Today we learn when to order.

By when I do not mean time, I mean quantity, at what level of inventory we place an order.

At what level of inventory should we place an order to be able to satisfy the incoming demand during the lead time by high probability.

Lead time is the elapsed time between when we place an order and when we get the order.

This is called a continuous inventory system, when we continuously trace the inventory and place an order when inventory reaches the point equal to the demand during the lead time plus a safety inventory.

If we place an order when inventory is equal to the average demand during lead-time, there is a 50% probability of understock and 50% of overstock. We usually place an order when inventory is more than the average demand during lead time.

By having this much inventory, with a probability of more than 50%, we can satisfy the incoming demand during the lead time by using our inventory.

In continuous or perpetual inventory system, the quantity that we order is fixed, but the time of the order is variable. It depends on when the inventory reaches a specific point. The reorder point or ROP.

We also have periodic inventory system when we place an order at the beginning of each period (week, month, etc.). In a periodic inventory system, the time of placing an order is fixed, but the quantity of the order is variable. We will discuss the periodic inventory system later.

Let’s review the four characteristics of all forecasting techniques

Forecasts are always inaccurate because of random noise.

Forecasts should be accompanied by a measure of forecast error. The coefficient of variations (standard deviation divided by average) defines the degree of confidence in the forecast.

Aggregate forecasts are more accurate than individual forecasts. Aggregate forecasts reduce the amount of variability – relative to the aggregate mean demand. StdDev of sum of two variables is less than sum of StdDev of the two variables.

Long-range forecasts are less accurate than short-range forecasts. Forecasts further into the future tends to be less accurate than those of more imminent events. As time passes, we get better information, and make better prediction.

Lets review now let's go to the

order point look when I had a and for casting I talked about some

features of all forecasting techniques

forecasts are usually or always inaccurate you can never think that what

your forecast is exactly what will happen and that is why when there will be forecasts we say this is our average

forecast we don't know what the actual demand would be or what the actual that

variable will come up this is our average forecast and we need to always

accompany our average forecast with the standard deviation of forecast the

degree of variability which is associated with that average the third

fact about forecasting is aggregate forecasts are more accurate than

individual forecasts for example forecasts for Ford Motor Cars is more

accurate than forecasts Ford Mustang the variability or coefficient of variation

for all Ford products is smaller than for Mustang and then for all cars of all

manufacturers variability is less than that of Ford Motor alone and forecast

for next year economy is more accurate less variability less coefficient of

variation compared to forecast for car industry and forecast for summation of

10-days demand is more actually than forecast for one-day demand the

variability for 10 days is less than variability in one day up and downs

cross each other's out in people's language in mathematical language it is

the variance of those 10 random variables which are added so if I have 10 random variables each one has a

standard deviation and when I add them up it is not their standard deviations

which is added up it is their variances so it'd be 10 times so one of them and then when we

translate variants into standard deviation we should put it under the square root and then 10 goes under the

square root therefore standard deviation of a summation of ten random variables is not

ten times the standard deviation of one of them but ten under the square root which is much less and the longer range

forecasts are less accurate than short-term forecasts the more removing

to the future our knowledge about future will get less accurate and then variability goes up

indeed if we look at the time from now until when we need that forecast as a

lead time standard deviation of forecast for all time units away from now that

doesn't go under square root why it doesn't go because in the previous

situation it was in the random variables which were added to each other but here there is one random variable which is

multiplied by something statistically we can prove that when we add several

random variables the variances get added to each others and therefore the summation or the number which is in this

example was 10 will go under the square but when we talk about a time from now

200 days from now on average hundred days which it could be 50 days or 150

days the standard deviation of this neat time will be multiplied by demand per

day to come out with the total standard deviation of that time period

now let's look at reorder point problem we do have two types of ordering

periodic inventory system or period in ordering and perpetual ordering in

pivoting ordering we order at the beginning of the period beginning of the

week beginning of the mouth beginning of the season so reorder point the point at

