Introduction

Sunday, October 22, 2023 9:27 PM

- Supply chain meaning and chain (a single one is called echelon)

Suppliers $\underset{\text{supply}}{\overset{\xleftarrow{\text{demand}}}{\longrightarrow}}$ Manufacturer $\underset{\text{supply}}{\overset{\xleftarrow{\text{demand}}}{\longrightarrow}}$ Wholesaler $\underset{\text{supply}}{\overset{\xleftarrow{\text{demand}}}{\longrightarrow}}$ Retailer $\underset{\text{supply}}{\overset{\xleftarrow{\text{demand}}}{\longrightarrow}}$ Customer

$\Downarrow$

Activities that are interrelated for the manufacturer:

Production, Design, HR, logistics, Marketing, Finance, Quality, ...

* So the supply chain are interrelated processes in order to produce a specific service or material for its customers

What if: the demand is higher than the supply?
the supply is higher than the demand?

$\Downarrow$

this will be costly to suppliers/manufacturers in both cases, and losing profit is a cost.

* So we have to match supply = demand.

Logistics $\Longrightarrow$ transporting.

Supply Chain $\Longrightarrow$ coordination between processes.

Logistics

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Logistics

- schedule
- MRP
- aggregate planning.
- inventory
- warehousing
- purchasing
- transportation
- waste
- forecasting

Forecasting

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Forecasting

What to forecast?

- level of aggregation (cluster)
  - highest level → all products
  - lower level → each group
  - lowest level → each <u>sku</u>
    - ↓ stock keeping unit
    - كل قطعة الها كود و كمية مخزنة
    - seperate item stocked somewhere in supply chain operation.
    - (could be item, patients, customers ...)

- units of measurements
  - highest level → unit/year
  - lower level → unit/month, unit/quarter
  - lowest level → unit/day, unit/week, unit/shift

choosing forecasting system.

choosing forecasting technique.

- no historical data on demand for product/service
  - ↓ judgemental methods
    - executive opinion
    - market research
    - salesforce estimates (from dealing with customers)
    - delphi method.
- historical data on actual demand
  - ↓ quantitative techniques.
    - causal methods
      - simple linear regression
      - multiple linear regressions
      - neural networks.
    - Time series analysis
      - naive approach
      - simple moving average
      - weighted moving average
      - exponential smoothing.
      - trend.
      - multiplicative seasonal analysis.

Causal method

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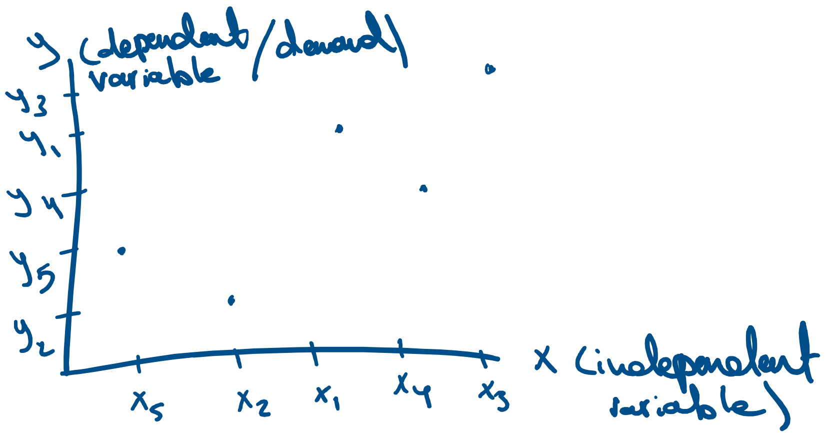
Simple linear regression.

relationship between 2 variables + trend pattern

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	$x_2 y_2$	x_2^2	y_2^2
3	x_3	y_3	$x_3 y_3$	x_3^2	y_3^2
⋮					
Σ	Σx	Σy	Σxy	Σx^2	

$\bar{x} = \frac{\Sigma x}{n}$, $\bar{y} = \frac{\Sigma y}{n}$



$$\boxed{y = a + bx}$$

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

تأخذ أي قيمة
at any x_2 (you pick)

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

→ a, b and anything you need is in teams and not memorizable.

---

1 correlation coefficient: $-1 \leq r \leq 1$

$$r = \frac{n\Sigma xy - \Sigma x \Sigma y}{\sqrt{(n\Sigma x^2 - (\Sigma x)^2)(n\Sigma y^2 - (\Sigma y)^2)}}$$

علاقة طردية عكسية ← $-$ $+$ → علاقة طردية طردية

-1 $\boxed{0}$ 1

not linear if zero

يعني النقاط اذا سالب او موجب

← stronger → (Low error النقاط قريبة من بعض)

→ weaker ← (high error النقاط بعيدة عن بعض)

2 coefficient of determination: regression $0 \leq r^2 \leq 1$

if $r = 0.9$ then $r^2 = 0.81$ so there is a 81% strong relationship if $r = 0.9$ then $r^2 = 0.81$ so there is a 81% strong relationship between x and y.

if $r = 0.6$ then $r^2 = 0.36$ so there is a 36% weak relationship between x and y.

$\boxed{3}$ Standard error of estimate, S

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

Time series

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past ← → future

$t-3$ $t-2$ $t-1$ $\boxed{t}$ $t+1$ $t+2$ $t+3$

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

D_{t-1} → second most recent demand

D_t → most recent demand

F_{t+1} → next forcasted demand

$\boxed{F_t}$ → last forcasted demand

$$\boxed{E_t} = D_t - F_t = \begin{cases} +ve & \text{underestimate} \\ -ve & \text{overestimate} \end{cases}$$

E_t → error in forcasted demand.

Demand patterns

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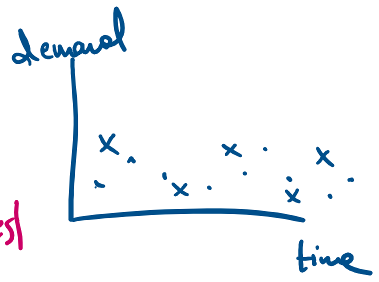
Demand patterns : horizontal, trend, seasonal, cyclical, random.

- horizontal :

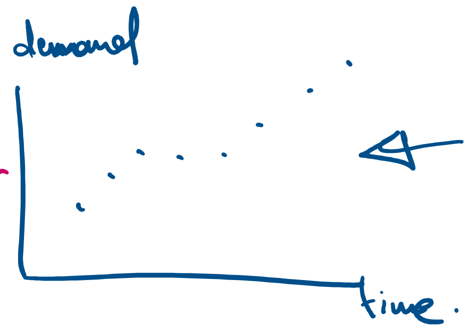
(First 4 time series techniques)



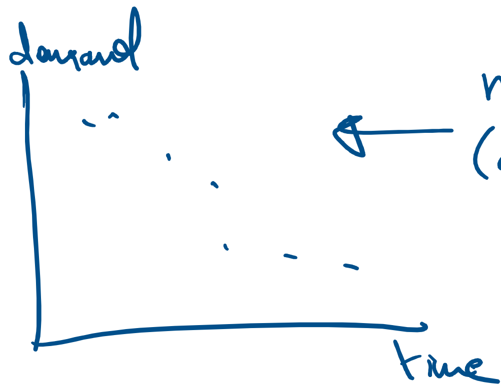
(dots = pattern 1
x = pattern 2)

- trend :

(Simple linear regression)

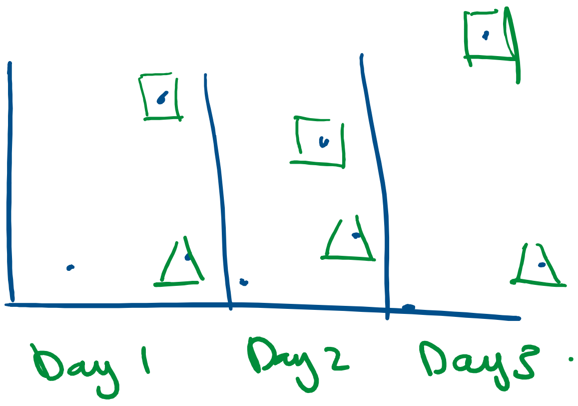


poistive trend (increase in demand)



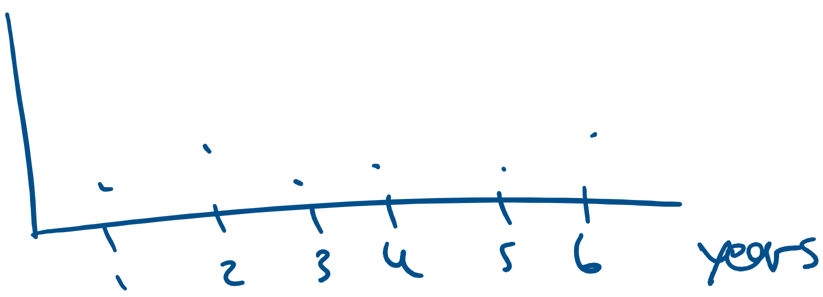
negative trend (decrease in demand).

- seasonal :



(same routine)

- cyclical :



(gradual)

Time series techniques
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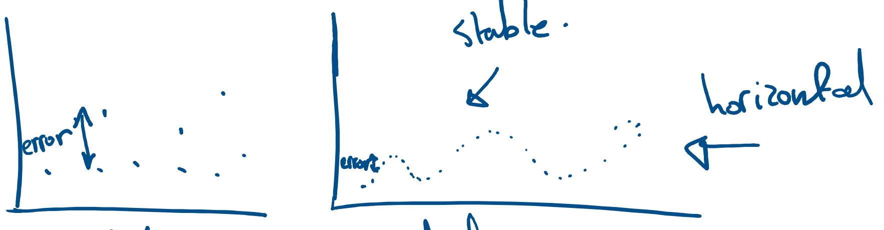
1 Naive approach: (easy and effective approach, and using increase/decrease from before we can add/subtract to that)

$F_{t+1} = D_t$



Product 1 product 2

using naive is better here.

* the narrower the the cluster, the smaller the error, the more confident we can be using naive.

