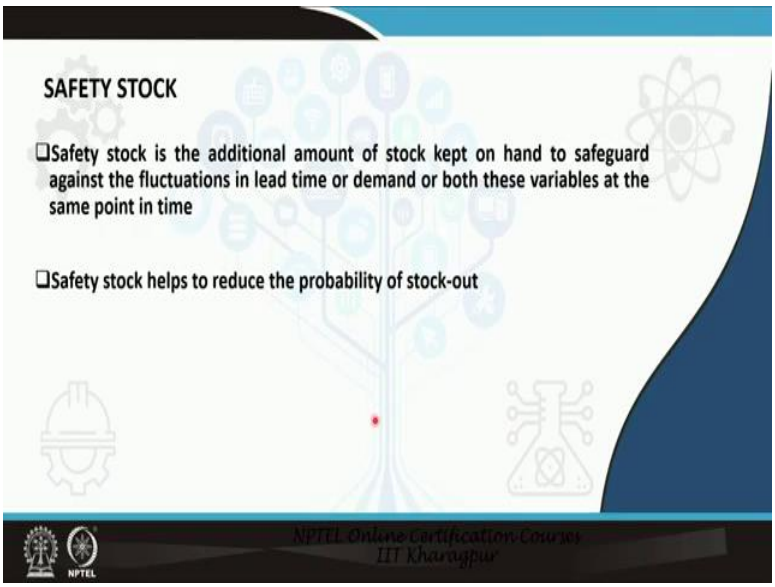
Modelling and Analytics for Supply Chain Management
Professor Kunal Kanti Ghosh
Vinod Gupta School of Management
Indian Institute of Technology, Kharagpur
Lecture 30
Safety Stock and Reorder Level

Hi, good afternoon we welcome you to our session on safety stock and reorder level in the context of inventory management.

(Refer Slide Time: 00:24)



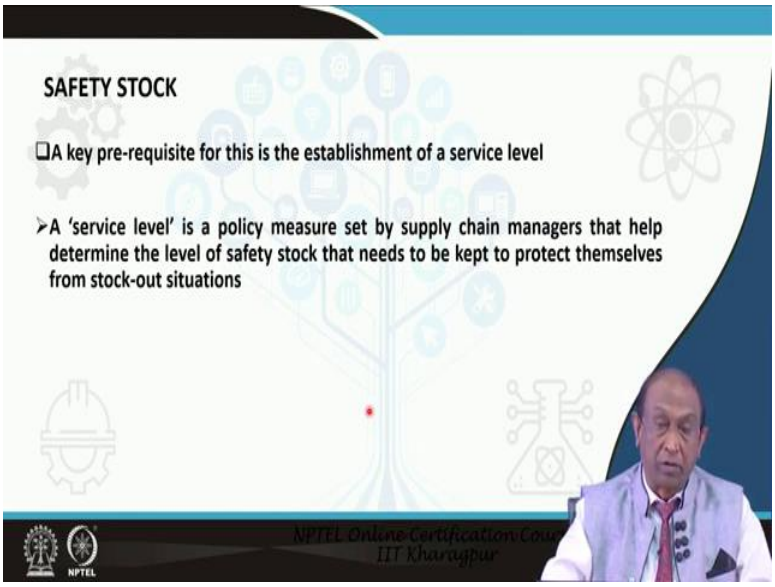
Now, when we want to discuss about safety stock we need to know what is meant by that. So, safety stock is the additional amount of stock kept on hand to safeguard against the fluctuations in lead time, or fluctuations in demand or fluctuations in both these variables at the same point in time. Lead time we have already defined is the time that elapses between

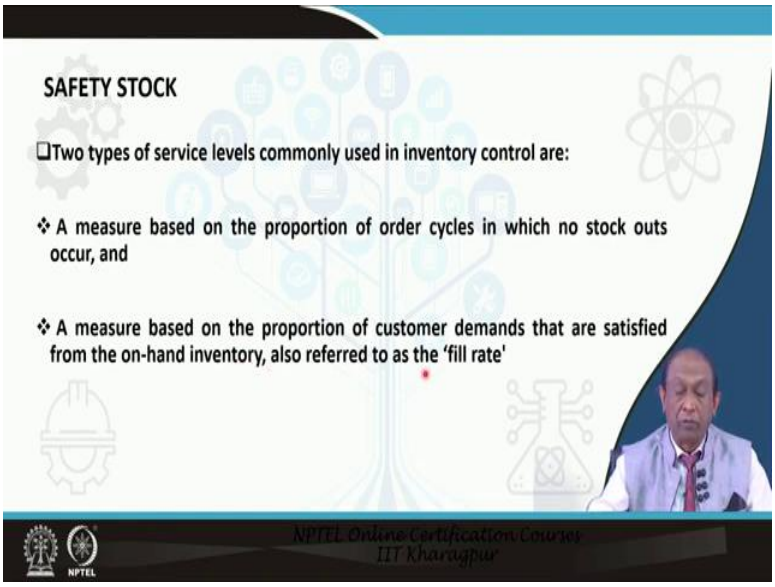
the placement of an order on to the supplier. And the receipt of the goods, from the supplier at the premises of the manufacturer.

Now, these fluctuations in statistics it is measured by the standard deviation of the particular variable. If it is lead time, then will be referring to the standard deviation or variance in lead time. At the measure of the fluctuation of lead time and similarly, if it is fluctuation in demand we have to compute the standard deviation or the variance of demand.

Now, safety stock basically helps to reduce the probability of stock-out and we need to know, what is the optimal amount of safety stock that we must keep in our organisation. So, that the probability of stock-out is as per desired service level.

(Refer Slide Time: 02:40)

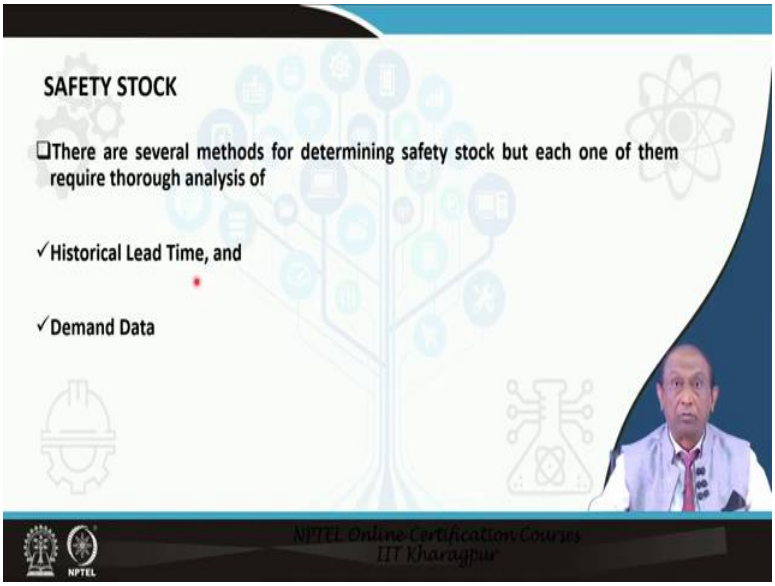




A pre-requisite for this then is a establishment of a service level. Now, you might ask me what is the service level? So, a service level is a policy measure set by supply chain managers, to help them determine the level of safety stock that needs to be kept to protect themselves from stock-out situations. So, basically is the policy level decision and there are two types of service levels commonly used in inventory control.

