightarrow$ we don't check IP

at the end of $(P) \Rightarrow$ we check IP

when order ?? $\Rightarrow$ if the IP reaches R

*** لأي نوع من ال items يستعمله (S-s cheap or expensive items)

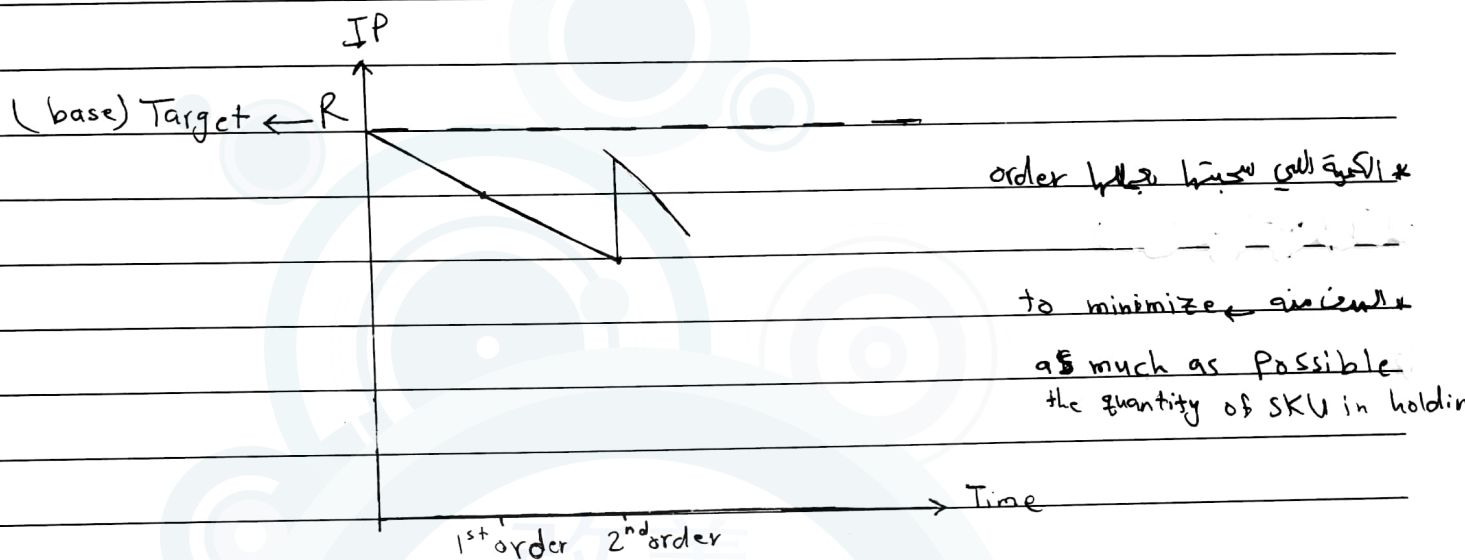
بما انه ما يجعل order كل مرة P at the end P وإنما يفتقر للفترة التي تبدأ فيها order

فالنسبة قليل عليه ال order التي قد تكون مكلفة أكثر من عليه ال Holding و Karas items in cheap

Very cheap items (Large T, خزانة)

2 Base-Stock system

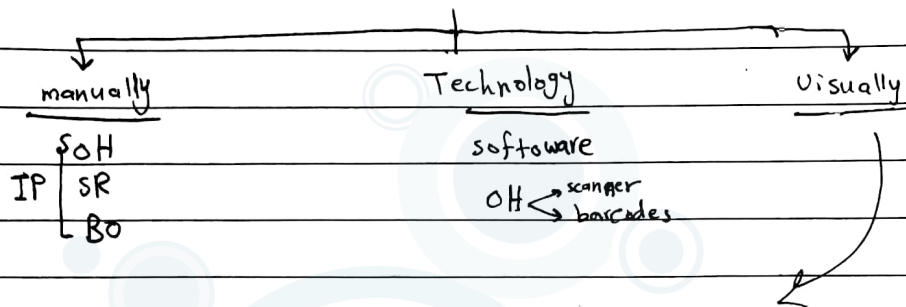
→ continuous review system / Q-system (P-system من جرثية من)
amount of quantity ordered