2 Simple moving average.

* this could have 2, 3, 4 ... period

$F_{t+1} = \frac{D_t + \dots + D_{t-n+1}}{n}$ (its basically average of demands)

for ex 3 period moving average:

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

Ex: → Find forcasted demand for week 4.

week	Patient Arrivals (demand)
t-2 ← 1	400
t-1 ← 2	380
t ← 3	411

$F_{w4} = \frac{D_3 + D_2 + D_1}{3} = \frac{411 + 380 + 400}{3} = 397$ patients

- If week 4 had actually 415 patients, what is the error?

$E_{w4} = 415 - 397 = 18$ patients (underestimate)

- Find forecasted demand for week 5.

$F_{w5} = \frac{415 + 411 + 400 + 380}{4} = 402$ patients.

3 Weighted moving average.

$F_{t+1} = w_1 D_t + \dots + w_n D_{t-n+1}$

as $w_1 + \dots + w_n = 1$
and $w_1 > w_2 > w_3$

for ex 3 period moving average:

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

$w_1 + w_2 + w_3 = 1$ and $w_1 > w_2 > w_3$

Ex: → find F_{w5} using 3 period.

month	customer arrivals
1	800
t-2 ← 2	740
	810

$w_1 = 0.5$, $w_2 = 0.3$

1		
t-2 ← 2	740	
t-1 ← 3	810	
t ← 4	790	

$w_1 = 0.5$, $w_2 = 0.3$

$w_3 = 1 - \underline{0.8} = 0.2$
$\quad 0.5 + 0.3$

$F_{w5} = 0.5 \times 740 + 0.3 \times 810 + 0.2 \times 740 = 786$ customers

$E_{w5} = 805 - 786 = 19$ customers.

(if actual was 805)

$F_{w6} = 0.5 \times 805 + 0.3 \times 790 + 0.2 \times 810 = 801.5 \simeq 802$ customers.

* for weighted moving average try only using it for <u>2-3 period</u> moving average

[4] Exponential smoothing.

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

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

D_t : this period's demand

F_t : last period forecast (this)

Ex: , Find F_{w4} if $\alpha = 0.1$

Weeks	Patient arrivals	
1	400	F_{w1}
2	380	F_{w2}
t ← 3	411	F_{w3}
4	415	

* Here we assume $F_{w1} = D_{w1} = 400$, so $F_{w3} = D_{w3} = 411$

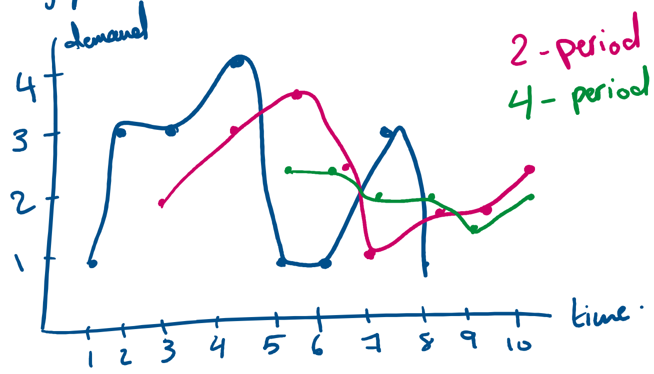
$F_{w4} = 0.1 \times 411 + 0.9 \times 411 = 411$ ← ??

⇒ Using the before methods to see the graph of demand:

$F_{t+1} = \dfrac{D_t + \cdots + D_{t-n+1}}{n}$

$F_{t+1} = w_1 D_t + \cdots + w_n D_{t-n+1}$

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



2-period simple moving avg → Ex: at time 3: $\dfrac{1+3}{2} = 2$ (at 1, at 2)

4-period simple " " → Ex: at time 5: $\dfrac{1+3+3+4}{4} = \dfrac{11}{4} \simeq 2.75$ (at 1, at 2, at 3, at 4)

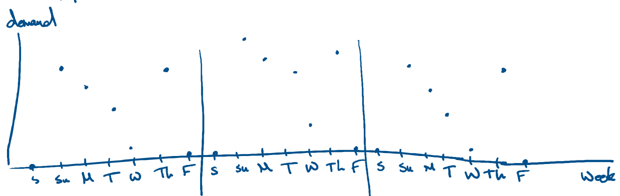
Responsive forecast → smaller n, larger α

Smoothed forecast → larger n, smaller α

Continue.

Tuesday, October 24, 2023 10:41 AM

⑤ Multiplicative seasonal method.



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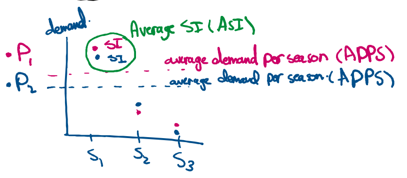


SI (seasonal index) $= \frac{D}{ADPS}$ so $D = SI \times ADPS$

For period 3: $F = ASI \times \underline{E}ADPS$ (estimated)

This method in practice:

season	Period 1 D	③	Period 2 D		ASI	Period 3.
S_1	$D_{P_1 S_1}$	$SI = \frac{D_{P_1 S_1}}{APPS_1}$	$D_{P_2 S_1}$	same thing.	④ $ASI_{(S_1)} = \frac{SI_{P_1} + SI_{P_2}}{\text{num of periods}}$	$F_{P_3 S_1} = ASI_{S_1} \times EADPS_{P_3}$
S_2	$D_{P_1 S_2}$	$SI = \frac{D_{P_1 S_2}}{APPS}$	$D_{P_2 S_2}$		$ASI_{(S_2)} = \frac{SI_{P_1} + SI_{P_2}}{\text{num of periods}}$	$F_{P_3 S_2} = ASI_{S_2} \times EADPS_{P_3}$ ⑦
S_3	$D_{P_1 S_3}$	$SI = \frac{D_{P_1 S_3}}{ADPS}$	$D_{P_2 S_3}$		$ASI_{(S_3)} = \frac{SI_{P_1} + SI_{P_2}}{\text{num of periods}}$	$F_{P_3 S_3} = ASI_{S_3} \times EADPS_{P_3}$

① Total demand $= D_{P_1 S_1} + D_{P_1 S_2} + D_{P_1 S_3}$ | Total demand = "

② $ADPS_{P_1} = \frac{TD_{P_1}}{\text{num of seasons}}$ | $ADPS_{P_2}$ = "

⑤ Estimated total demand (ETD_{P_3}) = use appropriate technique according to Total Demand time series.

⑥ Estimated average demand $EADPS_{P_3} = \frac{ETD_{P_3}}{\text{num of seasons}}$

* Seasonal factor = SI

Ex:

Quarter	Year ① D	SI	Year ② D	SI	Year ③ D	SI	Year ④ D	SI	ASI	Year ⑤ Forecast
1	45	$\frac{45}{250} = 0.18$	70	$\frac{70}{300} = 0.23$	100	0.22	100	0.18	$\frac{0.18 + 0.23 + 0.22 + 0.18}{4} = 0.2043$	$0.2043 \times 650 = 132.7 \simeq 133$ customer
2	335	$\frac{335}{250} = 1.34$	370	$\frac{370}{300} = 1.23$	585	1.3	725	1.32	$\frac{1.84 + 1.23 + 1.3 + 1.32}{4} = 1.29779$	$1.2979 \times 650 = 843.6 \simeq 844$ customer
3	520	$\frac{520}{250} = 2.08$	590	$\frac{590}{300} = 1.96$	830	1.84	1160	2.1	2.0001	$2.0001 \times 650 = 1300$ customer
4	100	$\frac{100}{250} = 0.4$	170	$\frac{170}{300} = 0.56$	285	0.63	215	0.39	0.4977	$0.4977 \times 650 = 324$
	TD = 1000, ADPS $= \frac{1000}{4} = 250$		TD = 1200, ADPS $= \frac{1200}{4} = 300$		TD = 1800, ADPS $= \frac{1800}{4} = 450$		TD = 2200, ADPS = 550			ETD = 2600, EADPS $= \frac{2600}{4} = 650$

ETD is calculated by simple linear regression since demand is increasing trend.

time (years) (X)	demand (Y)
1	1000
2	1200
3	1800
4	2200
5	?

TD

How to choose best technique

Saturday, November 4, 2023 4:36 PM

* We should have data about the errors for at least 5 periods.

Period	D_t	F_t	$E_t = D_t - F_t$
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

$\boxed{1}$ Cumulative sum of forecast error: $CFE = \sum_{t=1}^{t=n} E_t$.

if

Method 1	Method 2	Method 3
E	E	E
4	-4	-4
3	-3	-4
-1	1	-4
2	-2	-4
CFE = 8	CFE = -8	CFE = -16.
underestimate demand	overestimate demand.	bigger error value.

same error value

so method 1 or 2 are better than method 3

$\boxed{2}$ Mean Bias: $\bar{E} = \frac{CFE}{n}$.

$\boxed{3}$ Mean absolute deviation: $MAD = \frac{\sum_{t=1}^{t=n} |E_t|}{n}$

Period	Method 1 E	Method 1 $\lvert E \rvert$	Method 2 E	Method 2 $\lvert E \rvert$
1	-2	2	-10	10
2	2	2	10	10
3	-4	4	-4	4
4	3	3	3	3
CFE	-1	11	-1	27
MAD		$\frac{11}{4}$		$\frac{27}{4}$

this method is better

this method is better

4) Mean squared error: $MSE = \frac{\sum_{t=1}^{t=n} E_t^{2}}{n}$

Period	Method 1 E	Method 1 E^2	Method 2 E	Method 2 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		$\frac{4}{4}=1$		$\frac{16}{4}=4$

emphasises large errors.

5) Mean absolute percent error $MAPE = \frac{\sum((|E_t|/D_t) \times 100)}{n}$

this is the right version of the [illegible], it's written wrong in the book.

Using any method/technique:

	E	D	$\frac{\lvert E \rvert}{D}$
product x	1	10	$\frac{1}{10}$
product y	1	1000	$\frac{1}{1000}$

this method is best used for this product because 1 error makes a difference for 10 demands [illegible] with 1000.