Number one, is a measure based on the proportion of order cycles in which no stock outs occur. Is a measure based on the proportion of order cycles in which no stock outs occur, and the second definition of service level. Service level is a measure based on the proportion of customer demands that are satisfied from the on-hand inventory. This is also referred to as the fill rate.

(Refer Slide Time: 04:26)



There are several methods for determining the safety stock. But, each one of them require thorough analysis of Historical Lead Time and Demand Data. Until and unless adequate amount of data related to these two entities lead time and demand is available. Safety stock determination will not be accurate.

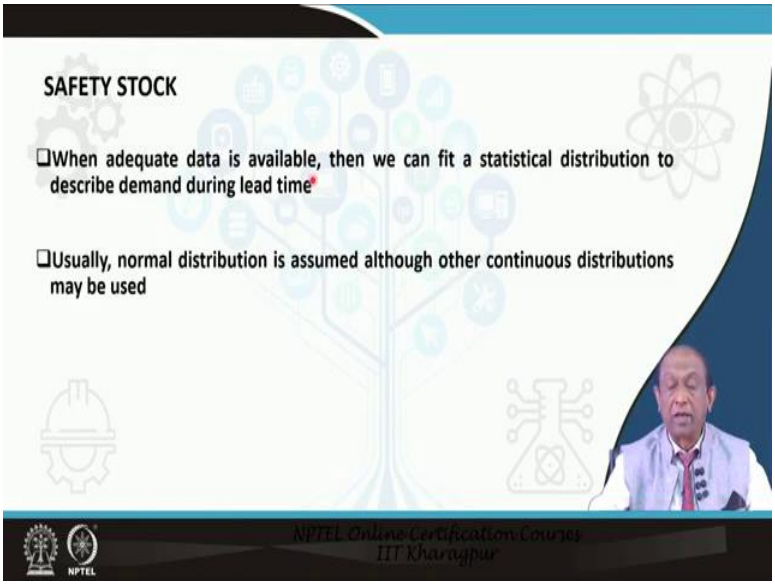
Today of course with the help of computer systems particularly with the adherent of enterprise resource planning systems, there are various ways in which we can extract relevant data related to lead time and demand. The demand data can be obtained from consumption master files.

Because in any organisation whenever there is an issue that issue transaction is being captured in the data base. And over a period of time we can extract all those issue

transactions to find out average demand and the standard deviation of demand for any particular item. Similarly, this historical lead time though we can we have defined that lead time is the difference in time between placement of purchase order and receipt of the item. This receipt of the item can be obtained from the computer systems based on goods receipt date.

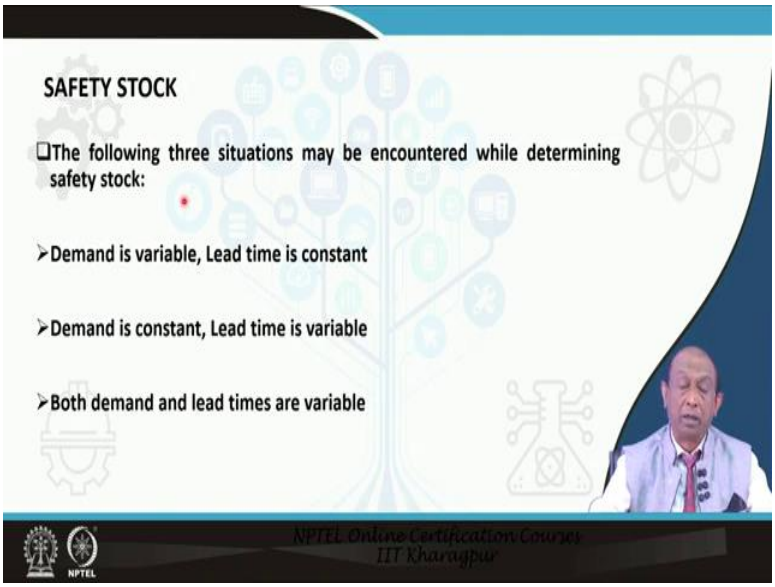
And we know the purchase order date, so we will get the difference between this to (())(06:39). To get an idea or measure of lead time and we will capture all the receipt transactions over a period of time. To get the average lead time and the standard deviation of lead time.

(Refer Slide Time: 07:00)



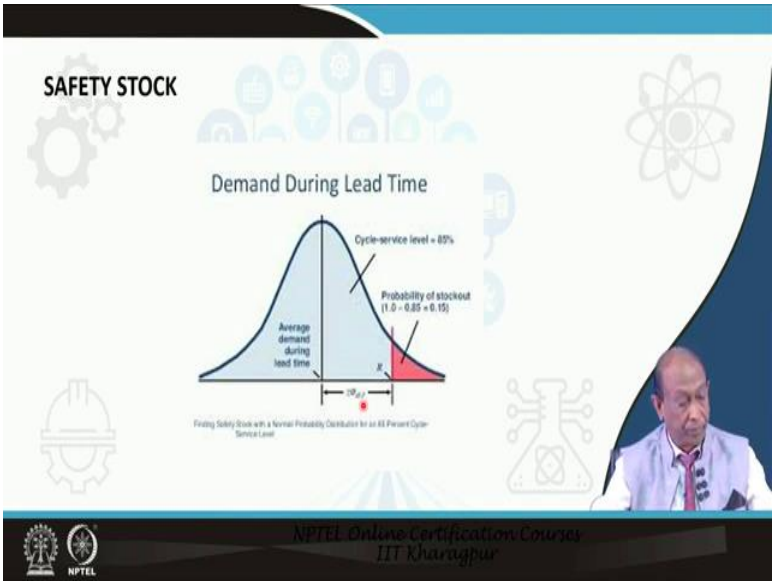
So, when adequate data is available, we can fit statistical distribution to describe demand during lead time. And normally we assumed normal distribution to fit as the distribution of demand during lead time. Although, any other continuous distributions maybe used.

(Refer Slide Time: 07:36)



While discussing about safety stock, we have to keep in mind the following three situations that may normally be encountered while determining the safety stock. The first one is, the demand is variable while lead time is constant. The second one is demand is constant but the lead time maybe variable. And the third one is both these entities demand and lead times are variable.

(Refer Slide Time: 08:37)



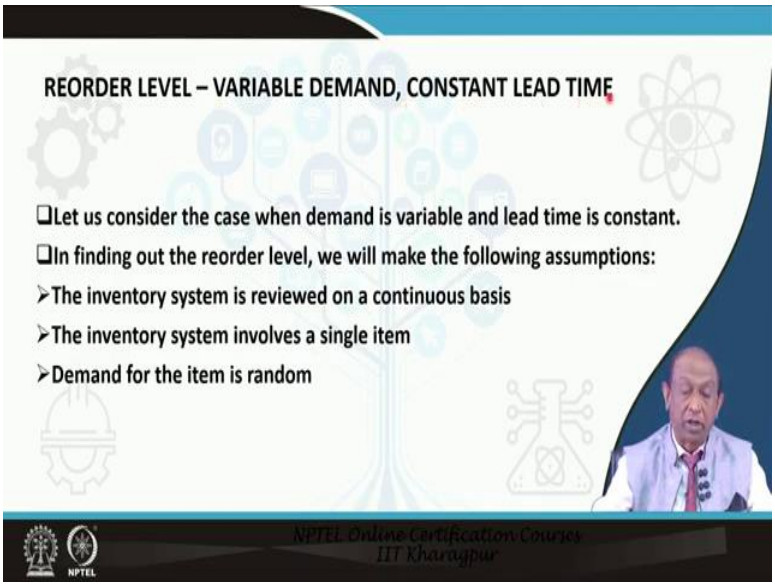
Now, as long as the demand during lead time is less than its average value, then everything is in order, and we are not bothered about the safety stock. The safety stock concept comes in, when these variables either demand or lead time values exceed their average values. So, here we see a normal distribution curve and see average demand during lead time.

