Modeling & Simulation of Discrete Event Systems
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Lecture - 38
Inventory Control Simulation using Monte-Carlo Technique

Welcome to the lecture on inventory control simulation using Monte-Carlo technique. So, in the last lecture, we saw that in Monte-Carlo normally we have ones the frequency distribution we find the cumulative frequency distribution based on that random numbers assigned for the particular value of the variable which has to be taken during the iteration. So, we will solve for one inventory control problem how in that we can find the point where the reordering is to be done, what is the demand on a particular day, when the ordering has to be done. And ultimately what is the stock in hand because of the ordering and ultimately you have to find the total cost because you will have some cost for holding the material, there may be shortage sometimes, so there will be shortage costs. So, this we will see that how we can model through this technique.

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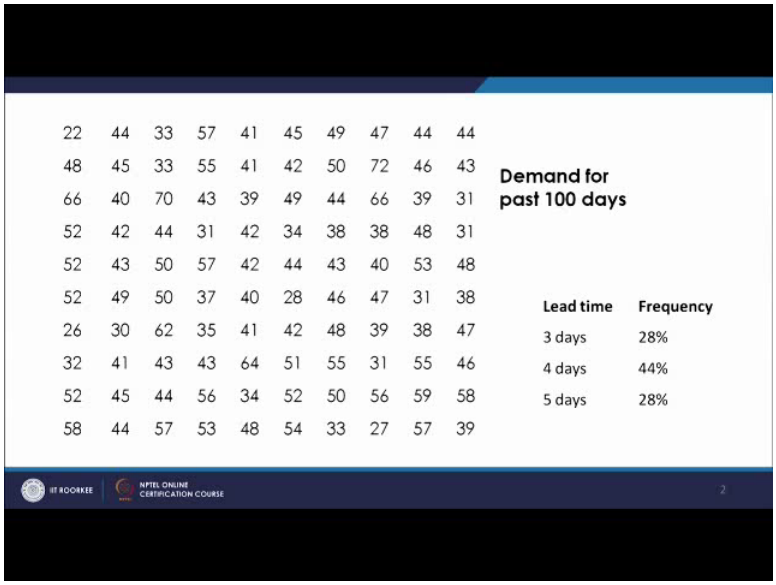

To suppose you have certain demand is given for the past hundred days and you have to basically see that how you can further find that what will be the demand in the coming days and then there is another data which is given that is lead time data. So, in that it is told that you have the frequency of lead time having three days is seen to be 28 percent.

So, 28 times out of 100 times in 3 days the ordered quantity has arrived. Similarly, on 44 occasions it has come on 4 days; on 28 occasions it has come on 5 days so like that. So, these are basically the frequencies which are available to you they may not be, but you can have a standard frequency distribution data also. And if this data from the past is given to you then you can have these frequency distribution map to find the random number. I mean the random number which will be for a particular lead time like there will be some range of random numbers, which will be right for 3 days, some will be right for 4 days some may be right for 4 days. So, like that you will have the stream of this range of random numbers.

Now, in this problem you have been given another you know quantity. So, you have as we know that in the case of inventory control, you will have to see that when you have to order you have many systems like fixed quantity system fixed period system, so that way there are many ways, so that you can study through the books on inventory control.