6) Standard deviation error:

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

std. dev

Ex:

Month	Demand	Forcast	Error	$\lvert E_t \rvert$	E_t^2	$\frac{\lvert E_t \rvert}{D_t} \times 100$	$(E_t - \bar{E})^2$
1	200	225	-25	25	625	$\frac{25}{200} \times 100 = 12.5$	$(-25 - -1.875)^2$
2	240	220	20	20	400	$\frac{20}{240} \times 100 = 8.3$	$(20 - -1.875)^2$
3	300	285	15	15	⋮	⋮	⋮
4	270	290	-20	20			
5	230	250	-20	20			
6	260	240	20	20			
			-40	40			

5	[illegible]	240	20				
6	260	240	-40	40			
7	210	250	35	35			
8	275	240	35				
			15	195	5275	81.3	

$$CFE = \sum_{t=1}^{t=n} E_t = -15$$

$$\bar{E} = \frac{-15}{8} = -1.875$$

$$MAD = \frac{\sum |E|}{n} = \frac{195}{8} = 24.4$$

$$MSE = \frac{\sum E^2}{n} = \frac{5275}{8} = 659.3$$

$$MAPE = \frac{\sum \left(\frac{E_t}{D_t} \times 100\right)}{n} = \frac{81.3}{8} = 10.2\%$$

نسبة ال error من ال Demand ال Actual (زادت 10.2% أو اقل بـ 10.2%)

$$\sigma_E = \sqrt{\frac{\sum (E_t - \bar{E})^2}{n-1}} = 27.4$$

variation about mean.

Forecasting cases

Thursday, November 9, 2023   11:01 AM

① If we had two methods that are considered the best, we use combination forecasting:

Period	Method 1	Method 2	Forecast (Decision)
10	$F_{M_1P_{10}}$	$F_{M_2P_{10}}$	$F_{P10} = \frac{F_{M_1P_{10}} + F_{M_2P_{10}}}{2}$

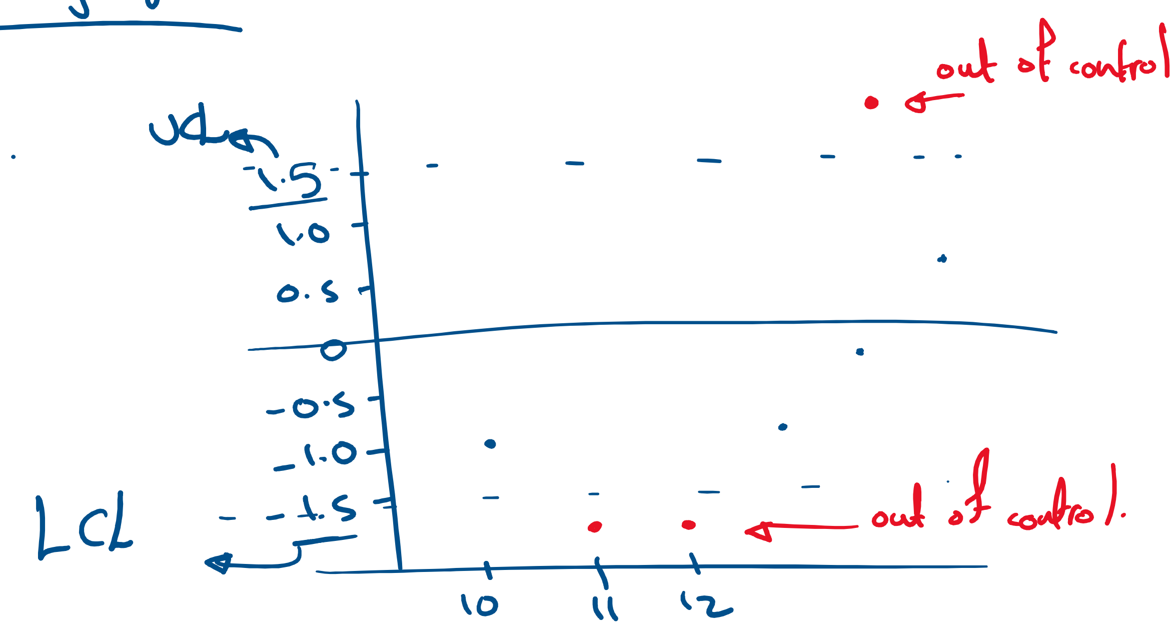
② Focus Forecasting : we focus on the method that gives the best and least MAD

Period	M_1 D	M_1 F	M_1 E	M_1 MAD	M_2 D	M_2 F	M_2 E	M_2 MAD	Forecast (Decision)
10	D_{10}	F_{10}	E_{10}	MAD_{10}	D_{10}	F_{10}	E_{10}	MAD_{10} less	F_{11} (method 2)
11		F_{11}		MAD_{11} less		F_{11}		MAD_{11}	F_{12} (method 1)
12		F_{12}		MAD_{12}		F_{12}		MAD_{12}	

③ Tracking Signal $= \frac{CFE}{MAD}$ (Knowing if technique is in control or not)

not → we need to change technique

Period	D	F	E	CFE	MAD	TS (tracking signal)
10	D_{10}	F_{10}	E_{10}	CFE_{10}	MAD_{10}	TS_{10}
11	D_{11}	F_{11}	E_{11}	CFE_{11}	MAD_{11}	TS_{11}



Summary

Sunday, November 12, 2023 10:54 AM

Availability of previous data about actual demand
- → No → judgemental methods
- → Yes → quantitative methods.

Judgemental methods
- market research
- executive opinion
- Delphi
- sales force estimates.

Quantitative methods
- → causal methods → if assumption that there is variable/s affect demand.
- → time-series analysis → if behaviour over time has certain pattern.

Causal methods
- → linear relationship → simple linear regression / multiple linear regressions.
- → non-linear relationship → artificial intelligence / neural networks.

test r / r^2 / s to check suitability.

Time series analysis
- → horizontal → naive, simple / weighted moving average, exponential smoothing.
- → trend → simple linear regression, ARIMA, trend adjusted exponential smoothing.
- → seasonal → multiplicative seasonal method, additive seasonal method, SARIMA.
- → cyclical
- → random

To choose between options (time series analysis) ⇒ measures of error
- → bias → CFE / $\bar{E}$
- → average deviation of forecast from actual → MAD.
- → the technique not to produce large error in certain period compared to rest of periods → MSE
- → average deviation of forecast from the actual as a percent from actual → MAPE
- → variability of error produced → σ_E

If more than one suitable technique
- → choose one of them
- → combination forecasting.
- → focus forecasting.

Check if the process of forecasting using the chosen technique is within control → develop control chart (TS)
- → in control → keep using
- → out of control → use another technique

Inventory Vs warehouse

Saturday, November 11, 2023 9:32 AM

Inventory we'll talk about inventory

(products related to work)

Warehouse

(the space and place dedicated to store inventory)

⇓

warehouse management ⟺ (related) inventory management

decisions ⟺ (related.) decisions

- location
- design
- size
- first in first out
- dedicated / not

- how much to order
- when to order
- when to review
- categorizing

Inventory management

- classification of sku.
  - ABC classification
- choosing inventory control system.
  - how much to order?
  - when to order?
  - how often to check inventory position?

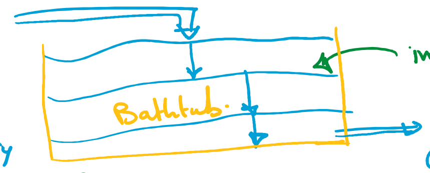
independent demand SKU

- continuous review system
- periodic review system.
- hybrid system.
  - optional replenishment system
  - base stock system.

dependent demand SKU.

- materials requirements planning (MRP).

inflow
(replenishment)



inventory.

warehouse

outflow
(consumption / demand)
using Forecasting

- how often to review inventory position?
- when to order?
- how much to order?

Inventory management

Saturday, November 11, 2023 9:55 AM

Supplier $\underset{D}{\overset{S}{\rightleftarrows}}$ Manufacturer $\underset{D}{\overset{S}{\rightleftarrows}}$ Wholesaler $\underset{D}{\overset{S}{\rightleftarrows}}$ Retailer $\underset{D}{\overset{S}{\rightleftarrows}}$ Customer

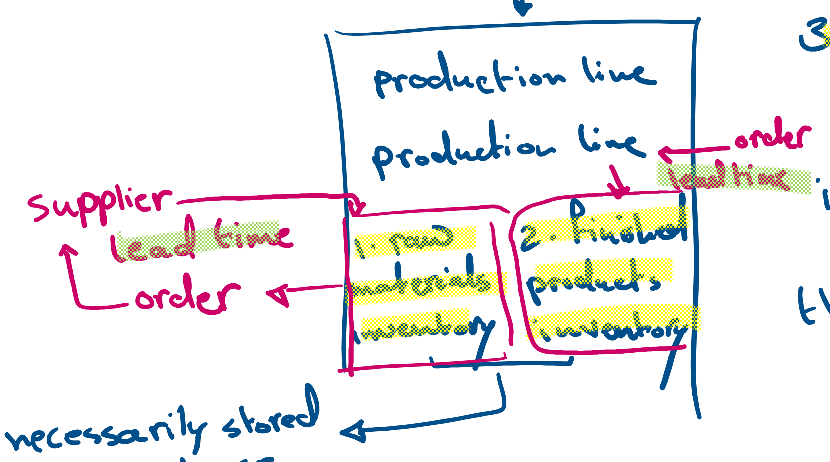
stockless inventory!

there has to be reliable information + reliable transportation.

Nowadays cutumers demand : [highest quality, lowest delivery time, lowest cost] so, there becomes competition between supply chains on that.

Now talking about inventory categories (depending on what we want to categorize for)

Manufactures



not necessarily stored in same warehouse.

3. work in process inventory (WIP)

if we want to do lean manufacturing (eliminating waste)

this category is bad and will take space.

skus (stock keeping units).

dependent demand sku.

(sku(s) that depend on finished products needs)

ex: rubber depends on how many wheels for bikes we plan to make.

and usually related to raw materials inventory.

independent demand sku.

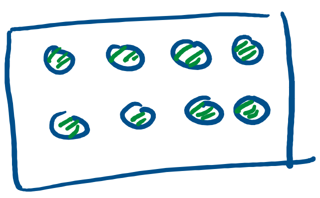
(skus that depend on market needs)

ex: wheels depend on how much people need bikes)

and usually related to finished products for a specific industry.