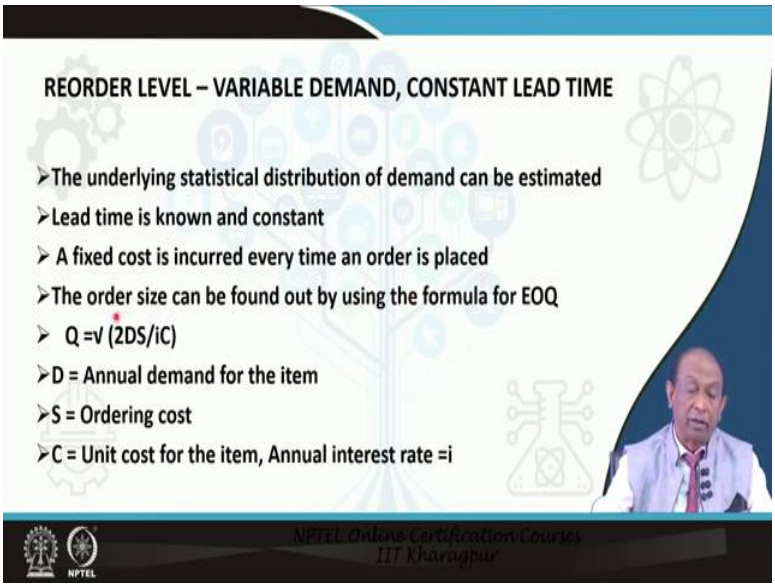
As long as the in reality the actual demand is less than the average demand during lead time. There is no question of safety stock but, when the demand exceeds this average value, then we have to protect that through its safety stock or the buffer stock.

Now, we have already defined that if the cycle service level is specified. Saying this case, cycle service level is specified at 85 percent. Then the corresponding normal random, standard normal random variate is pointed here, at this point 0.85 corresponding to that whatever Z value is there.

See in that case, if Z value is at this point the probability of stock-out will be 1.0 minus 0.85 is only 15 percent this ratio. So, we have to find out that particular Z value which will give us protection upto this level. And under such condition the amount of safety stock that we have kept is Z multiplied by the standard deviation of the demand during lead time.

(Refer Slide Time: 11:18)



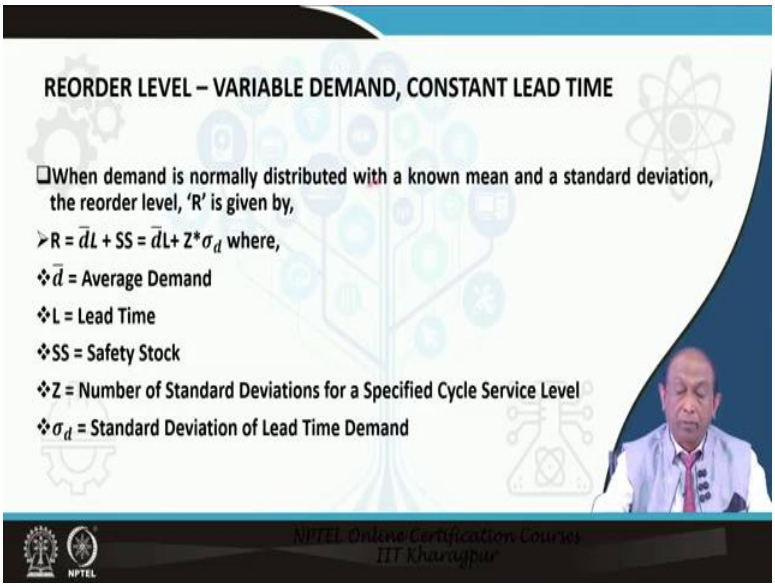


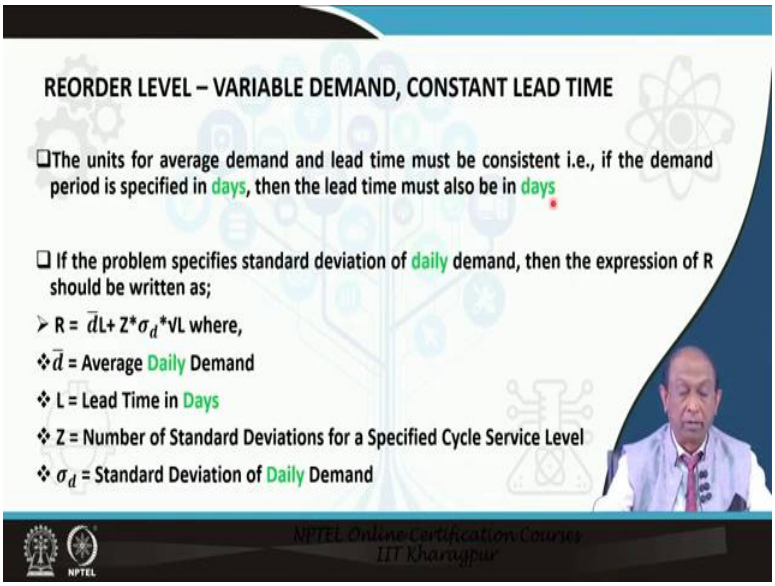
So, we will also determine the reorder level under each of the cases that we have mentioned. Let us take the case of determining the reorder level where the demand is variable and the lead time is constant. In finding out the reorder level we will make the following assumptions. The first assumption is that the inventory system is reviewed on a continuous basis.

The inventory system involves a single item and demand for the item is random. The underlying statistical distribution of demand can be estimated that is also a one assumption. And in this case normally we have assumed that is a normal distribution. Lead time is known and constant and the another assumption is that a fixed cost is incurred every time an order is placed which will basically call the ordering cost. The order size we have already discussed about this in our economic order quantity determination exercise.

That the order size can be find out by using the formula for EOQ which is nothing but, square root of 2DS by i into C. Where, D is annual demand for item, S is the ordering cost and C is the unit cost for the item and the annual interest is given by i.