which we order is defined in terms of time but we also have perpetual inventory

system in which reorder point the point at which we order is defined not in

terms of time but in terms of how much inventory do we have on hand here we

discuss perpetual inventory system so we have an inventory and it gradually goes

down we have this much inventory and each day we consume some of it down down

down and at each of this point this is what we have on hand this is what we

have on hand this is what we have unhappy goes down down down down down

down down and we have concealed all of

our inventory and we have nothing here so suppose this is our lead time for

example this two days three days four days whatever or why axis was quantity

or inventory and our x-axis is time

suppose if I place an order here I will

get the order over there and because this is how my inventory is consumed if

I need the order over there I need to place an order here therefore I should

have this much inventory on hand and that is what we call it the Boydell pot

that is lead time from the time that we place an order until the time that we

get that line shows our consumption

therefore my material here I should place an order here and when I

am here during this time I will consume

this much therefore when in winter on Honda's this much I will place an

order average demand during it but the reality is that inventory is not

consumed in a linear fashion it will go up and down demand everyday demand is

not equal to the other days whenever inventory on hand reaches the average of

what I need during lead time I place an order I have assumed that on average the

inventory will go down like this based on the average demon however inventory may go down like this

because the demand is low and therefore at the time when I get the orders I

already have this much inventory on hand on the other hand inventory may go down

quite fast faster than the average in that case for a period I will not have

inventory this is what I have on hand this is time this is the inventory it

will go like this down but I estimate that it is going down in a linear

fashion this is my lead time therefore I am expecting it to go like that and when

the order is received I have nothing on hand and this is my reorder point this

is averaged demand during lead time and over there in this situation reorder

point is equal to average demand during lid time but if I place an order over

there I'd be consumed inventory quite fast therefore for a period I may be out

of material that is a risk and usually

we wanna reduce that risk because if I place an order when inventory on hand

is equal to the average demand during lead time there is 50% probability that

the demand during the time exceeds what I have and there is 50% probably that is

less than what I have 50% probability of over the stock 50% probability of under

the stock cost of under stock is usually more than over stock therefore I usually

like to reduce the probability of under stock when I place an order inventory on

hand is not equal to the average demand during the leader it is equal to the

average demand during the lead time plus safety stock i order at a higher level

if I order at a higher level probability of old stock is more than 50% and

probability of under stock is less than 50 person the probability of under stock

is referred to as risk the rest of the probability is referred to as service

love when I place an order I do know that the band during the time based on

its average and its standard deviation but they don't know exactly what it is it will have a normal distribution if I

place an order when inventory on hand is equal to average demand 50 50 50 percent

probability of overstock 50 percent probability of risk under stock 50

percent service level 50 percent risk but if I go ahead and add something to

it as safety stock and place an order when inventory on hand is this much not

this much in that case service level is

more than 50 person and risk is less than 50 person there is

a probability that during lead time demand is quite high or quite low high

or low high or low safety stock makes it

possible that probability of under stock to be less than probability of over a

stock risk to be much less than service

level usually with 90% probability we

have the material with 10% we don't have now let's try to solve this problem

based on the knowledge you have about normal distribution we know that from

the time that we place an order until the time that we get it the demand has

an average of 200 and standard deviation of 25 now if we place an order when we

have 200 that is 50% risk and 50 percent

service level but we like to increase this green area and we want to reduce

the red part such that service level is

much higher than risk how do we do that

by adding safety stock to the average demand during lead time such that this

probability is something that we like and this probability is something that

we like but don't forget summation of red and green is always one we wanna

ready read in favor of Greek average demand

during the lead time service level we wanted more than 50% therefore be our

safety stock to average demand during lead time and that is all reorder point

and this small probability is risk we one have 90 percent service level 10%

risk average demand for 200 standard deviation 25 if we place an order

when inventory on hand is 250 percent

red 50 percent blue we don't want it we

want this area service level to be

larger this area risk to be smaller

service level in this case is 50 percent we want a situation like this here is

risk here is service lava we go to exit we type nor inverse 90% is service level

this probability 200 is average and 25

is a standard deviation we get to 32 and that is our reorder point 232 is about

32 units more than 200 and that is what we refer to it as eye safety safety

stock if we place an order when inventory on hand is to 32 to 33

service level goes up from 50 percent to 90 percent and risk probability of stock

out comes down from 50 percent to 10 percent

by adding 32 point something to our average demand during lead time and

place an order when invent on hand is that much we increase our service level

from 50 percent to 90 percent and risk

is reduced from 50 percent to 10 percent now let's see if you can solve this

problem here we do not have the

distribution of demand during a time we

do have the distribution of demand per day or per period and we have the time

in terms of days or periods days weeks month we need to be able to translate

this problem into the previous problem as soon as we can transform it then we

can use the previous problem to solve it previous problem we had demand during

little average and standard deviation here we don't have here we have lead

time and average and standard deviation of demand per day if we can translate

this problem into the previous problem we are done lead times fix will refer to

it as L demand per day is a random variable normally the sufficient random variable