Inventory position = on-hand inventory + scheduled receipt − back orders.

- on-hand inventory: what I already have
- scheduled receipt: what I ordered but have not received yet.
- back orders: what is demanded from others but I have not given them it yet.



حالة المخزون

$$\boxed{FP = OH + SR - BO}$$

Sku classifications

Saturday, November 11, 2023 11:58 AM

First what is the meaning of usage value ?

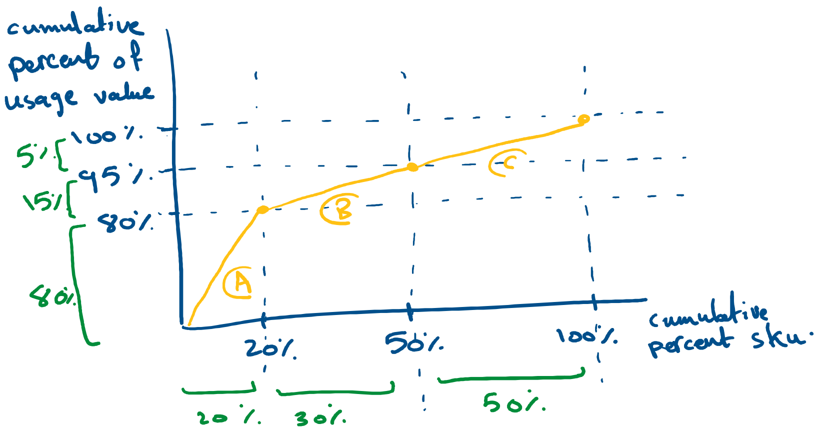
if we had:

	cost	Annual demand	dollar usage cost x demand
product x	1 $	100000	100000 $/year
product y	1000 $	5	5000 $/year

dollar usage → this is called usage value

100000 $/year → more usage value.

- ABC classification method: (pareto chart, 80-20 rule)



Few % of skus → largest % usage value. A

large % of skus → smallest % usage value. C

Ex:

SKU num.	description	Quantity used per year	unit value ($)	usage value Annual demand x cost
1	Boxes	500	3	1500
2	cards	18 000	0.02	360
3	covers	10 000	0.75	7500
4	glue	75	40	3000
5	inside cover	20000	0.05	1000
6	tape	3000	0.15	450
7	signatures.	150 000	0.45	67 500

Solution: we start with ranking best usage values

sku #	description	usage value	% usage value	% SKU	cumulative % SKU	cumulative % usage value.
7	signature	67 500	83%	14.3%	14.3%	83%
3	covers	7500	9.2%	14.3%	28.6%	92.2%
4	glue	3000	3.7%	14.3%	42.9%	95.9%
1	boxes	1500	1.8%	14.3%	57.1%	97.8%
5	inside covers	1000	1.2%	14.3%	71.4%	99%
6	tape	450	0.6%	14.3%	85.7%	99.6%
2	cards.	360	0.4%	14.3%	100%	100%
		81310 $				

$\frac{67\,500}{81310} \times \frac{100}{100}$

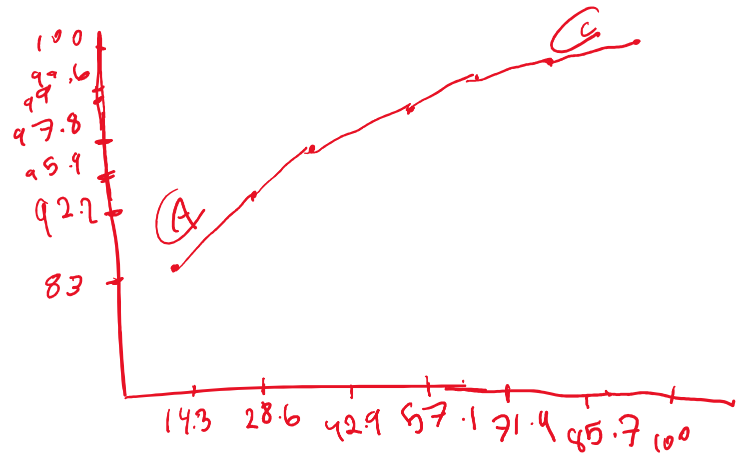
$\frac{7500}{81310} \times \frac{100}{100}$

⋮

$\frac{1}{7} \times \frac{100}{100}$

$\frac{1}{7} \times \frac{100}{100}$

⋮



Avg inventory and num. of orders.

Thursday, November 16, 2023 10:03 AM

Case ① We ordered once 100 units and our annual demand is 100 unit/year.

$Q = 100$

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

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

Case ② We ordered 50 units initially and annual demand 100 unit/yer

$Q = 50$

Avg inventory $= \frac{50}{2} = 25$

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

Case ③ We ordered initially 25 units " .. ...

$Q =$ 25 units

Avg inventory $: \frac{25}{2} = 12.5$

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

Inventory Cost

- holding cost.
  - Capital cost (ضياع مصاري يعني مصاري قاعدة مكانها)
  - Storage and handling cost.
  - taxes, insurance, shrinkage.
    - pilferage (theft)
    - obsolescence (outdated) (زي لما تشتري اشي ويقدم بيقل قيمته)
    - deterioration (damage). (ممكن تكبه او تبيعه بسعر اقل)
- order / setup cost.

* Order costs can include giving raw materials as a supplier, or ordering materials for production line.

H : unit holding (keeping in storage) cost

$ / unit / year.

as a percent from unit cost.

10%, 20%, 15% ...

S : order / setup cost

$ per order

$ per setup.

Total annual cycle inventory cost (C) =

Annual holding cost + Annual ordering cost.

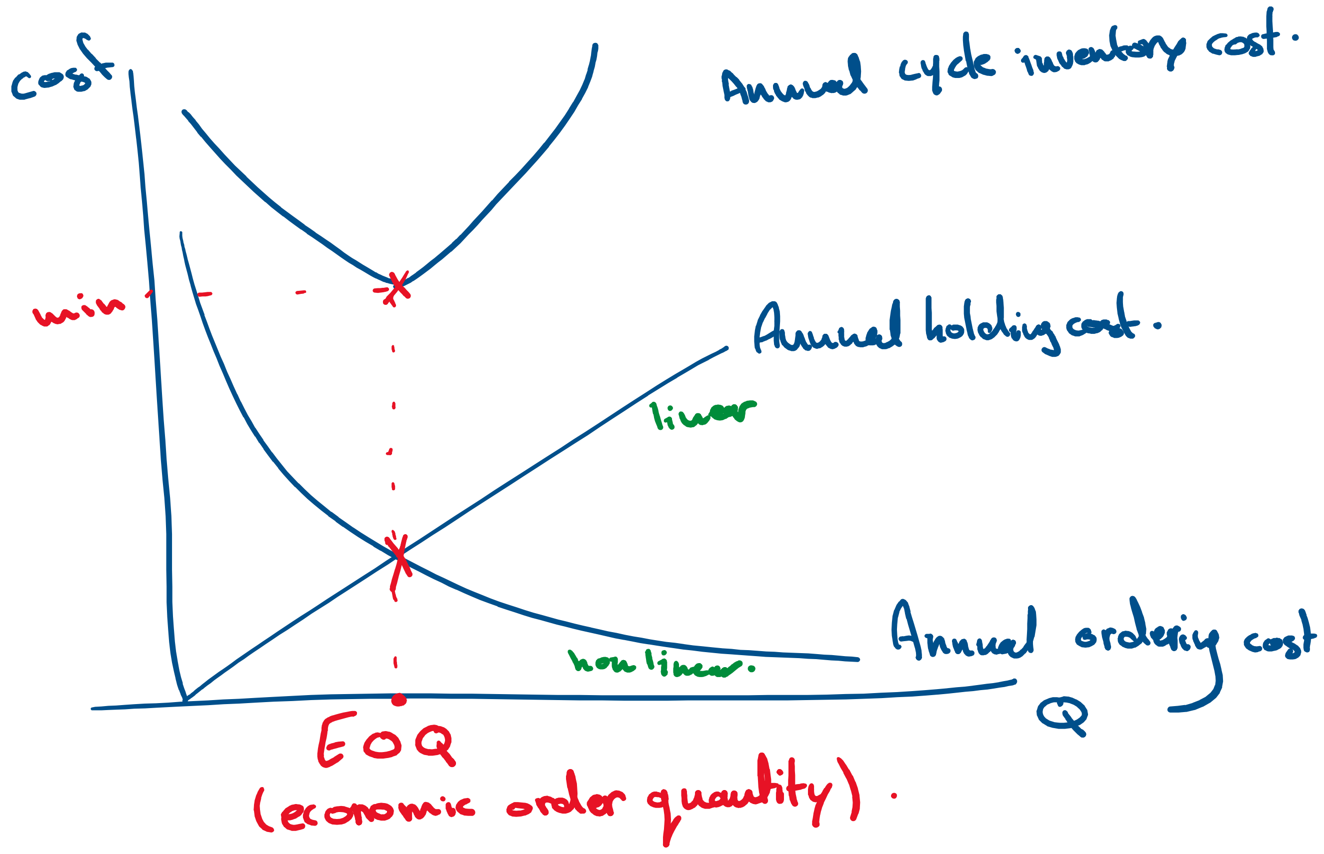
in year   in year.

Annual holding cost = Average cycle inventory x unit holding cost.

$$\left(\frac{Q}{2}\right) \times (H)$$

Annual ordering cost = Number of orders per year x ordering / setup cost.

$$\left(\frac{D}{Q}\right) \times (S)$$



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

Time between orders (TBO) = $\frac{Q\ (\text{unit})}{D\ (\text{unit/year})}$ in year

↓

For practicality we sometimes need to change to months, weeks, days

↓

$\frac{Q}{D} \times 12$ months

$\frac{Q}{D} \times 52$ weeks

$\frac{Q}{D} \times 365$ days

Ex : operates 52 weeks , sales 18 units / week. ($D = 18$ unit/week)
unit cost = 60 \$ /unit , order cost (S) = 45 \$ / order.,
holding cost (H) = (0.25×60) = 15 \$ / unit / year, $Q_{current}$ = 390 unit.