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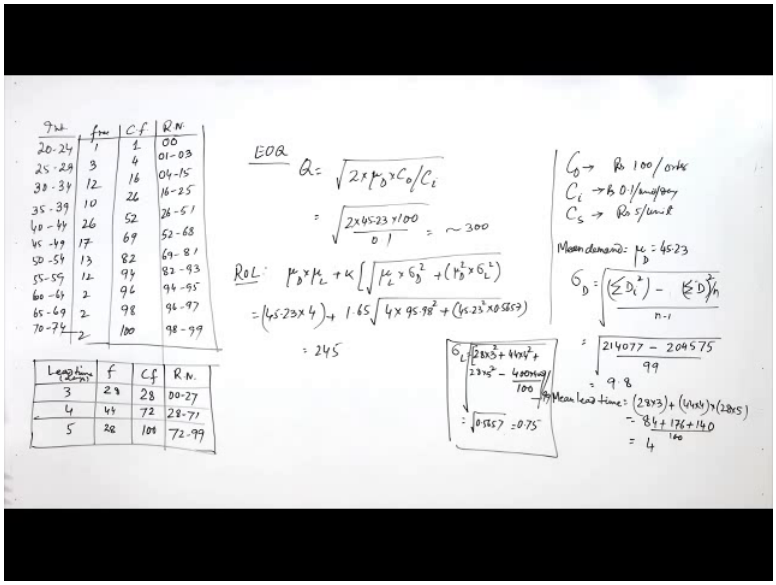

Now, what has been given is that you have some cost of placing the order. So, suppose the cost of placing order is given so that is C o that is cost of placing order and that is given suppose as rupees 100 per order. Similarly, you have the cost of holding size stock, so that is cost holding item, so that is C i and it is also given some value say 0.1 per unit per day then you have also as cost of shortage is also given like you have rupees 5 per unit. So, these are the data which are required in case of the inventory control inventory

calculation because whenever you have shortage you will have to bring it from local market at higher price. So, you have to have the cost of shortage at a higher rate that is given.

Now depending upon the data what you see is that you will have to find the random numbers assigned, but before that we will calculate that what will be the reordered level or what will be the other quantities to be calculated. So, if we do some statistical calculations on that on this number we will if we do that will have the mean demand. So, if we do the mean demand calculation, we have to add all these demand values for the 100 days and that we get as mu d. So, this we get as 45.23. So, out of this demand values, the mean demand value comes out to be 44.2, 45.23. Similarly, you can have the standard deviation of the demand, and this standard deviation of the demand again can be calculated, so that will be summation of D i square and then it will be minus of n time summation of D prime, so that is square summation of D square. So, this will be summation of D square divided by n and then it will be divided by n minus 1. So, then it will be having the under root.

So, in this case you can have the standard deviation and is 100 here. So, if you do the calculation on these numbers the summation of the square of their demand terms that comes out to be 214077. And then if you do the summation of the demand square at divided by n, so that this is basically summation of mean so that is mean demand basically. So, this is basically summation of the mean demand. So, this will be all right this is 44523, so 4523 square and divided by again 100, so that comes out to be 204575 and then you have divided by 99 and then it is under root. So, this comes out to be something close to 9.8. So, for the demand data, you have to find the mean data as well as the standard deviation of the data. Similarly, you have to calculate the mean value of the lead time. So, mean lead time mean lead time will be as you know we have 30 percent times 28 percent time 3 days you have 44 percent time 4 days and 28 percent time 5 days.

So, you can calculate that. So, 28 into 3 plus 28 into 3 plus 44 into 4 and then you have plus 28 into 5 divided by 100, so it will be 84 plus 176 and then 140. So, 84 plus 176 will be I mean 260, no, it will be 84 plus 176 plus 140, so it will be 260 plus 144 by 100. So, it is 4. So, lead time comes out to be 4 days meanly times coming out to be 4 days. You can also find the standard deviation of the lead time. And if you find the standard

deviation of the lead time, it will be 28 into 3 square plus 44 into 4 square plus 28 into 5 square, so that will be summation of a D I square and I mean phi and this x i square and then minus of again similar formula will be used.

So, this way if you calculate it will be. So, you can do that basically you can calculate this as standard deviation of the lead time. So, it will be 28 into 3 square plus 44 into 4 square plus 28 into 5 square and then mean square mean value was actually that was 400 and then that divided by. So, 400 square and divided by 100 and then that will be divided by basically 99. So, once this value comes this value will be divided by 99 and its under root will be taken. So, this value if you calculate it will be coming out to be under root of 0.5657 and that is coming out to be 0.75. So, this calculation you can do from the available data.