with average of all and standard deviation of Sigma are the difference is

this in the previous problem we had lead time demand which was normally

distributed with average of lead time demand is when we write it a little bit

ball to show that it is a random variable and this one is average of that

random variable and this is standard deviation that random variable so if Li time is L

and demand per day is R therefore it is a common sense that average lead time

demand is L times R this is quite simple common sense and we can use this formula

that standard deviation of demand during lead time is square root of lead time

multiplied by standard deviation of demand per day so we have this formula

and we have this formula and therefore

this problem is already translated into the previous problem if demand is

variable and lead time is fixed if L is a lead time which in this case is 16

days if R is demand per day or demand per period which here is 20 per day if

Sigma of or is standard deviation of demand per day or per period which is 5

so note that here lead time is defined in terms of days it could have been

defined in terms of period weeks months this is because that is days this is

demand per day if that was week here I needed demand per week because that is

days here I have standard deviation of demand per day I have all these

information the time demand is average demand during lead time it is lead time

multiplied by average demand and that is 320 standard deviation of lead time

demand is square root of leta square root of 16 multiplied by standard

deviation of demand per day this 16 is over there 5 is here 5 is not under

parentheses so it will become 4 times 5 which is 2 an and that's it now the

problem has been translated into the previous

problem was originally like this we had demand per day and standard

deviation of demand per day now we have translated into demand during the time

and the standard deviation of demand during the time and this is exactly the

same as the previous problem and we know how to solve it lead time demand is 320

standard deviation of lead time demand is 20 service level is 90 percent plug

it in into norm inverse because we do have probability we do have mean and we

do have standard deviation and we get reorder point we need to place an order

when inventory on hand is this much or 346 and the gap between that one and

this one is all safety stock safety stock is 26 by adding 26 to 320 we go

from a 50% risk to 10% risk so this is

the answer to the problem this is reorder point this is average

demand during the lead time and this is our safety stock now let's go to another

problem please read this problem and see if you can find the difference between

this problem and previous problem so we had a problem a in which we had average

and standard deviation of demand during tea time we had problem B in which lead

time was fixed but we had the average and standard deviation of demand fell

period per day per week and so on in whatever the lead time is defined in

terms of that unit now let's see if you can find the difference between problem

C and problem B in be lead time was fixed demand per period

was variable in this problem demand per

period is fixed lead time is valuable in the previous problem we had several

random variables L a random variables if the lead time is defined as L we had

elder random variables which we should add them together here we only have one

random variable and that random variable is lead time and that random variable is

multiplied by a demand which is fixed we

need to know what is the average demand during determine we need to know what is the standard deviation of demand during

the time if you can answer these questions then problem C also is

translated into problem a and we are done demand per day is fixed lead time is a

random variable it has an average and standard deviation and we want to use

this data to compute average and standard deviation of demand during lead

time average demand during leta in this case also the same as previous case is

averagely time multiplied by demand per day this's or average determined SS

demand per day and that is average demand during lead time but standard

deviation of demand during lead time which we again show it by Sigma of Ltd

does not have a square root over there is simply or multiplied by standard

deviation of the time why because this problem is one random variable which is

multiplied by a constant problem C has one random variable

which is lead time and that lead time is multiplied by a constant which is demand

per day the other problem problem be had earlier

random variables which are added together to define the demand during the

time that is why the previous one has square root this one does not have a

square root what it is and statistics issue we just need to remember this and

I will give you this formulas what we need to know is which formulas should we

use when demand is variable and lead time is fixed compared to when lead time is valuable