$C = \frac{Q}{2} \times H + \frac{D}{Q} \times S$ to make year (dont forget that time is in pfull)

(current Q)

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

$EOQ = \sqrt{\frac{2DS}{H}} = \sqrt{\frac{2 \times (18 \times 52) \times 45}{15}} = 74.95 \simeq 75$ units.

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

بسم الله الرحمن

Continuous review system.

Thursday, November 23, 2023 3:02 PM

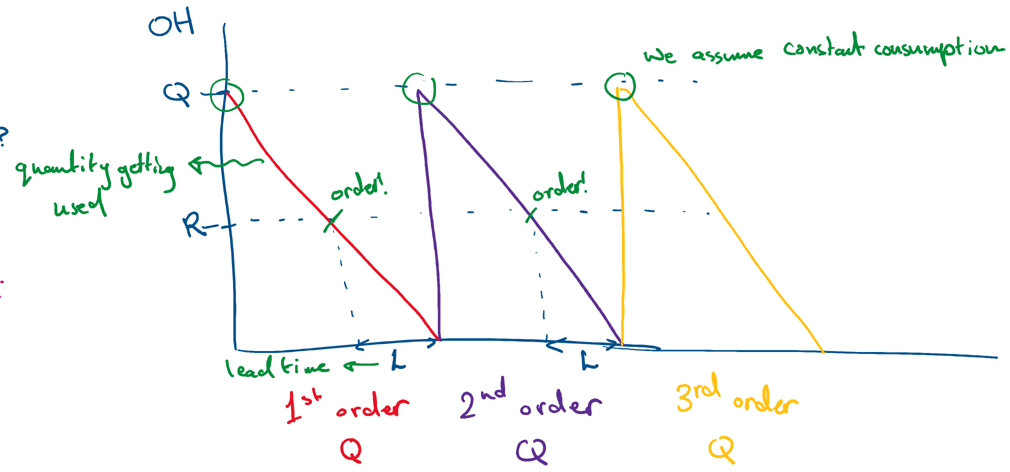
↳ other names: Fixed ROP system / Fixed quantity system / Q system.
reorder point

Remembering that: $IP = OH + SR - BO$

↳ [1] how often to review inventory position?
continuously at the end of each withdrawal.

[2] when to order?
when IP reaches a predetermined level R.

[3] how much to order?
A fixed quantity Q



* we assume constant lead time
* we need to continuously keep checking the inventory until it reaches R.

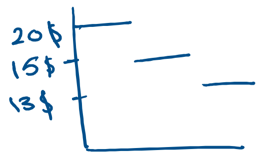
Q

considerations

EOQ (economic order quantity) → minimize cycle inventory cost.

container size

price break



if we bought an amount of quantity, we may have a discount!

quantity decided by management.
↳ supplier preference.
↳ expiry of products

R

constant demand (d)
constant lead time (L)
$R = dL$

variable demand ($\bar{d}$, σ_d)
constant lead time (L)
([illegible])

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

$SS = z\,\sigma_{dLT}$
safety (stock)

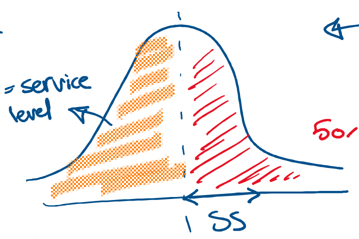
σ_d : standard deviation of demand.

z : number of standard deviation needed to acheive service level. (normal dist.)

σ_{dLT} : standard deviation of demand during lead time.

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

or



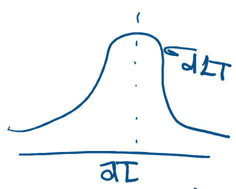
variable demand ($\bar{d}$, σ_d)
variable lead time ($\bar{L}$, σ_{LT})

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

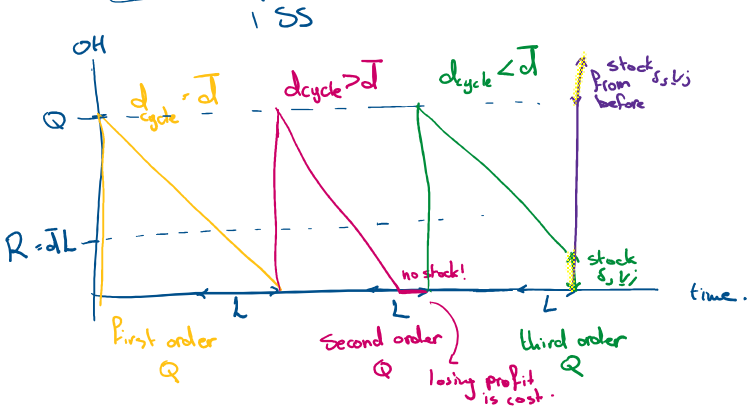
$SS = z\,\sigma_{dLT}$

z : number of standard deviations to achieve required service level.

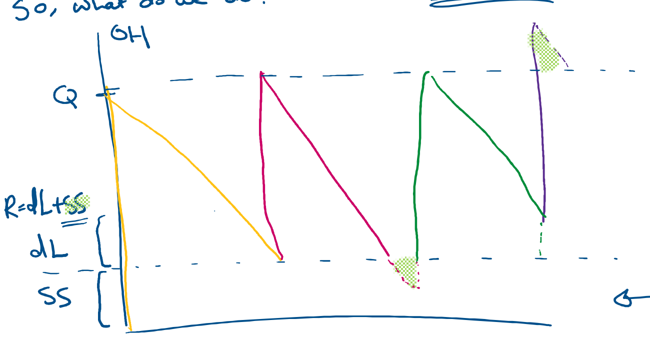
$\sigma_{dLT} = \sqrt{\bar{L}\sigma_d^2 + \bar{d}^2\sigma_{LT}^2}$



distribution of demand during protection interval (L)



So, what do we do? we make a safety stock in order not to run out or have too much



← S.S has only holding cost.

important

Ex: operates 52 weeks, $d = 18$ units/week, $\sigma_d = 5$ units, $L = 2$ weeks, using Q system, $H = 15$ \$/unit/year, $S = 45$ \$/order.

$Q = ?$ $R = ?$ $S.S = ?$ service level = 90%.

Ex: operates 52 weeks, ...

$Q = ?$ $R = ?$ $S.S = ?$ service level $= 90\%$

$\boxed{Q = EOQ = 75 \text{ unit}}$

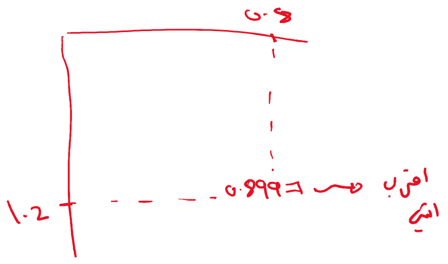
$R = \bar{d}L + S.S$

$\bar{d}L + z\,\sigma_{dLT}$

normal distribution

$z\,\sigma_d \sqrt{L}$

$1.28 \times 5 \times \sqrt{2} = 9.05 \simeq 9$ units



$18 \times 2 + 9 = 45$ units.

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

C: total inventory cost

S.S: safety stock (only holding cost)

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

---

continue / The last check of OH = 70 unit, recently, a withdrawal has been made for 22 units. There is no scheduled receipt and no back orders. Is it time to order? If yes, how much?

$IP_{current} = OH + SR - BO = (65 - 22) + 0 - 0 = 43$ unit.

$IP_{current} < R \Rightarrow 43 < 45$ yes, we order.

$Q = 75$ units (EOQ)

What is time between orders?

$TBO_{avg} = \frac{Q}{D} = \frac{75}{18 \times 52} \times 52 = 4.1 \simeq 4$ weeks.

Ex: $\bar{d} = 12000$ pen/week. $\sigma_d = 3000$ pens $Q_{current} = 156000$ pen

$\bar{L} = 6$ weeks $\sigma_{LT} = 2$ weeks service level 95% $R = ?$

area $= 0.95 \Rightarrow z = 1.65$

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

$S.S = z\,\sigma_{dLT} = z\sqrt{\bar{L}\,\sigma_d^2 + \bar{d}^2\,\sigma_{dL}^2}$

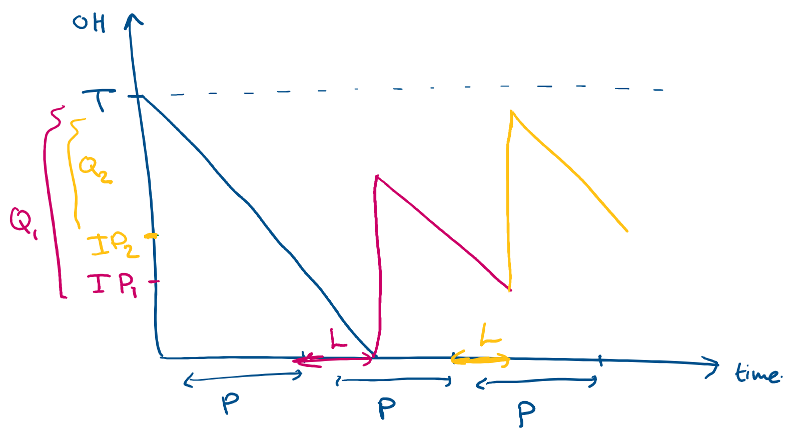
$1.65\sqrt{5 \times 3000^2 + 12000^2 \times 2^2} = 41117.79 \simeq 41118$ pen.

So $R = 12000 \times 5 + 41118 = 101118$ pen.

Periodic Review system

Sunday, December 3, 2023 11:05 AM

↳ other names: fix interval reorder system / periodic reorder system / P- system.



1^{st} order: $Q_1 = T - IP_1$

2nd order: $Q_2 = T - IP_2$

[1] How often to review IP?

Periodically, at end of review period P.

[2] When to order?

at end of review period P

[3] How much to order?

Quantity = Target − Inventory position

$Q = T - IP$.