(Refer Slide Time: 13:21)



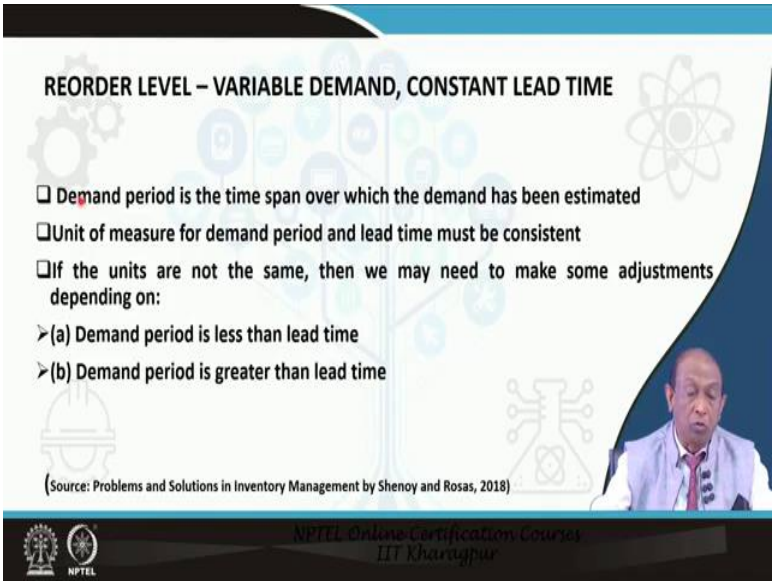


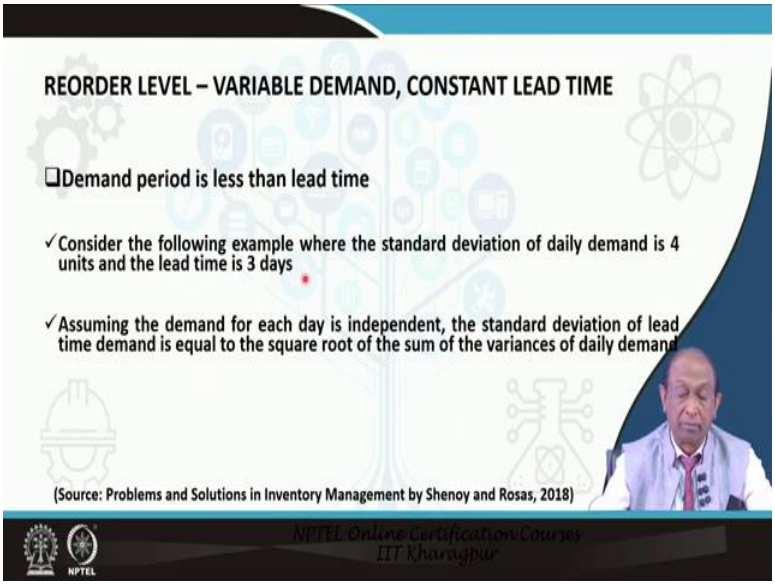
When demand is normally distributed with a known mean and the standard deviation, the reorder level, R is given by average demand into lead time which is constant, plus the safety stock. Which is nothing but d bar into L plus Z multiplied by sigma d. Where d bar is the average demand, L is a lead time, S is the safety stock and Z is the number of standard deviations for a specified cycle service level.

Sigma d is nothing but the standard deviation of lead time demand. Here, we have to remember one thing, that the units for average demand and lead time must be consistent. That is, if the demand period is specified in days, then the lead time must also be in days. If this unit of measures are not the same, then appropriate conversion has to be made.

For example, if the problem specifies standard deviation of daily demand, then the expression for reorder level should be written as d bar into L plus Z times sigma d multiplied by root over of L. Where, d bar is the average daily demand, L is the lead time in days, Z is the number of standard deviations for a specified cycle service level. And sigma d is a standard deviation of daily demand.

(Refer Slide Time: 15:42)

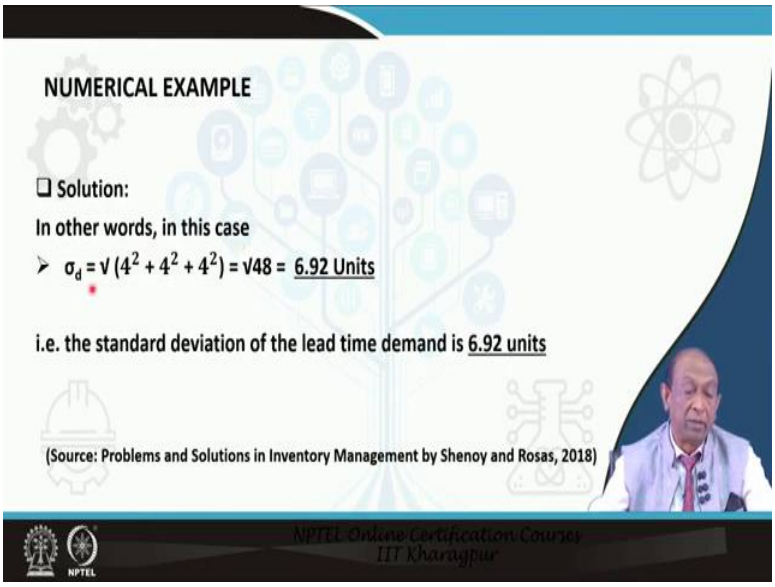


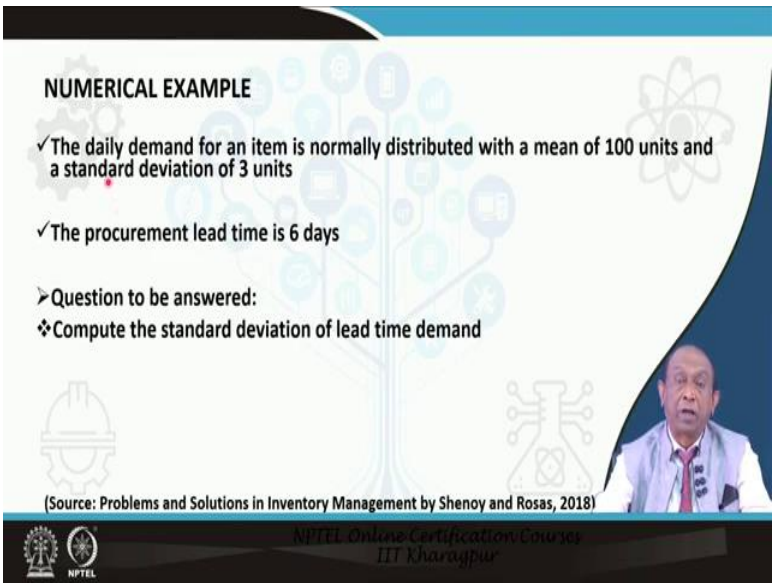


So, you need to know that the demand period which we have basically mentioned here, is the time span over which the demand has been estimated. Unit of measure for demand period and lead time must be consistent. It I am repeating because this is very important assumption and need to be satisfied is a pre-requisite.

If the units are not the same, then we may need to make some adjustments depending on demand period is less than lead time or demand period is greater than lead time. If the demand period is less than lead time. For example, consider the following example where the standard deviation of daily demand is 4 units and lead time is 3 days. Assuming the demand for each day is independent, then in that case the standard deviation of lead time demand is equal to the square root of the sum of the variances of daily demand.