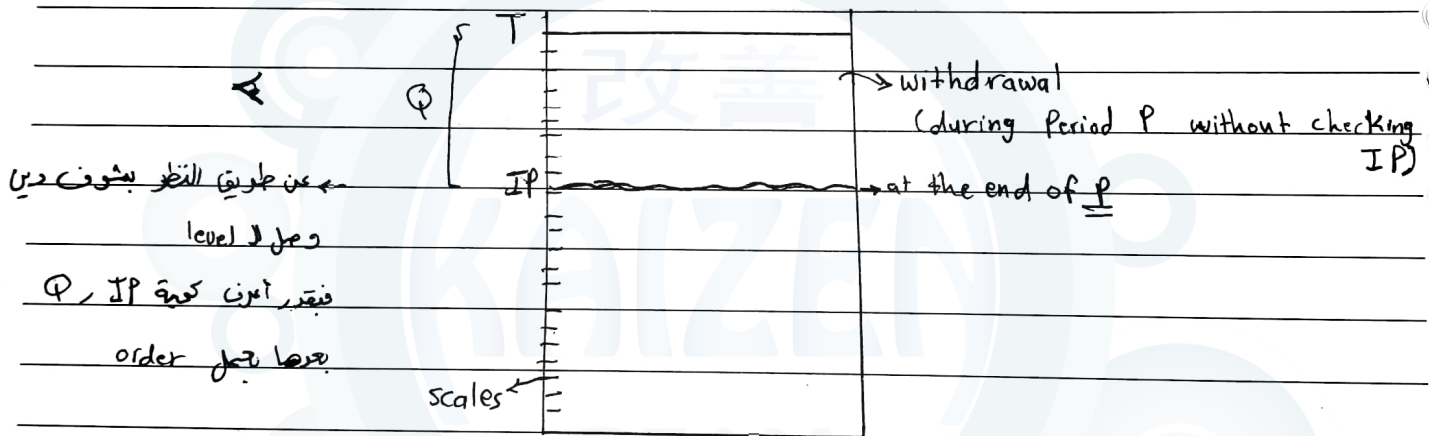
For Expensive items

Lec 17

IP in P-system (check it)



Visual P-system / one-bin system → one bin only



→ immediately visually we can know How much the quantity we order by reading the scale in this bin

← متى بيكون (جباري) استخدم the one-bin sys. with liquids or gases

↓ scales ↓ gage

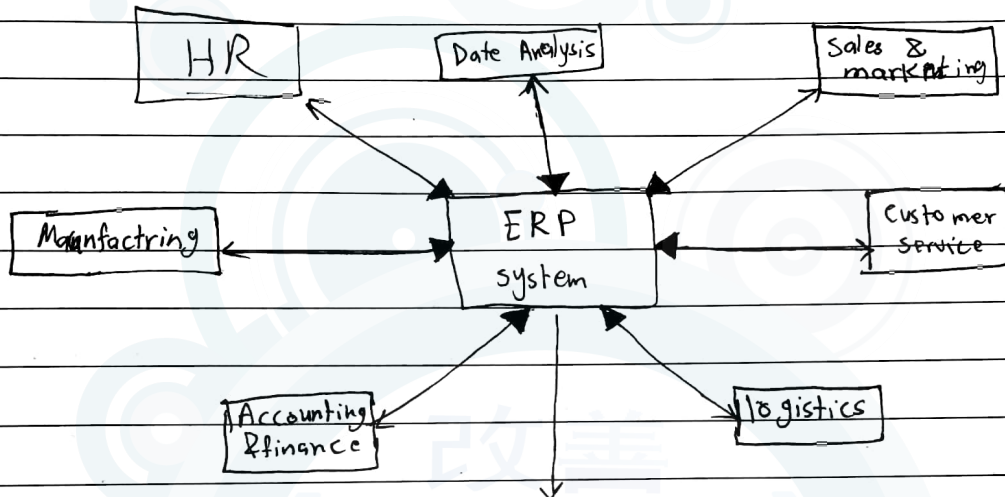
The - End - of - chapter

New chapter: Efficient Resource Planning

still study Inventory management → dependent SKU (using MRP)

* Enterprise resource Planning (ERP)

↳ Information system / comprehensive database
to streamline the information from all functions



information system by all organization function

→ all transaction at each function will information about this transaction is updated automatically in this system

→ The ERP system make streamlining to the information flow throughout the organization ⇒ The decision making is based on updated information