Now, the thing is that after calculating this data, you have to find the histogram. So, you have to find the histogram of these demand and the demand is seen that you can have this demand ranging from may be 20 onwards. So, you will have to find the histogram of the demand and if you find the histogram of the demand you will have these categories. So, you will have demand as 20 to 24, 25 to 29, then 30 to 34, 35 to 39 and then 40 to 44, 45 to 49, 50 to 54, 55 to 59, then 60 to 64, 65 to 69 and then 70 to 74. So, these were you have maximum of 74 values up to 74 values you have in this maximum. And then that way because when you have to take the values, you can take the mean of this that is in that case you can take 22 as the demand. So, when you have to predict the demand, you can have it as 22, if you comes in that interval.

So, making the histogram, if you have the this is the interval for the demand and once you have the frequency if you this look at the frequency of this the frequencies calculated to be 1, 3, 12, and then 10, 26, 17, and further you have 13, 12 and then further 2, 2, and 2. So, if you add them 4 plus 12 – 16, 26, 52, 69, 82, 94, and then 6 it is 100. So, it is all 100 working I mean days demand. So, then again as we had discussed that we will find the cumulative frequency. So, cumulative frequency will be like this 1, 4, 16, 26, 52, 69, 82, then 94 96, 98 and 100. Now, this number can further be now you have to assign the random numbers for this simulation.

So, as we know if we generate the two digit numbers you can generate the two digit number from 00 to 99; you can generate four digit number, I mean three digit number

from 000 to 999; you can generate four digit numbers it all depends how much of accuracy you want to do. So, if you assign the random numbers, so as we discussed, so it will have the first random number it will be 00. So, this random number will be, so if is the random number comes zero ever, it will be taking that demand to be 22 in that case. Similarly, from 01 onwards 01 to 03, you will have this is the random number for the demand of 27, then that way you can have all these numbers 04 to 15, then 16 to 25, 26 to 51, 52 to 68, then you have 69 to 81, 82 to 93, 94 to 95, 96 to 97, 98 to 99. So, this way you have assigned the random numbers for this particular demand values. So, whenever you will have the random number coming as this value then you will have the demand of accordingly you have to raise this demand suppose it comes 65, so you have to raise in that at that particular time a demand of 47 units.

So, similarly you can have the calculation of random number assigning the random numbers even for the lead time. So, as we see in the lead time you have 3, 4 and 5 days. So, if you look at the lead time calculation, so for the lead time you have three values 3, 4, and 5. So, days in the 3, 4 and 5, so its frequency is given as 28, 44 and 28. So, then its cumulative frequency will come out to be 28, then you have 72, and then it is 100. So, you will have the random number from 00 to 27, and then you will have 28 to 71, and 72 to 99. So, if you at you are generated to digit number between 0 to 100, in that case you will have, so before 100 up to 99, so you will have these values. So, if number comes like 83, then at that time if the order is done the lead time will be 5 days. So, this is how you calculate these values.

Then you have to see that what will be the economic order quantity. So, once you have calculated this values, you can have the order quantity. So, you have the order quantity economic order quantity you can order and because this is we think that we are ordering a fixed quantity. So, we are ordering that, so that quantity you are calculating Q as, so you have the standard formula you can use it will be under root 2 into mu D C naught and divided by C i. So, you can refer this may be you can take another parameters also into account, but we have not taken that.

So, if you see that you put this is in the formulas you have got the mean as 45.23 you have c naught given as 100 rupees per order and then it is divided by 0.1. So, that is coming out to be closed to 300. So, we are taking the ordering quantity as 300, so that time whenever the stock quantity will reach below certain limit then we have to order

this quantity because we are going for fixed quantity system. Now, how to determine that quantity went to order, so that is known has reorder level. So, for the reordered level, you have certain formula reorder level. For reorder level the formulas is given is mu D into mu l plus k into under root mu L into sigma D square plus mu D square into sigma L square. So, this is the formula which is used for calculating the reorder level.