(Refer Slide Time: 17:18)

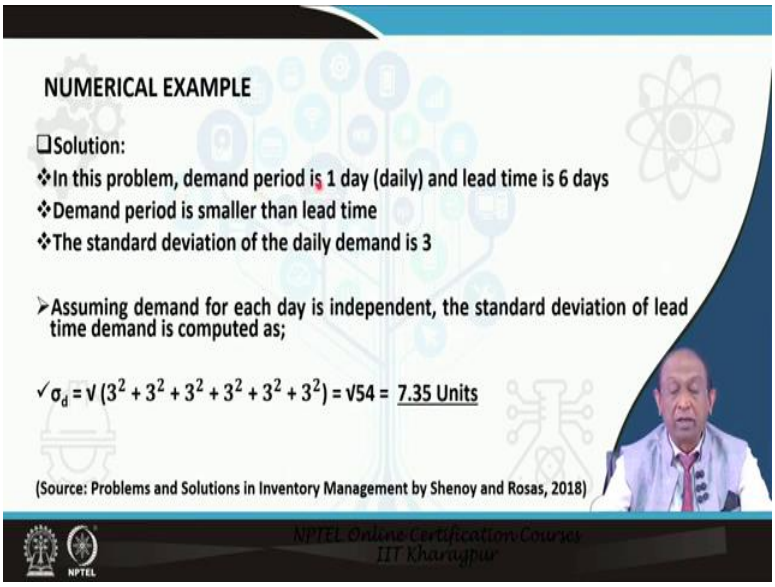




In this case, sigma d will be root over of 4 square plus 4 square plus 4 square. That is root of R of 48 that is 6.92 units, which is the standard deviation of lead time demand. Consider this numerical example that daily demand for an item is normally distributed with a mean of 100 units and a standard deviation of 3 units.

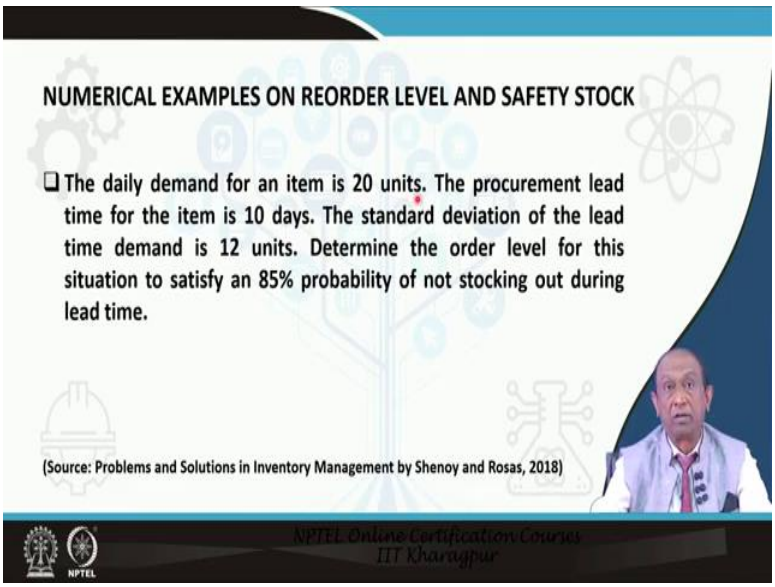
The procurement lead time is 6 days. The questions to be answered is compute the standard deviation of lead time demand. So, lead time is 6 days and we have been given, that the demand distribution particular daily demand distribution is normal with a mean of 100 units and the standard deviation of 3 units.

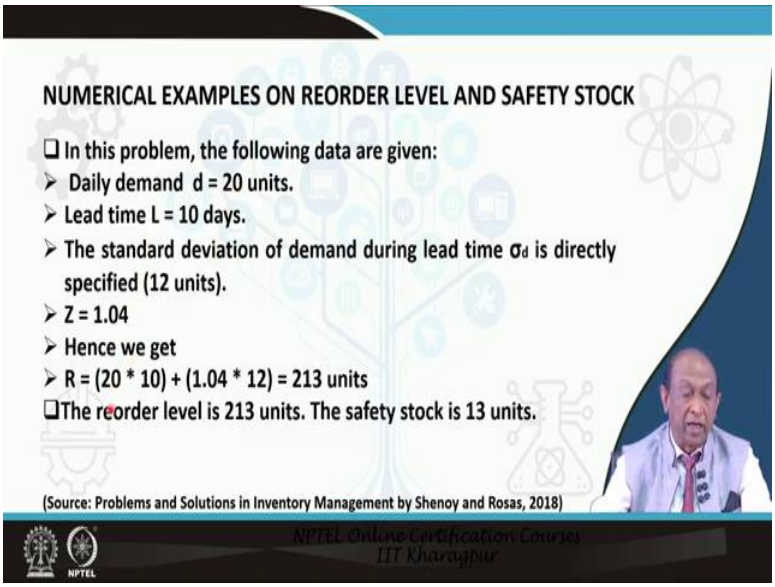
(Refer Slide Time: 18:39)

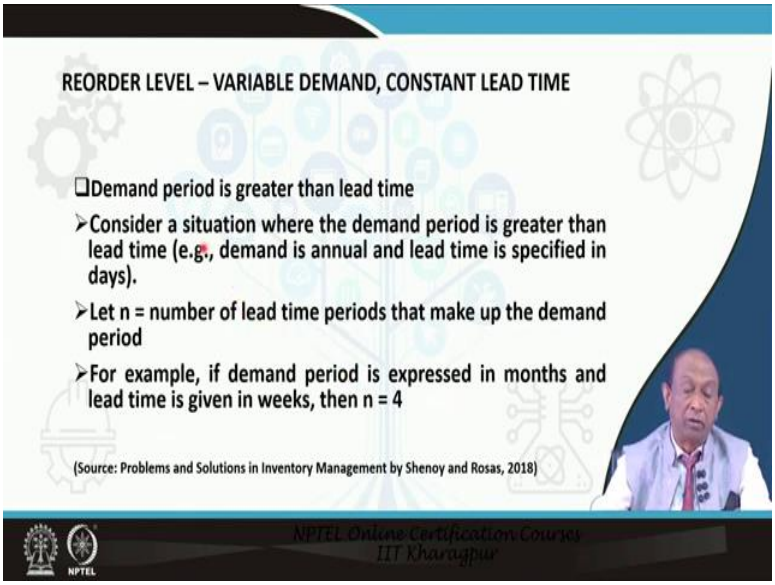


So, demand period in this case is 1 day because daily demand and lead time is 6 days. So, demand period is smaller than lead time. Hence we have to first compute the standard deviation of daily demand. The standard deviation of daily demand is given is 3. We have to compute the standard deviation of lead time demand, which is nothing but as before root of R of 3 square plus 3 square plus 3 square like this, root over of 54 that is 7.35 units.

(Refer Slide Time: 19:25)



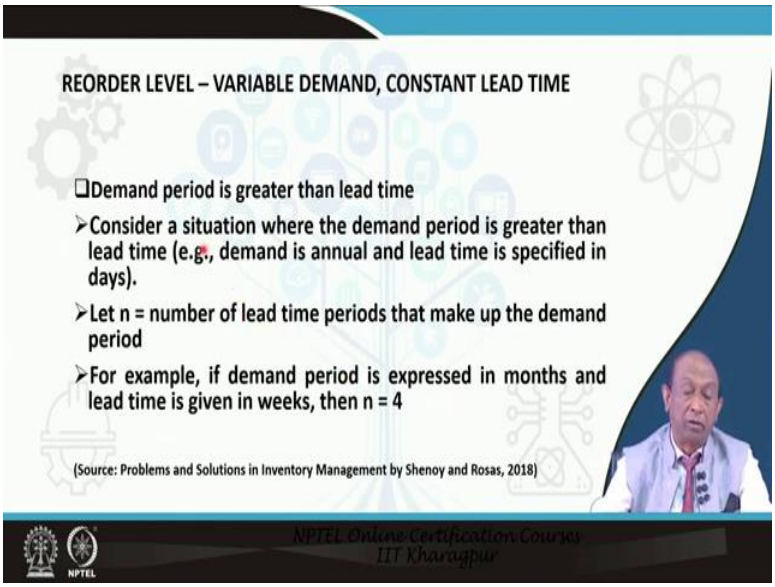




Look at this example, the daily demand for an item if 20 units. The procurement lead time for the item is 10 days. The standard deviation of the lead time demand is 12 units. Determine the order level for this situation to satisfy an 85 percent probability of not stocking out during lead time.