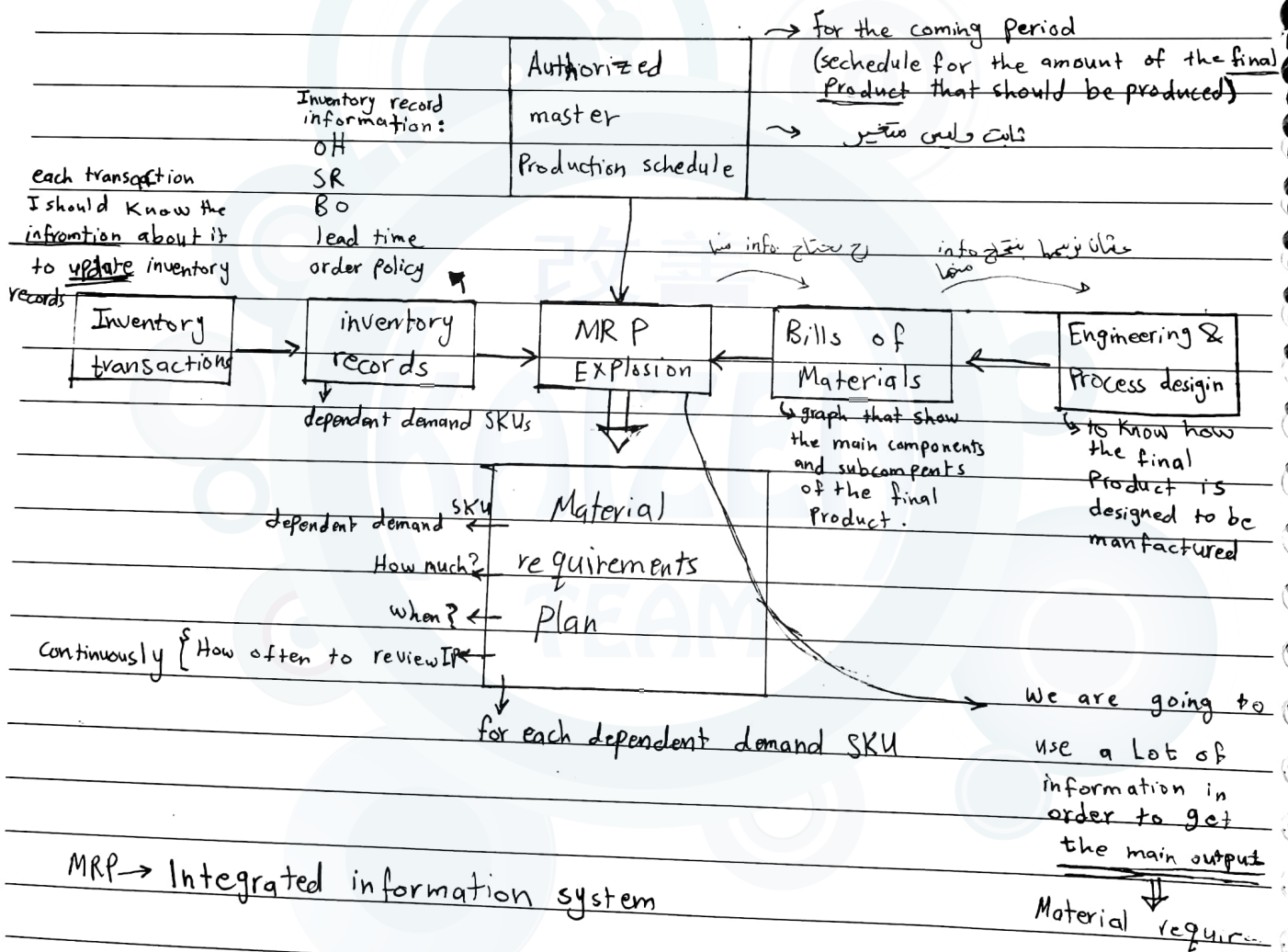
→ ERP ⇒ we are going to planning all resources (not just the material resources) of whole organization

* Materials requirements planning (MRP) → ERP

↳ used to manage inventory of dimension and demand SKU's

MRP = computerized information system used to manage inventory for dependent demand SKUs

make decisions:
how much to order?
when to order?
How often to review IP?



MRP → Integrated information system

(220)

schedule for coming weeks (in future) ←

How much + 0 as (exp.) ←
Produce from final product

	1	2	3	4	5	MPS
MPS start					10	

OH = 5 ⊗

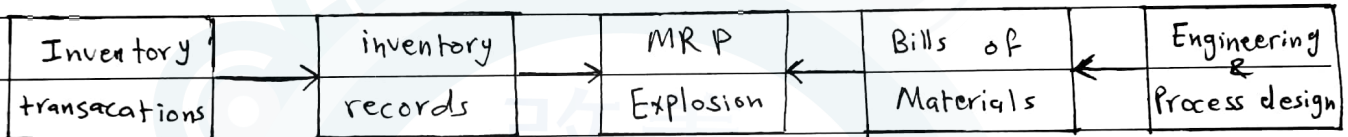
SR = 0

BO = 0

lead time = 2 weeks

Authorized master

Production schedule



graph of

the final product:

⊗ (MRP) ←

	1	2	3	4	5
Gross requir.					20
When? how much?			15		

order

⊗	Material
□	requirement plan
□	
□	
□	

- sub components
- main components
of final product
+ the Quantity
relationship

the design:

بنيان كل القطع ونظم
⊗ ⊗ head (exp.)

كل وحدة من
للم يكن لها
MRP

كل وحدة من
dependent demand
SKUs