So, when the stock quantity will come to this, the day it will come below that then you have to order. So, again putting the values into this, so you have the now this value k this k is basically the value it is how many times the standard deviation value you are for being safe you are putting this value of k. So, this k will tell because the value of k, this quantity which is inside this square root that is basically the radiance of the demand during the lead time. And it tells that it tells you about the probability that what is the probability will be there dependence like we take 1.65 then it will tell that only 5 percent is the chance that there will be shortage of the stock. So, you can have this one point, so it will be standard deviation times that, so that is why if we take it 1.65 it will be you are 95 percent sure that there will not be any shortage. It has also value of about one point even 2.33, when there is 1 percent chance that there will be shortage.

So, in this case we take 1.65 assuming that there is only 5 percent chance that there will be shortage. So, we take this values again mu D is 45.23, mu L is 5, so that will be there plus again we can take 1.65, because we assume that we assume that 95 percent probability we are assuming that there will not be any shortage. And then putting all these values mu L is again 4 and sigma D square that is 95.98 square and then plus again 45.23 square into 0.5657. So, once we compute that we get the value of 245, this will be larger. If we take if we try to be 99, percent sure that there will not be any shortage in those cases you have to go for the larger value more than 2. So, in that case it become quite when considerably larger. So, what we see that you have the order quantity of 300 and you have the reorder level of 245.

Now we have to start basically the simulation. So, how to start this simulation and you have got all these values you need these for the calculations. So, how to do the rest simulation as the time progresses.

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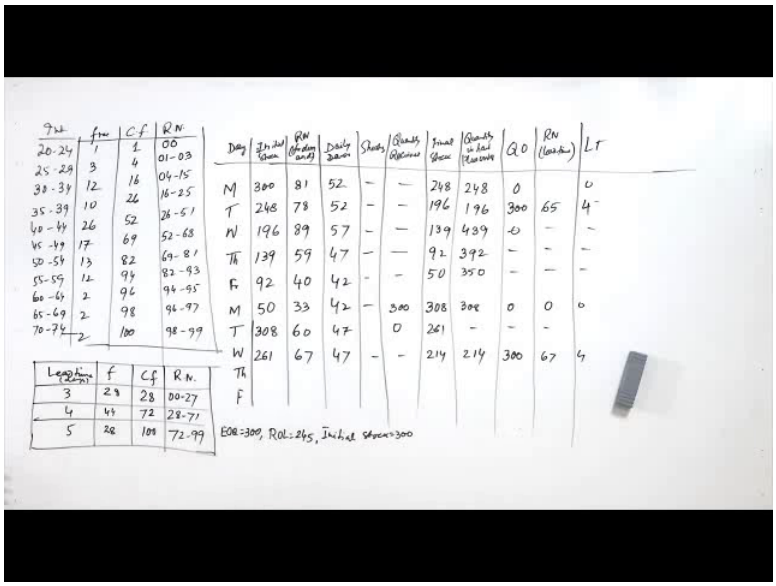

Now, since we have computed that you have the economic order quantity as 300 and reorder level is you know it is coming as 245. Now, will start the simulation we assume that the initial stock is 300. So, we have 300 in our stock and on the Friday evening - suppose of any month, now on the Friday evening it was 300. So, we will start the simulation from Monday onwards. So, we will start from the day. So, first will be day. So, the day will be like we will have Monday, Tuesday, Wednesday, Thursday and Friday. So, for the day, it will be Monday, Tuesday, Wednesday, Thursday and Friday; again Monday, Tuesday, Wednesday, Thursday and Friday. So, this way your simulation will go move.

Now, in that first of all you have to write the initial stock. So, you have whatever initial stock you have on Monday you assume that you have initial stock of 300, then you have the random number for the demand. So, as we see we have to see that from this table. So, the random number can be generated as we know that if you put in the excel 100 into rand function, so that will generate the random number from 1 to 100. Or you can generate using linear conversion generator where you can have the formula A x I minus 1 plus C and mod do it with 100. So, anyway any random number which you will get that will be less than 100. So, this way you can generate the random number up to 100.