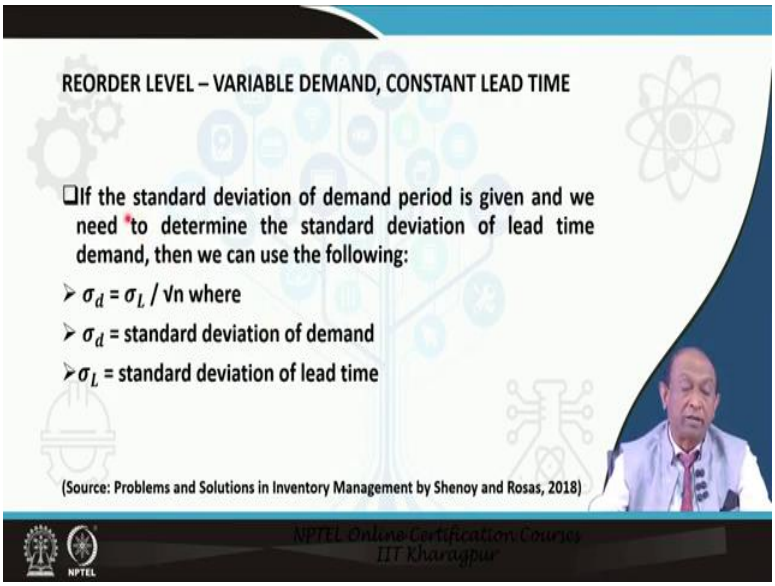
So, here you see is a very straight forward problem. Because the standard deviation of lead time demand is given and hence the reorder level is nothing but daily demand d bar. 20 into lead time which is 10 plus corresponding to 85 percent service level the value of Z is 1.04. That you will get it from a normal distribution, standard normal distribution table that multiplied by 12 which is the standard deviation of demand during lead time is given. So, multiply you will get 213 units, so here the reorder level is 213 units. Therefore, the safety stock in this case is only 1.04 multiplied by 12, which is 13 units.

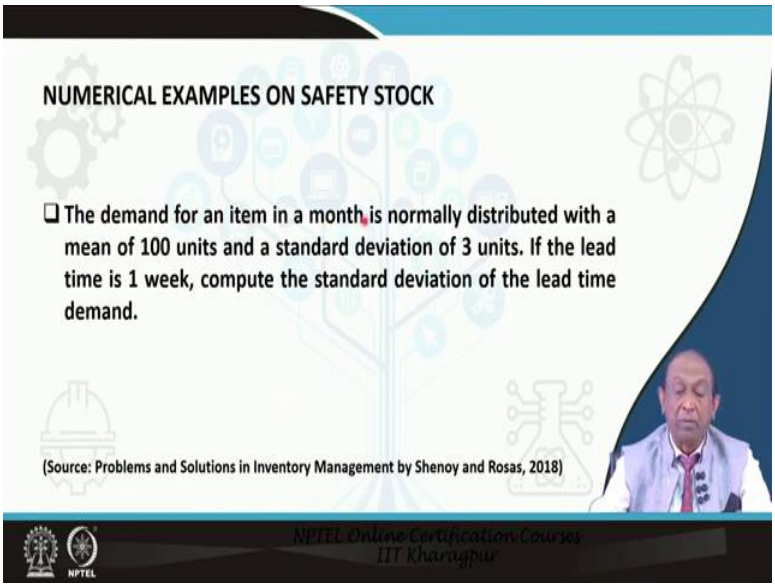
(Refer Slide Time: 21:00)

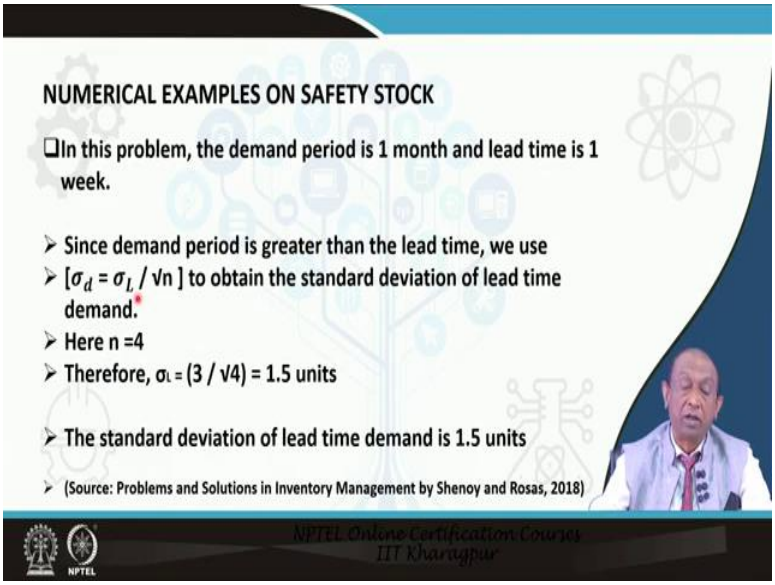


Now, let us discuss the case where the demand period is greater than lead time. Consider a situation where the demand period or in some problem it may be given that only. Where the demand period is greater than the lead time. For example, annual demand is given and lead time is specified in days less than of course 365. In that case, let n be the number of lead time periods that make up the demand period. For example, if demand period is expressed in months and lead time is given in weeks, then n equals 4.

(Refer Slide Time: 21:57)