- choosing P:

P:
- $TBO = \frac{EOQ}{D}$
- $TBO = \frac{Q \text{ constant size}}{D}$
- $TBO = \frac{Q \text{ price break}}{D}$
- $TBO = \frac{Q \text{ decided by management}}{D}$

- Figuring T

T:
- Constant demand (d), constant lead time (L)
  $T = d(P+L)$
- Variable demand ($\frac{\bar{d}}{\sigma_d}$), constant lead time (L)
  $T = \bar{d}(P+L) + SS$
  $S.S = z\, \sigma_{P+L}$
  as z is the number of standard deviations needed to acheive required service level
  $\sigma_{P+L} = \sigma_d \sqrt{P+L}$.
- Variable demand, variable lead time.
  use simulation to estimate the demand during protection interval ($P+L$) so as to use it to select value of T (based on required service level)
  not solvable.

Ex: $\bar{d} = 18$ units/week, $\sigma_d = 5$ units, $L = 2$ weeks, operates 52 weeks, EOQ = 75 units, P-system

$P = ?\quad T = ?$

$P = TBO_{EOQ} = \frac{EOQ}{D} = \frac{75}{18 \times 52} \times 52 = 4.2 \simeq 4$ weeks.

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

and $S.S = z\,\sigma_{P+L} = z\,\sigma_d \sqrt{P+L} = 1.28 \times 5 \times \sqrt{4+2} = 15.68 \simeq 16$ units.

$T = 18 \times (4+2) + 16 = 124$ units.

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

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

Q system		P system
1259	<	1365
L	<	P+L

continue: at end of review period the OH = 60 (no scheduled receipts and no back orders), is it time to order? how much?

Yes, we order.

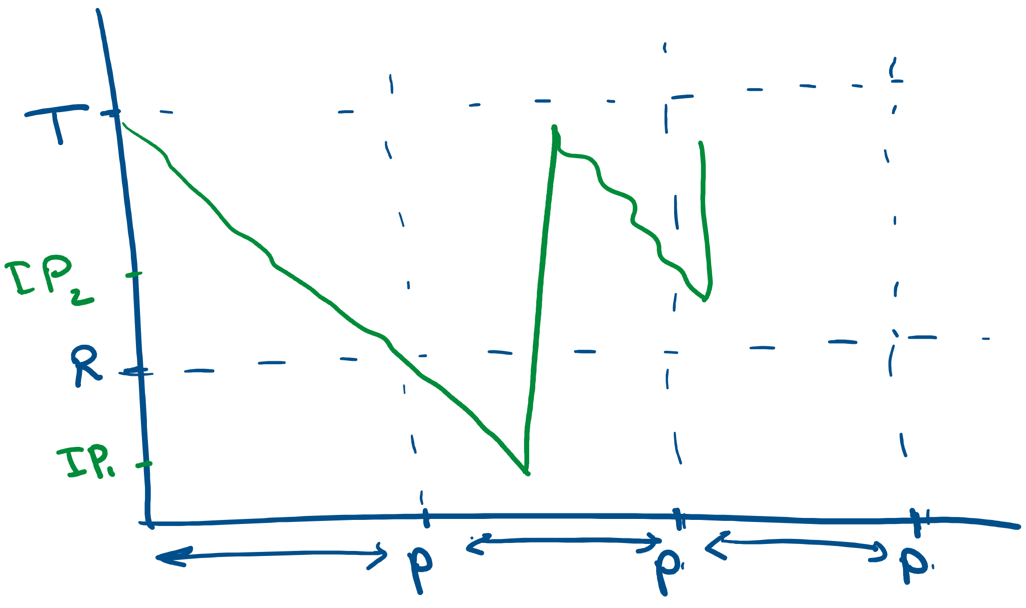
$Q = T - IP = 124 - (60 + 0 - 0) = 64$ units.

سبحان الذي يسبح
الرعد بحمده و
الملائكة من
خيفته

Hybrid review systems

Thursday, December 7, 2023 10:41 AM

- Optional replenishment system. / Max-Min system. / S-s system

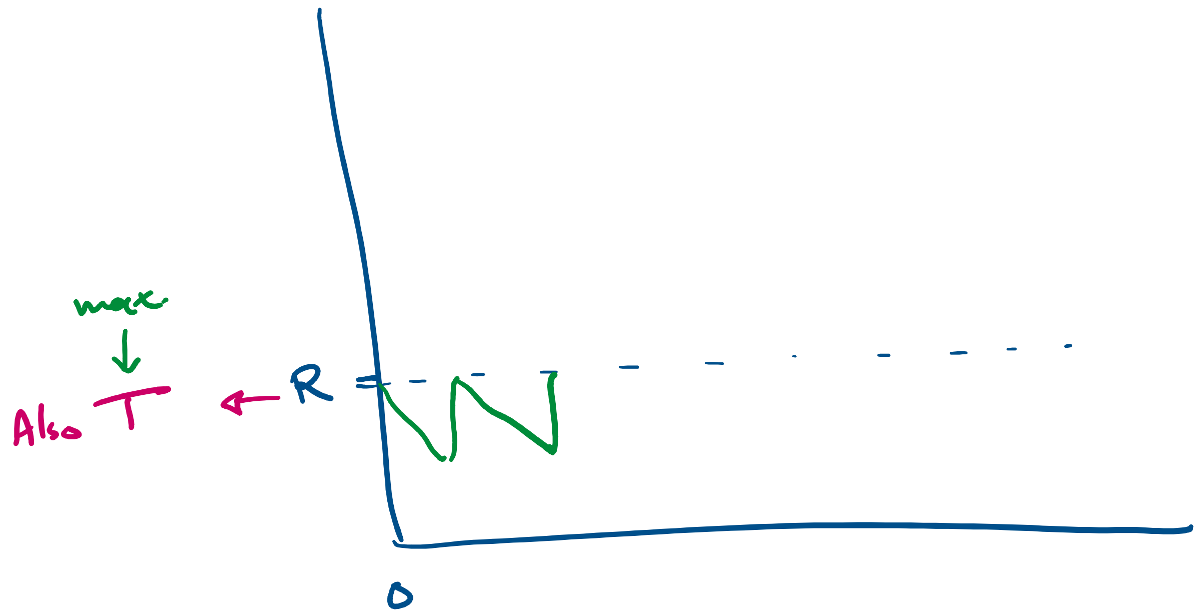


$Q = T - I_p$

It is [illegible] for cheap items because holding cost is low. (For safety stock also).

annual holding cost for S.S , $S.S \times H$

- Base Stock system.



It is [illegible] for very expesive items because holding cost of it is extremely high. (when we need we get)

Inventory Position

Sunday, December 3, 2023 10:53 AM

$$IP = OH + SR - BO$$

Manually

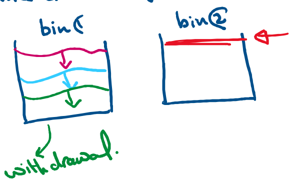
- OH → shelf.
- SR → purchasing
- BO → Marketing

Technology.

OH: loan codes scanning software

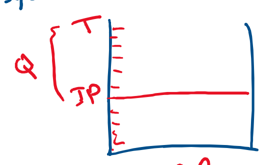
Visual Q system (two-bin system).

⇒ For things that are hard to count like small things and liquids



← R (when bin② has begun being used)

Visual P-system. (one-bin system).



refilled every period.

uncountable stuff.

Q system VS P system.

Thursday, December 7, 2023 11:00 AM

Q system.		P system.
Annual Inventory cost	<	Annual Inventory cost
S.S	<	S.S
protection interval	<	protection interval.
Q fixed		Q variable.
TBO variable		TBO fixed.

Examples for p-system include: a nurse that should care for people in need but also see stock.
an industry ordering more than one sku from same supplier.

Examples for Q-system include: a warehouse that has someone dedicated to logistics.
an industry that has something that runs out alot or having a [illegible] on ordering a lot of things from a supplier

ERP and MRP

Sunday, December 10, 2023 10:41 AM

Enterprise Resource Planning.
- capital
- human
- materials
- components

Materials Requirement planning
- dependent demand SKU's
- how much?
- when?

schedule for amounts of product for next period and when to start producing a product for it to be ready (MPS start) — Authorized master production schedule.

Master production schedule start

other sources of demand. spare parts and other..

Inventory transactions → Inventory records → MRP explosion ← Bills of materials ← Engineering and process design.

Inventory transactions: Anything going in or out of inventory, or has to do with changing inventory

Inventory records: records about inventory stuff. OH, SR, BO, lotsize, lead time. (should be regularly updated after transactions).
↓
when and how much to order.

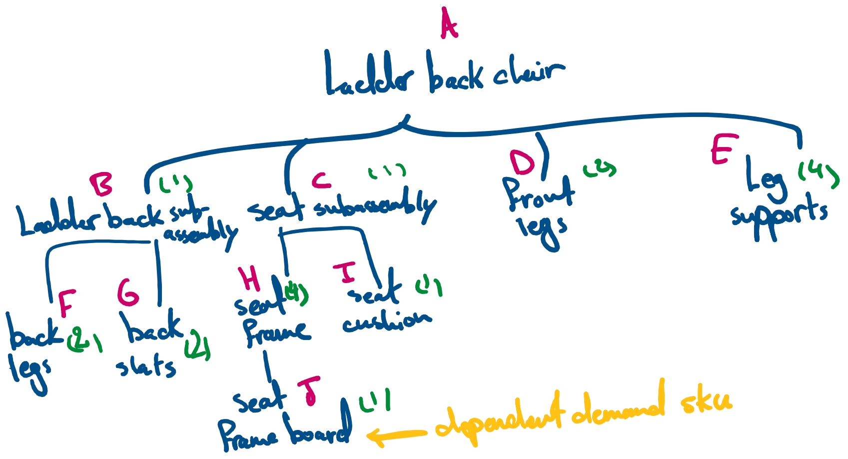
Bills of materials: main and sub components of products and how they are put together. and quantities needed to produce.

MRP explosion
↓
Materials requirements planning.
gross requirements and other release.