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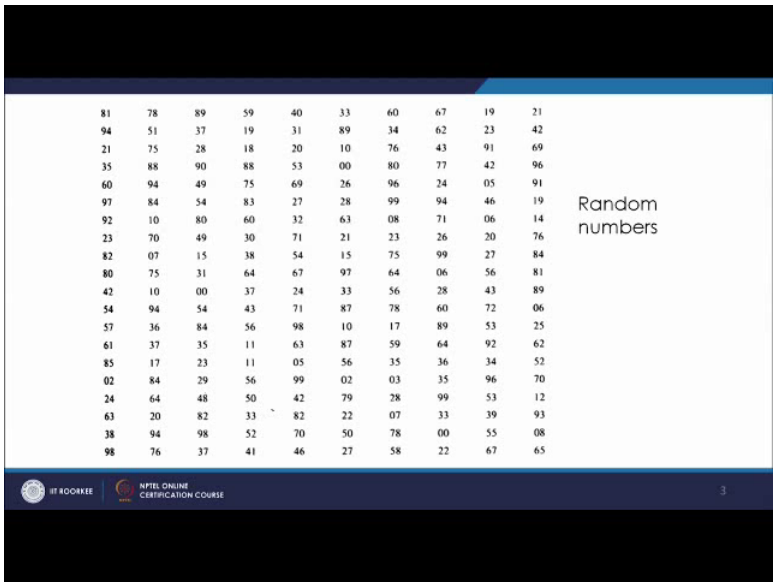

So, suppose this is the random number which is to be used, so we have to use the first random number 81, then 78, 89, 59 like that. So, the random number is coming out to be 81. Then next is the demand daily demand. So, from 81 now this is the random number for the demand we assume that in this case we are taking the random number for demand from the north and west corner. So, from this side 81 and 78 onwards; and for the lead time we will take it from the opposite diagonally opposite corner that is from 65 onwards 65, 67, 22, 58 like that. So, this way we will go for the lead time random number.

Now for the daily demand if you look at the 81 and if you see 81 comes here. So, the demand is between 50 and 54 that is the average value will be 52. So, your daily demand comes out to be 52. Now, we may have one table for shortage. So, anyway there is no shortage so far then you have the demand for quantity received because once we order then you will get after certain time you will get, so that will be quantity received. Further you have this final stock, so that is initial stock and then final stocks, so once you receive something you will have some final stock. There another table is quantity in hand plus order quantity in hand plus order, so that is whenever you order that time in hand you have how much and plus how much you have ordered that is another parameter which is calculated. Then quantity ordered will be the one, which will depend upon when you order when you order what is the random number. So, for that there will be random number for lead time.

So, note I mean lead time will vary because of that quantity ordered will be basically that is anyway that you are fixing that is 300 and lead time. So, this lead time will depend upon the random number. So, you will have lead time. So, what you see is you have shortage is there is no shortage, there is no quantity received. So, final stock will be 300 minus 52, so it will be 248. So, in hand plus order, you have 248. Now, whether you have ordered, so your reorder level is 245. So, since you have not gone below 245, you are not going to order it. So, you are going with 0 and 0, here lead time also there is nothing, so nothing, you do not have any random number assigned at this point whenever you require to order that time lead time will come into picture. So, your initial stock now comes out to be 248.

So, you look at the table again, the next random number is 78. So, this is 78. Now, this 78 again comes in which range. So, 78 again comes into this range only. So, there will be again 52 minus. So, shortage is not there no received. So, it will be 248 minus 52, so it will be 196. Now, you have not ordered today you are going to order. So, you have 196, but since it has reached below the reorder level. So, you are going to order today, so you are going to order 300. Now, since you are going to order, now it will take how much of lead time. So, this lead time will be depending upon the first random number which is there and for that in this as we discussed that for the lead time we are going to take this random. So, we are lead time we are going to move in this fashion; otherwise you may have several stream of the lead time. So, if you take that, so the first number is 65. Now, for the 65 the lead time you can see, so this 65 will come here; and for that we will see that where the 65 lies. So, in the case of lead time, 65 lies in this interval 4 days. So, 4 day will comes so on the fourth day, so you have Wednesday Thursday and Friday you will reach you will get the item of 300. So, this way you are going to get. So, you have 4 days basically, you we will get fourth day Wednesday Thursday Friday and then Monday. So, on the fourth day, after that you will get this item.