and demand is fixed if lead time is variable and demand is fixed if L is

lead time as a random variable and L not

Balt l is average lead time which in this case was 16 days and r is demand

per period or per day which is 20 here lead time demand average lead time

demand is R times L or is 20 L is 16 average lead time demand is 320 standard

deviation of lead time is four standard deviation of lead time demand is or

times standard deviation of lead time standard deviation of lead time was 4 or

was equal to 20 per day therefore lead time demand is 20 times 4 which is 80

now we do have all the information and problem see also is translated into

problem a average lead time demand 320 standard deviation of lead time demand

80 service level 90 plug it into the normal distribution known inverse

because we have probability we have happened we have standard deviation we

get X which is our ROP reorder point for 22 or 423 if we subtract it from 320 it

is 103 which is our safety stock or o.p

lead time demand safety stock no let me

once again a little bit explain about the three problems Part A or problem a

in that problem we had average demand during the lead time no matter how long

that lead time is we had the average demand during that period and we also

had the standard deviation of demand during that period and we just used our

knowledge in normal distribution and we solved prob then we talked about Part B

and Part C or problem B and problems in problem B the time was fixed it was for

example five days so lead time is fixed what is valuable it is demand demand

fill period demand per day how do we know what is fixed what is variable by a

standard deviation if in a problem I don't give you standard deviation about

something that means it is fixed in this specific situation we give Santa

deviation with respect to daily demand and lead time doesn't have standard

deviation so it is fixed in problem 2 it

is the time which has standard deviation and demand does not have standard

deviation therefore in this case demand

per day is faced and it is lead time which is variable in both cases

we showed how to transfer the problem into the original problem and then use

the knowledge in normal distribution and solve the original truck in the first

problem or indeed in problem B your demand per day is multiplied by lead

time and that is average demand during data in the second case also average of

the time is multiplied by demand per day and it forms the average demand during

did but for standard deviation they are different where the demand per day is

variable lead time goes under the square root and then is multiplied by standard

deviation of dim-lit time goes under square in Part C or problem C there is

no square root demand per days here it

is simply x slanted deviation of lead

you may ask why one of them has square root the other one doesn't have because

these truth problems are very different and I will show it to you let me click on these two graphs look at

the blue graph and red graph and let me

know what do you see blue graph is

problem B red graph is problem C what is

the difference in problem B or blue graph I always have 5 bars and that is

when each of them goes for one of the days because lead time is 5 days lead

time is fixed and I have 5 random variables

each time they are different in this problem demand dealing litter is

computed by adding five random variables or in general L random values the red

graph is entirely different sometimes we have three bars

sometimes five sometimes six sometimes seven four five but the height of the

bars are the same in this case it is one single random variable which is the time

and it is multiplied by demand per day the blue graph is summation of Elendil

variable the red graph is one random variable multiplied by a number that is

the difference and statistically we can prove that date standard deviation are

computed differently now let's solve this problem please read the problem

understand it clarify what is what and then we move forward together average

demand during lead time lead time demand

is 20,000 units standard deviation of

lead time demand is 5000 whenever inventory reaches 24,000 we place an

order so it is 24,000 is our o P and we

order 14 days of supply the quantity that we order is equal to 28,000 which

is equivalent to 14 days so if we divided by 14 we get demand per day to

be equal to 2 8,000 divided by 40 inventory holding cost which we show it by edge is to lead

time demand 20,000 standard deviation of D time demand 5003 order point 24,000

caddying cost $2 per unit per year demand per day mm q or e oq 28,000

computer service level so this is like problem A or Part A we shouldn't be

worried about translating the problem to the original problem it is already the

original problem what is the service level if this is demand during Lin time

I should find what is my average demand during the lead time and I should find

at which level do I place an order then

I can go to normal table and compute this area which is the risk or this area

which is the service lab average demand during lead time is 20,000 standard

deviation of demand during the time is 5,000 reorder point is when inventory

reaches 24,000 therefore the problem becomes quite simple I have this X I

have the average I have the standard deviation I can go ahead and compute

this probability and that is myself normal distribution reorder point of

this demand using lead time and the standard deviation and we want to

compute probability we don't want to draw the curve so we put 1 and the

property or service level is about 79% and risk is the difference between 100%

and this one which is 21% therefore in this situation probability

of serving customer is almost four times of probability of not being able to

serve the customer this is 21 percent this is 70 nights about 70 knives

computer cycle inventory cycle inventories always defined as half of

what we ordered so in this case we ordered 28,000 in

cycling rental is half of it which is 14 and this is the logic we ordered Q units

at the beginning of the period by the end of the period it goes to 0 or by the

end of the cycle therefore during the cycle our average inventory is Q plus 0

divided by 2 or simply Q divided by 2

cycle inventory always of watry or 20,000 divided by 2 $14 compute the

average inventory average inventory is defined us cycle inventory plus safety

stock safety stock is not divided by 2 what we order is divided by 2 but safety

stock is not and I will explain we start consuming what we have until we reach to

a point when we realize that what we have on hand is a halt to the average

demand didn't lead during this period which is all the time we will consume

this much product gradually goes to see if we consume it based on the average

because we don't consume it with some average we place an order when we have

something more than average the dealing lead time and that is what we

called it safety stock therefore our reorder point is diamond dealing lead

time plus safety stock whenever the inventory on hand is equal to average demand during the time plus