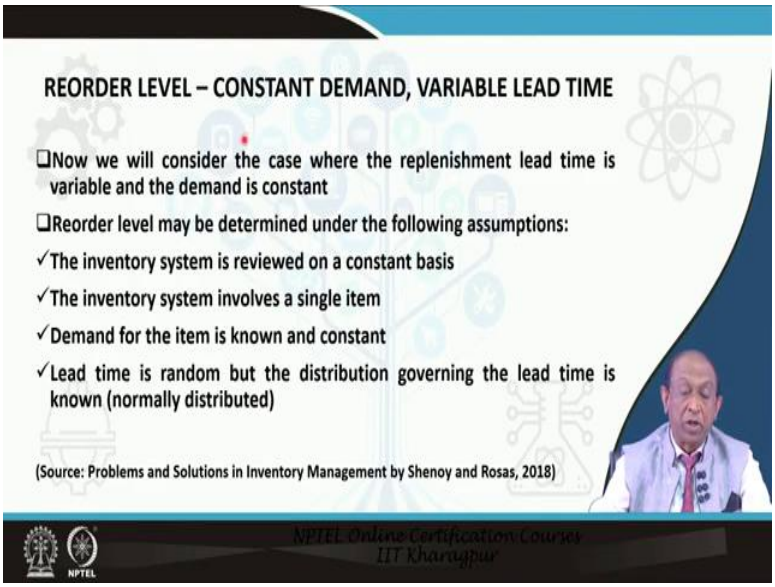


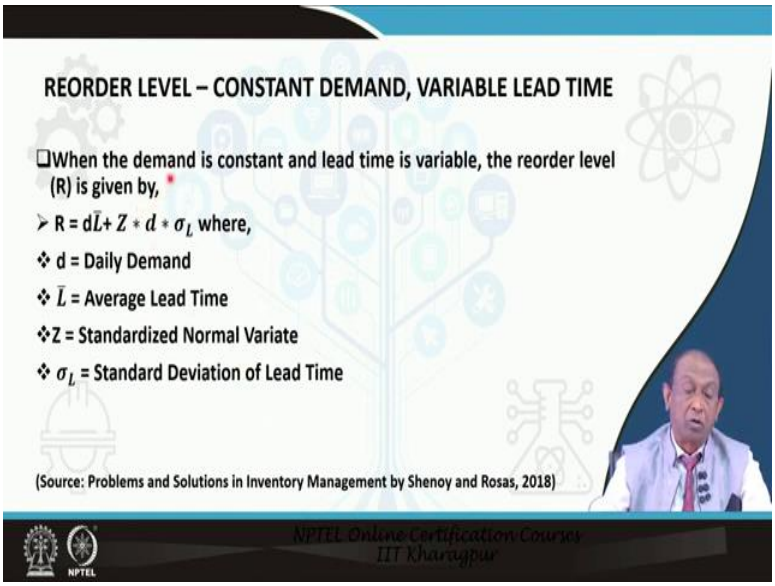


So, under such a situation if the standard deviation of demand period is given and we need to determine the standard deviation of lead time demand, then will use the following expression. Sigma d equal sigma L by root n where, sigma d is the standard deviation and sigma L is the standard deviation of lead time. Look at this example, the demand for an item in a month is normally distributed with a mean of 100 units and a standard deviation of 3 units.

So, monthly demand distribution is given. If the lead time is 1 week, compute the standard deviation of the lead time demand. Very simple will use this formula sigma d equals sigma L by root n, n equals 4. So, sigma L 3 by root 4 equal to 1.5 units, so the standard deviation of lead time demand is 1.5 units. Here, I have denoted this one, demand standard deviation of demand during lead time by sigma L.

(Refer Slide Time: 23:21)

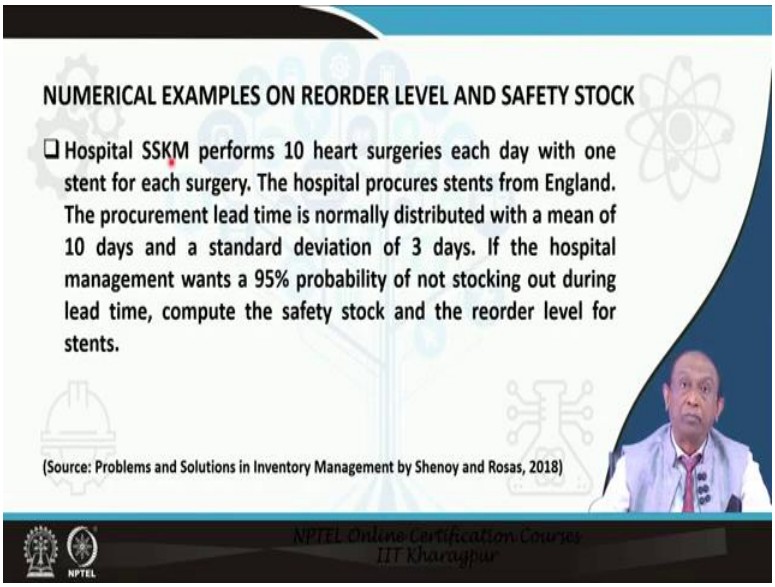


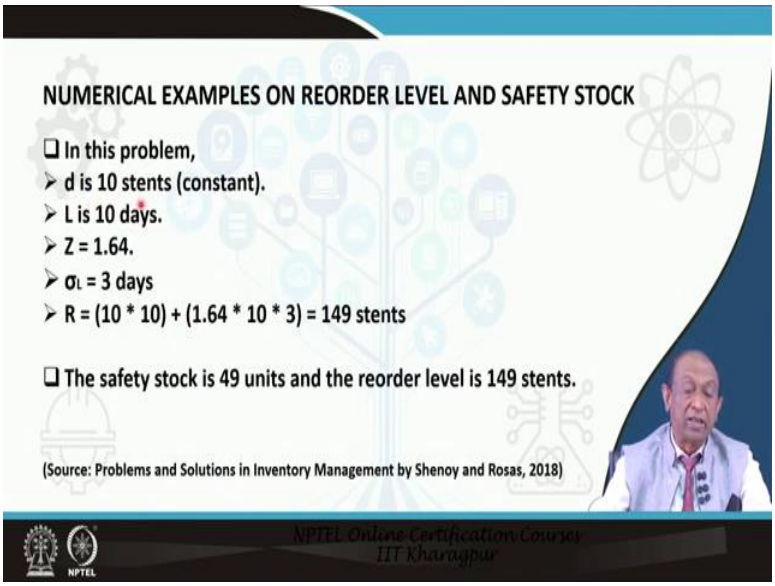


Now, will discuss a situation where the demand is constant but variable lead time. Lead time is variable. So, here also reorder level may be determined under the following assumptions that the inventory system is reviewed on a constant basis. The inventory system involves a single item. Demand for item is known and constant. Lead time is random but the distribution governing the lead time is known which is normally distributed.

So, in this case when the demand is constant and lead time is variable, the reorder level is given by d into L bar plus Z into constant demand d multiplied by sigma L. Where, sigma L is the standard deviation of lead time Z is standardized normal variate depending on the service level, we have to find the value of Z. L is the average lead time, d is the daily demand.

(Refer Slide Time: 24:40)





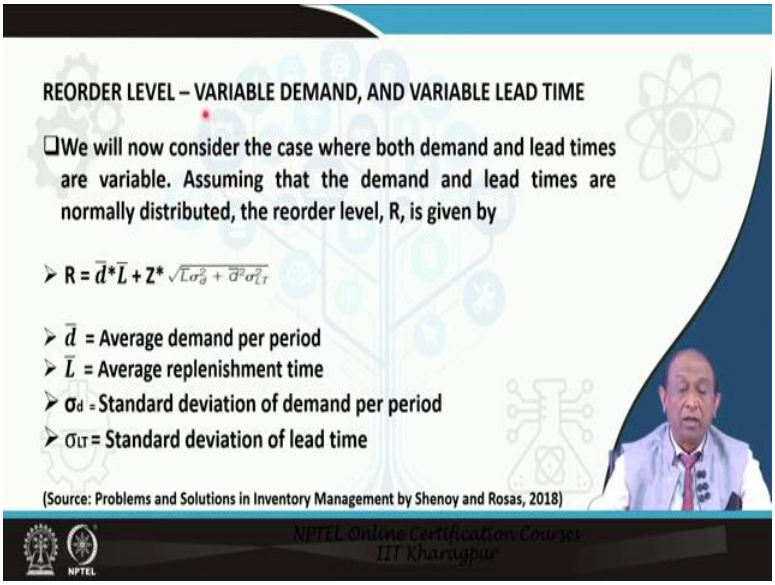
So, let us look at this example, hospital SSKM performs 10 heart surgeries each day with one stent for each surgery. The hospital procures stents from England. The procurement lead time is normally distributed with a mean of 10 days and a standard deviation of 3 days. If the hospital management wants a 95 percent probability of not stocking out during the lead time.