So, before that we will go on doing the simulation. So, now you have 196 remaining; next number is again you have to see from the table that is 89. So, for 89 you have again the number you can see here it is, so it will be 57. So, it will be 57. So, the shortage is still not there received not there. So, now 196 minus 57, it will be 139. And since you have the ordered already it is order is gone, so it will be 199 plus 300, so it will be 439 ordered. Now, we have not ordered anything, so it is nothing there and there is nothing.

So, here it will not be there. Then you are coming again back. So, this what we saw as is 300 this 300 is going to come received. So, this 300 ordered will come here on this date when it has to be received. So, here it will come 300. Before that the simulation has to move. So, we have 139 remaining.

Next random number comes out to be now 59. So, 59 for 59 the daily demand will be again looking being looked at here, so that will be 47. And it will be 139 minus 47, so it will be 92 no storage no shortage and no quantity received, and 92 will be there. And from this 92, you will have the 392 as the quantity in hand plus order, there is nothing for this. Further you come here as 92, this 92 from here the next random number is 40. So, this 40 comes. Again 40 the daily demand is 42. So, this will come as 50 remaining and we will have 350, again nothing in between.

So, again you will have 50 remaining and next random number is 33. So, we are reaching now on the date next week of Monday, and on this Monday, you have 50 stocks luckily you are having the random number as smaller one. So, on 33 you are having requirement of 42. So, you have now you have only 8 remaining. So, there is no shortage anyway you are receiving the 300 items anyway. So, your item becomes 308. So, today you have 308 remaining and then your things move like that it is going like this. Now, again you have start from 308, next will be next number after this 433 is 60. So, again 60 will be there, then 60 for that you will have 47 then you will have 308 minus 47, so it will be 261, so that will be moving like this. So, you will have nothing final stock, this is the no quantity received is not there you have this is 0, but this is 261 and nothing order here no quantity order like that.

So, again if you go if you go to next 261 has come. So, what will happen the next you have 261. And next number from the random number stream is basically 60. After 60 you have 67. So, after 67, it is 67, now 67 is coming in this, so you have 47. So, again in 47, 261 minus 47, so 214 will be the final stock. So, 241 once it has come now this is your in hand plus order, but now you have to order at this point because it has reached below this reordered level of 245, so you have to further order and the next number random number is from the bottom side.

If you look at this is 67, so again 67 comes into this range. So, it will take another four days. So, it will be 67 and this will be another four days. So, this quantity will further be

received. So, Thursday, Friday, and then Monday and Tuesday. So, on the next Tuesday this 300 quantity will come. So, this way you can do this simulation and carry on and then finally, you can have the calculation of the parameters which you need to calculate that you can find it. And this is how the Monte-Carlo simulation is carried out. So, whatever you have to find suppose the average you know stock which is there in the because on the basis of that you know you have different type of cost associated because you have to have to in the handling cost how much you are keeping, so all these cost will be that way calculated.

So, in that case you have suppose you have to find the you know cost of holding the inventories, so the cost of holding the inventory per unit and then you can multiply it with the final stock altogether. So, you can do the simulation for a month and then this total value can be multiplied with that, so that will tell you cost of holding the inventory. Similarly, cost of ordering, so how many times you have ordered. So, one the number of times you have ordered multiplied by cost of doing an order. So, this way you can find and you can do the simulation. So, this is how the inventory simulation is carried out. Hope you have done it, you can carry on and you can find the results.

Thank you very much, done.