safety stock we place an order if you consume it based on the average it will

go to zero here and therefore by the end of the period still we will have the

safeties but the whole story of the safety stock is around this fact that we

know the demand is not constant it goes up and down

for example after I place an order in this point I may consume what what I

have like this therefore when I receive the next order by the end of the lead

time I still have something more than safety stock I have the safety stock and

I have something more than that however my demand may be like this so even

before the end of the cycle I am out of everything I have fully consumed my

safety stock I have zero inventory here I have more than safety stock inventory here I have

less than safety stock inventory or zero inventory I may consume it like this at

this point I received my order and I have a lot inventory on hand by the end

of the cycle is much more than safety stock or it may be consumed like this by

the end of the cycle I have consumed a part of my safety stock or it may be

like this I have more than safety stock like this I have consumed a large

portion of my safety stock or like this or like this therefore by the end of the

cycle sometimes I have the safety stock and something more than safety stock and

sometimes I have consumed safety stock entirely or partially therefore as we discussed

before diamond during the time has normal distribution with its average

equal to average demand during the lead time therefore by the end of the cycle

because sometimes I have more than safety stocks sometimes I consumed parts

of safety stock it is quite logical to assume on average

at the end of the cycle safety stock is always there and that is why when we

compute average inventory we divide what we have ordered by two and we call it

cycle inventory but we do not divide safety stock cycle inventory is equal to

what we ordered / - average inventory is cycle inventory plus safety stock at

three order point reorder 28000 cycle inventory is 14000 safety stock is 4,000

because we place the order when we have 24,000 while demand during three times

20,000 therefore 24,000 - 20 is 4,000

safety stock and therefore average inventory is 14,000 plus 4,000 18,000

compute the total holding cost 30 year average inventory is 18,000 holding cost

or carrying cost is 2 multiplied them by each other's average holding cost per

year is 36,000 compute the average flow

time we go back to our leaders law coverage inventories 18000 14 days of

supplies 28,000 so 28,000 divided by 14

is equal to 2,000 this is our this is I Drupal 10 slow

time is the core to inventory artists 2,000 per day I is 18,000 fellow flota

is nine days days because this 2,000 is

stated in terms of days let's solve this

problem we place an order when inventory on hand is 525 each week we consume 400

the time is one week and start a division of demand is 125 we have the

order point we have average demand during day time and we have centered

omission of demand put 1 and we get 84 percent at the bottom part I have tried

to show an efficient frontier efficient frontier between service and cost when

service level goes up our service is better but when service level goes up

safety stock should also go up and safety stock has a cost because we

should keep it throughout the year and that is safety stock multiplied by holding therefore that's a trade-off

trade-off between service and cost here in this table I have tried to discuss

this issue that when we try to have better service we have no other choice

to have more cost click on it open object this excel sheet opens this is

service level I compare and computer reorder point norm inverse 80 percent

service level I have averagely time demand and I do also have standard deviation of the time

so I have those therefore like buuuut reorder point I go here average

demand during lead time standard deviation of demand during Lita and this

is service level which is 90 percent the previous one was 80 person and then I

copy down I have it for everything if we assume 80 percent service level is are

100 percent then when we go from 80% to 90% 90% divided by 80 percent multiplied

by 100 and that would be 130 we are

going up by 13 person if I copy this down here we go up by 19% here we go up

by 24% so this was zero is a portal this

one - this one and like it 13% increase

19% increase and 24% increase that is

how my service increases but safety stock is the reorder point - average

demand during v-tach say cuatro the order point which is here - average

demand during day time copy down again

here if we assume this is hundred then this would be under ed x what I am here

up divided right the original value and

liked it because he wanna measure everything compared to the original value 152 195 - 74

- culture 0 equal to this one - this one

and lock it and copy down look at here I

increase myself despite 13% my carrying

cost my safety stock cost went up by 52% increase it by 19% my safety stock cost

went up by 95% I increase it by 24% cost

went up by one hundred and seventy-six percent this is our efficient frontier

if we want to improve our service level like this from one hundred two hundred

and five ten fifteen twenty and 125 our cost will go up by this one hundred and

twenty five percent I mean 25 percent compared to hundred we'd lead to about

three hundred percent and indeed three hundred minus hundred which is two hundred percent increase in costs