Bills of material

Tuesday, December 12, 2023 10:39 AM

- For example lets make a ladder back chair:



Immediate parent → what is above the product

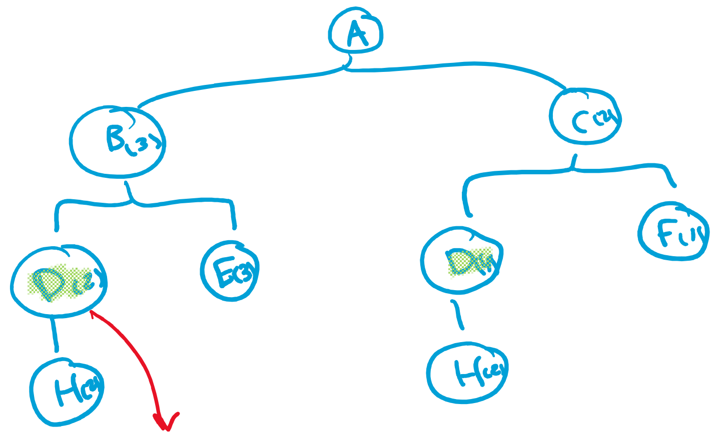
Intermediate parent → has a child and an immediate parent

purchased item → has an immediate parent but no child.

number we need to make 1 of A.

rank or رمز القطعة so we can نميز

Another example:



2 of D make 1 B

A = 5 units

B = 3 × 5 = 15 unit

C = 2 × 5 = 10 units

D = 2 × 15 + 4 × 10 = 70 units

E = 3 × 15 = 45 unit.

F = 1 × 10 = 10 units

H = 2 × 70 = 140 units.

because both H's have the same parent D and we have already calculated for both H's

MPS

Monday, December 18, 2023 9:44 PM

↳ Master Production schedule

Lets make one:

item: ladder back chair

quantity to order whenever shortage is expected.

order policy: 150 units.

lead time: 1 week.

Quantity on hand: 55 units

	April 1	April 2	April 3	April 4	May 1	May 2	May 3	May 4
Forecast	30	30	30	30	35	35	35	35
orders booked	38	27	24	8	0	0	0	0
expected. projected on-hand inventory → onhand - book or forcasted → Chose larger الأكبر	55 - 38 = 17	17-30 = ⊖13 shortage! → after ordering: 150 + 17 - 30 = 137	107	77	77-35 = 42	7	-8 shortage! → after ordering: 150 + 7 - 35 = 122	122-35 = 87
MPS quantity: plan to receive a quantity	-	150 (order policy)	-	-	-	-	150	-
★ important! MPS start: when to start producing depending on lead time?	150	-	-	-	-	150	-	-
Available to promise (ATP) inventory: أحجز من عندي الطلبات الأكيدة	17 ⟦55 - 38⟧ OH+MPS booked	91 ⟦150 - 27 - 24 - 8 - 0 - 0⟧ MPS only, booked until next order	-	-	-	-	150 ⟦150 - 0 - 0⟧ MPS only, booked	-

zeros because customers usually book for a close period.

1 week lead time.

قبل الزياده

Notes:

... before the longest lead time of a component in a product and 2 months before

Notes:

1- we need to do this before the longest lead time of a component in a product and 2 months before

2- why don't we get a bunch at once? holding cost :) + it might deteriorate.

3- after making sure of everything we <u>freeze</u> this schedule (هاد الجدول المعتمد وما رح أغير طلباتي)

MRP

Friday, December 22, 2023 3:31 PM

* For MRP scheduling, we will show 3 cases of lot size, then we will change safety stock (S.S).

First we will do aggregate planning for gross requirements:

chairs manufacturer: aggregate plan on high level (all chairs) →

	April	May
chair family	670	670

After making MPS for kinds of chairs: MPS starts

	April 1	2	3	4	May 5	6	7	8
ladder back chair	150					150		
kitchen chair				120			120	
office chair			200			200		
			= 670			= 670		

require same seat subassembly : kitchen & ladder back chair require each 1 seat subassembly to make 1 chair.

MRP FOQ

Friday, December 22, 2023 3:52 PM

item : C

description : seat subassembly

$\boxed{OH = 37}$

Fixed order quantity.

lot size : FOQ = 230

lead time : 2 weeks.

safety stock : zero.

we consider shortage when on hand is less even with safety stock.

quantity needed to make parents.

	weeks							
	1	2	3	4	5	6	7	8
Gross requirements	150			120		150	120	
scheduled receipt	FOQ 230							
Projected on hand.	117	117	117	after order. 227 shortage even with safety stock	227	77	after order 187	187
planned receipts	no need. –	–	–	230	–	–	230	–
planned order releases.	–	230	–	–	230	–	–	–

2 weeks lead time

MRP POQL

Friday, December 22, 2023 4:08 PM

item : A

lot size : POQL (P=4)

lead time : 1 week.

OH = 0.

S.S : zero.

	week 1	2	3	4	5	6	7	8	9	10.
Gross requirements.		60		25		35		45		60
scheduled receipt										
projected on hand.	0	25	25	0	0	45	45	0	0	60
planned receipts	0	85	0	0	0	80	0	0	0	60
planned order releases.	85				80				60	

because P=4, at the week we have shortage in, we take it and the next 3 weeks gross requirements $60+0+25+0 = 85$, we order this much

Well, how do we know how much P should be?

$TBO_Q = \frac{Q}{D} \times 52$

time between orders

$Q_{required} = 80$

orders

$$D = \frac{60+0+25+35+0+45+0+60}{10} = 22.5 \text{ unit/week.}$$

$$\frac{80}{22.5} \times 52 = 3.5 \simeq \underline{4} = P$$

MRP L for L

Friday, December 22, 2023 4:26 PM

item : A

$\boxed{OH = 0}$

lot size : L4L → بجيب قدما بحتاج بالضبط

Lot for Lot.

its a case of periodic review system.

lead time : 1 week.

S.S : zero.

week

	1	2	3	4	5	6	7	8	9	10
Gross requirements		60		25		35		45		60
scheduled receipts.										
projected on hand.	0	0	0	0	0	0	0	0	0	0
planned receipts	0	60	0	25	0	35	0	45	0	60
planned order releases	60		25		35		45		60	

Having Safety Stock

Tuesday, December 26, 2023 8:22 PM

item : C

seat subassembly

OH = 37

Lot size : POQ (P=3)

lead time : 2 weeks

S.S = 80

	weeks							
	1	2	3	4	5	6	7	8
gross	150			120		150	120	
scheduled receipt	230							
projected OH	117	117	117				80	80
planned receipt.	0			4			120	
order releases						120		

* Remember! if projected OH was less than S.S we order depending on تبعا the way we are using

Advantages and notes

Tuesday, December 26, 2023 8:10 PM

	Advantages	Disadvantages
FOQ	no need for S.S	holding cost. (reminent).
POQL	-	needs S.S in case of unreliable supplier/transport system
L4L	almost no holding cost.	ordering cost, needs S.S " " " " "

So briefly:

	FOQ		POQL		L4L
holding cost	-	>	-	>	-
ordering cost	-	<	-	<	-

$\boxed{\text{FOQ}}$ is used when we have cheap sku, and we can order lots of quantity (high Q)

$\boxed{\text{L4L}}$ is used when we have expensive sku.

<u>POQL</u>: when we want to know how much to order, we add:

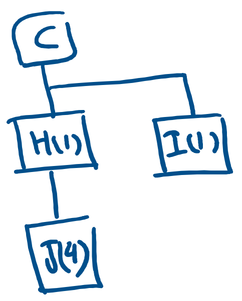
the week we have storage in + next(p-1) + <u>S.S - OH</u>

<u>L4L</u>: when we want know how much to order, we:

what we need + <u>S.S - OH</u>

MRP with tree of items

Tuesday, December 26, 2023 10:07 PM



We first start by doing MPS
then we start with MRP

Making MRP for this tree of items: *important: when making MRP for(J) for example, we only look at the number next to it, not the number of its parent

item: C

$\boxed{OH = 37}$

lot size: FOQ = 230.
lead time: 2 weeks

week

	1	2	3	4	5	6	7	8
gross	150			120				
"	230							
"	117	117	170	227	227	77	187	187
"	0	0	0	230	0	0	230	0
"		230			230			

item: H

$\boxed{OH = 40}$

lot size: FOQ = 300.
lead time: 1 week.

week

	1	2	3	4	5	6	7	8
gross		230			230			
"		300						
"	40	110	110	110	180	180	180	180
"	0	0	0	0	300	0	0	0
"				300				

item: I

$\boxed{OH = 0}$

lot size: L4L
lead time: 1 week.
S.S = zero.

week

	1	2	3	4	5	6	7	8
gross		230			230			
"								
"	0	0	0	0	0	0	0	0
"	0	230	0	0	230	0	0	0
"	230			230				

230 + 0 - 0

230 + 0 - 0

item : J

$\boxed{OH = 200}$

lot size : FOQ = 1500
lead time : 1 week.
S.S = zero.

	Week 1	2	3	4	5	6	7	8
gross				1200				
"								
"	200	200	200	500	500	500	500	500
"	0	0	0	1500	0	0	0	0
"			1500					

Scheduling

Sunday, January 7, 2024 5:[illegible]0 PM

strategy → Capacity planning
facility planning → Capacity planning
Economic environment, competitive conditions → Capacity planning

Capacity planning → Aggregate Planning → Master Schedule planning → Short term scheduling

Forecast of family of products (unit/month) → Aggregate Planning
Forecast each SKU (unit/week) → Master Schedule planning
Forecast each SKU (unit/shift, hour, day) → Short term scheduling

Capacity planning

long term (5-10years)

- facility location
- facility size
- no of production

Large investments

Aggregate Planning

medium term (months, quarters, --)

- facility utilization
- human resources
  - employment
  - part timers / full timers
- subcontracting

	April	May
Bikes	800	850

Master Schedule planning

short/medium term (weeks)