Compute the safety stock and the reorder level for stents. So, you see this problem demand d is 10 stents which is constant, demand is constant. Lead time mean is 10 days, Z is 1.64 depending on this 94, 95 percent service level. Sigma L is given in this problem as 3 days because lead time is variable, demand is constant.

The reorder level can be found out using the formula that I have discussed before d bar into L bar plus Z into sigma L into d which is 149 stents. So, the safety stock this portion if you

compute 1.64 into 10 into 3 works out to be 149. So, safety stock is 49 units and the reorder level is 149 stents.

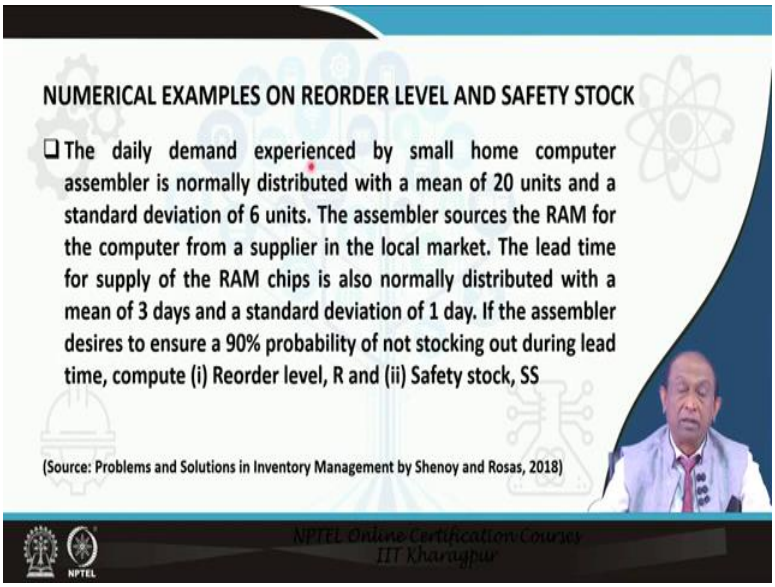
(Refer Slide Time: 26:22)



And the last case where both the demand is variable and the lead time is variable. In that case the reorder level R, is given by this expression, d bar into L bar plus Z multiplied by root over of L bar into sigma d square plus d bar square into sigma LT square. Where, sigma d is standard deviation of demand per period.

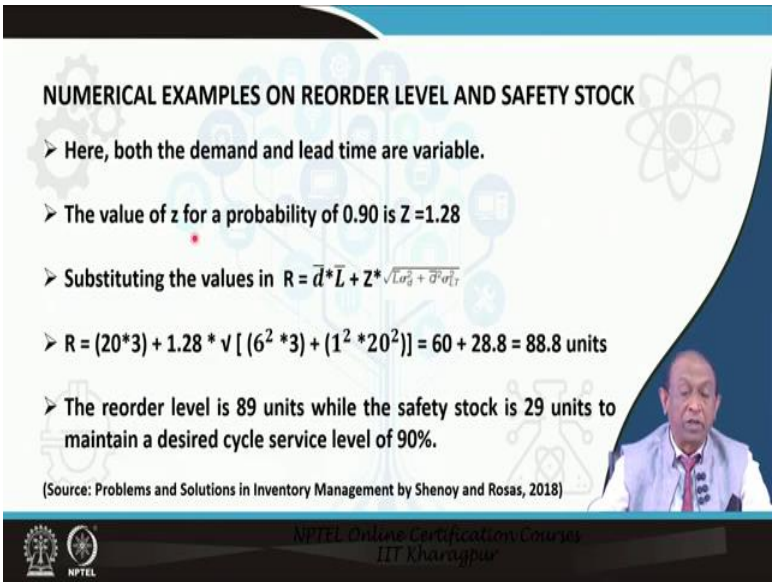
So, this is in quantity sigma LT is expressed in terms of days so in order to convert it to quantity, we multiplied by d bar. We add these two variances and take the square root of that to get the resultant variance and this is the formula over through which will determine R.

(Refer Slide Time: 27:19)



Look at this example the daily demand experienced by small home computer assembler is normally distributed with a mean of 20 units and the standard deviation of 6 units. The assembler sources the RAM for the computer from a supplier in the local market. The lead time for supply of RAM chips is also normally distributed with a mean of 3 days and a standard deviation of 1 day. If the assembler desires to ensure a 90 percent probability of not stocking out during lead time, compute reorder level R and safety stock.

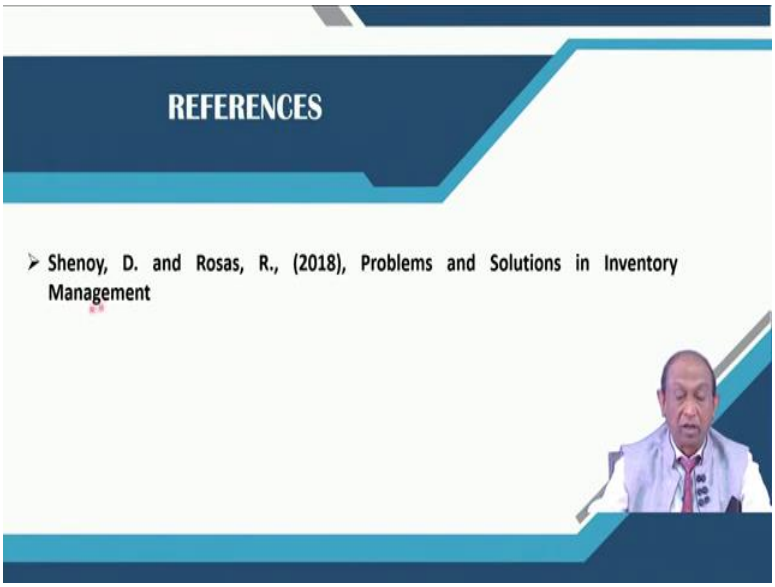
(Refer Slide Time: 28:10)



So, in this problem both demand and lead time is variable. The value of z for a probability of 0.90 is 1.28. We substitute that required values in the expression for R and we get R equals, 20 into 3 plus Z value of 1.28 multiplied by square root of this expression. L bar which is 3

into sigma d square 6 square plus d bar into sigma LT square. And we get R as 88.8 units, which can be rounded off to 89 units. So, the reorder level is 89 units while the safety stock is 29 units to maintain a desired cycle service level of 90 percent.

(Refer Slide Time: 29:25)



The reference or the source for all these problems and solutions is given in this book. Problems and Solutions in Inventory Management by Shenoy and Rosas, 2018. This is the reference given and thank you for your pleasant listening. Thanks.