- determine weekly capacity schedule

production - materials

Short term scheduling

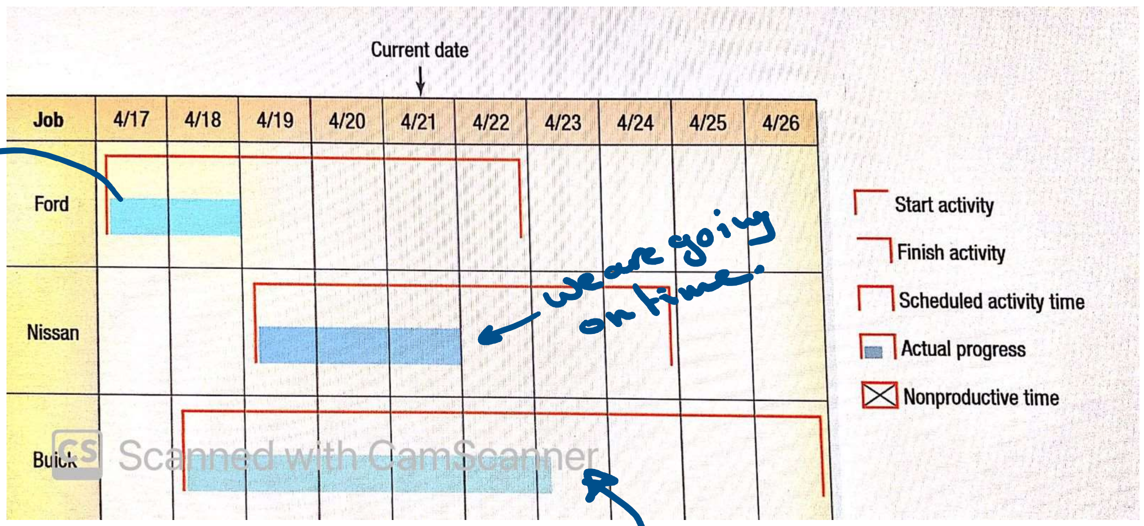
very short term (shift, day, hour)

- matching tasks to people and machines
  - Job + facility schedule
  - workforce schedule
  - sequencing jobs + workstations

Gantt workstation chart

Sunday, January 7, 2024 6:08 PM

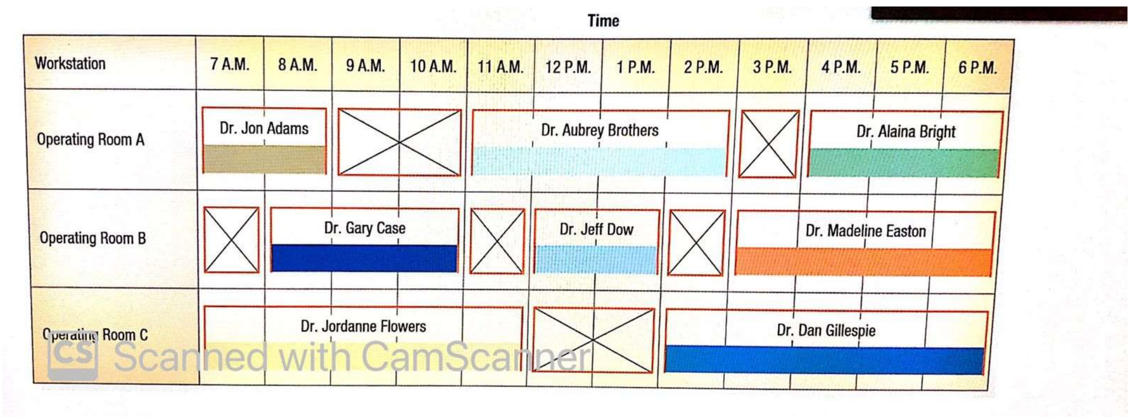
behind schedule our progress is very little (we are late!)



we are going on time.

Ahead of time in progress (we have done more than enough till today)

station 3 can accept more orders
station 1 cannot accept more orders.



Work force scheduling constrains:

- technical constrains
- phsycological constrains
- legal and behavioural considerations

→ performance measure : total slack capacity.

Scheduling Example (slack capacity)

Sunday, January 7, 2024 5:52 PM

1st Semester 2023-2024 | PPC(Inventory)(Sec2) | PPC(Inventory)(Sect1) | PM(Risk) | PPC(MRP)Sec1 | PM(Scheduling) | PPC(Sched)Sec1

Day	M	T	W	Th	F	S	Su
Required number of employees	6	4	8	9	10	3	2

→ technical constrain

ورا بعض →

The manager needs a workforce schedule that provides ~~two consecutive days off~~ and minimizes the amount of total slack capacity. To break ties in the selection of off days, the scheduler gives preference to Saturday and Sunday if it is one of the tied pairs. If not, she selects one of the tied pairs arbitrarily.

legal constrains

→ performance measure

ناس جايين
زيادة واحنا ما بنحتاجهم

← we take least 2 as off days

M	T	W	Th	F	S	Su	Employee	Comments
6	4	8	9	10	3	2	1	Sa/Su
5	3	7	8	9	3	2	2	S/Su
4	2	6	7	8	3	2	3	S/Su
3	1	5	6	7	3	2	4	M/T
3	1	4	5	6	2	1	5	S/Su
2	0	3	4	5	2	1	6	M/T
2	0	2	3	4	1	0	7	S/Su
1	0	1	2	3	1	0	8	M/T | T/W | S/Su | Su/M
0	0	0	1	2	1	0	9	M/T | T/W | Su/M
0	0	0	0	1	0	0	10	M/T | T/W | W/Th | S/Su | Su/M
0	0	0	0	0	0	0		

best

has Su

Employee	M	T	W	Th	F	S	Su	Comments
1	x	x	x	x	x	off	off	
2	x	x	x	x	x	off	off	
3	x	x	x	x	x	off	off	
4	off	off	x	x	x	x	x	
5	x	x	x	x	x	off	off	
6	off	off	x	x	x	x	x	
7	x	x	x	x	x	off	off	
8	x	x	x	x	x	off	off	
9	off	x	x	x	x	x	off	
10	~~x~~	~~x~~	~~x~~	~~x~~	x	~~off~~	~~off~~	

part time →

		M	T	W	Th	F	S	Su
Capacity, C		~~7~~ 6	~~8~~ 7	~~10~~ 9	~~10~~ 9	10	3	2
Requirements, R		6	4	8	9	10	3	2
Slack, C − R		~~1~~	4	2	1	0	0	0
		0	3	1	0	0	0	0

Total slack = 8

= 4

Sequencing Rules: (we choose one of them)

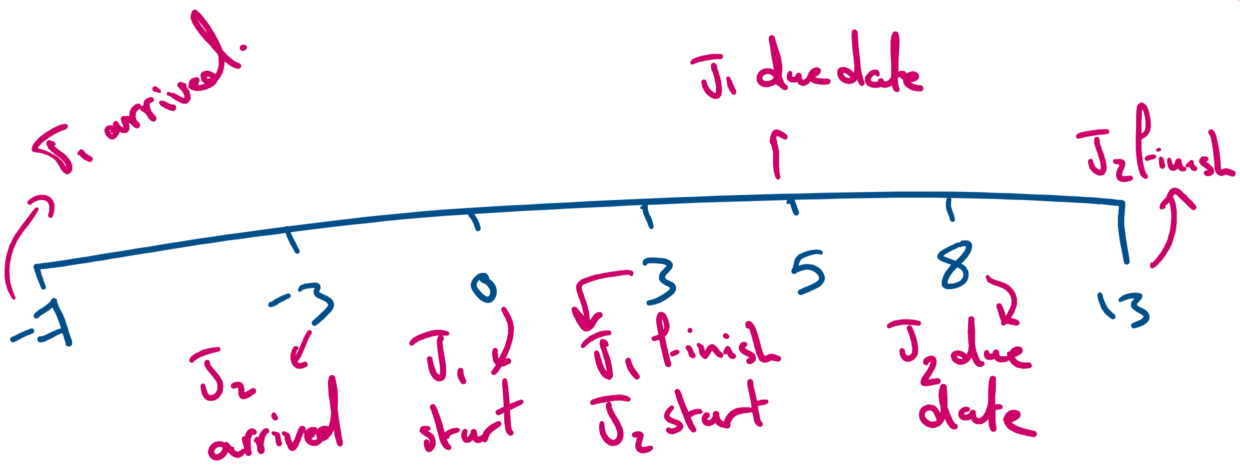
1. First come, first served (FCFS)
   $J_1 \rightarrow J_2$
2. Earliest due date (EDD)
   $J_2 \rightarrow J_1$
3. Shortest processing time (SPT)
   $J_1 \rightarrow J_2$

Due date	Time since order arrived	Processing time	Job
10	3	7	J_1
7	6	3	J_2

Measures to assess performance:

1- Average days past due.
2- Average flow time.

Due date	Time since order arrived	Processing time	Jobs
5	3	7	J_1
8	10	3	J_2



J_1 flow time : $3+7 = 10$ days
from arrival to finish

J_2 flow time : $13+3 = 16$ days

average flow time $= \frac{10+16}{2} = 13$

days past due = Finish time − due date.

if negative then we put zero because we have not been late

put zero because we have
not been late

$$\text{average days past due} = \frac{J_1 \text{ pastdue} + J_2 \text{ pastdue}}{2}$$

Sequencing rules example

Sunday, January 7, 2024 7:28 PM

Currently a consulting company has five jobs in its backlog. The time since the order was placed, processing time, and promised due dates are given in the following table. Determine the schedule by using the FCFS rule, and calculate the average days past due and flow time. How can the schedule be improved, if average flow time is the most critical?

Customer	Time Since Order Arrived (days ago)	Processing Time (days)	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

$\boxed{\text{FCFS}} \Rightarrow A \to B \to D \to C \to E$

Customer Sequence	Start Time (days)	Processing Time (days)	Finish Time (days)	Due Date	Days Past Due	Days Ago Since Order Arrived	Flow Time (days)
A	0	25	25	29	0	15	40
B	25	16	41	27	14	12	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

Average flow time $= \frac{40+53+61+70+77}{5} = 60.2$ days

Average days past due $= \frac{0+14+3+0+0}{5} = 3.4$ days

$\boxed{\text{SPT}} \Rightarrow D \to E \to C \to B \to A$

Customer Sequence	Start Time (days)	Processing Time (days)	Finish Time (days)	Due Date	Days Past Due	Days Ago Since Order Arrived	Flow Time (days)
D	0	10	10	48	0	10	20
E	10	12	22	80	0	0	22
C	22	14	36	68	0	5	41
B	36	16	52	27	25	12	64
A	52	25	77	29	48	15	92

Average flow time $= \frac{20+22+41+64+92}{5} = 47.8$ days

Average days past due $= \frac{0+0+0+25+48}{5} = 14.6$ days

pretty bad.