Introduction to Accounting and Finance for Civil Engineers

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Lecture-20
Simulation (Part-1)

Good morning namaskar and welcome to the course once again. In the last few lectures we discussed about various concepts involved in risk analysis, we have studied few key term such as additive probability, multiplicative probability, expected values and measures of variance. in this lecture we are going to start with a new topic that is known as simulation, will find simulation as such as lot of application in the context of civil engineering even in the case of economic decision making you will find it has what number of applications.

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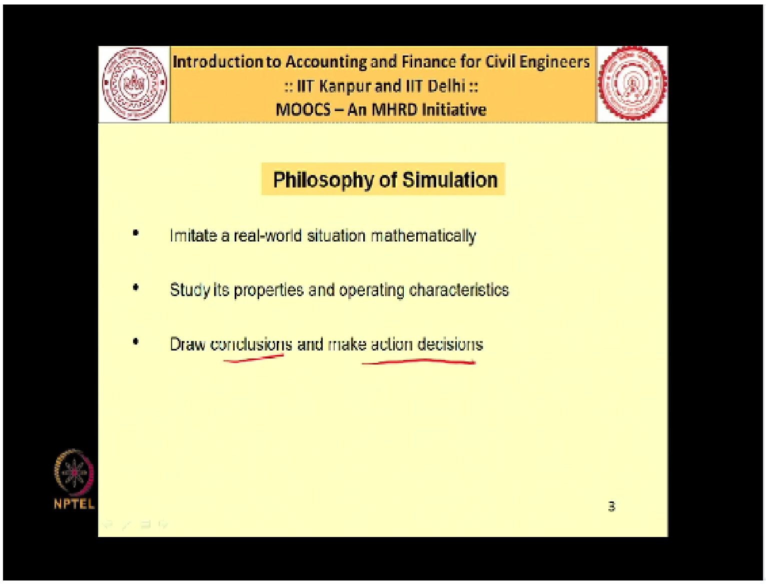

So straightaway we move to the philosophy of simulation, will try to understand what are the advantages associated with simulation, what are the drawbacks or limitations of simulation and we will illustrate you the concepts of simulation with the help of few small examples. Now if you see as far as simulation is concerned it basically imitates a real word situation in terms of mathematics, studies its various properties and the operating characteristics.

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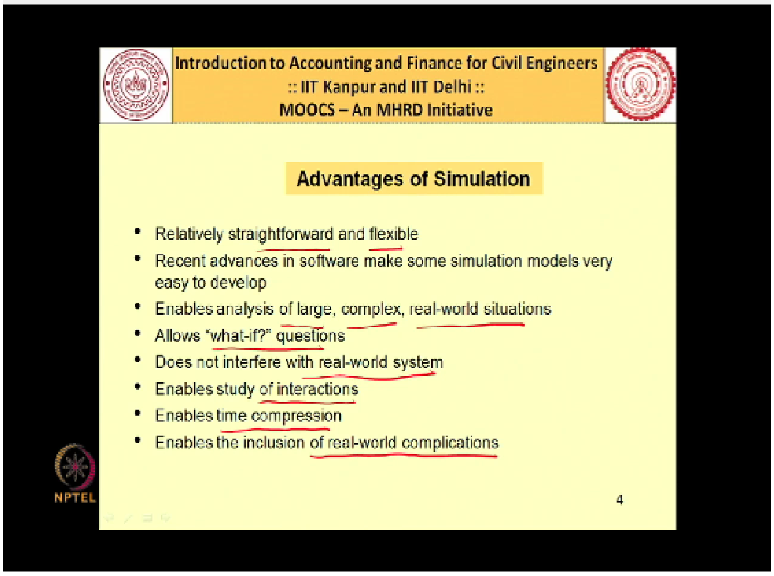

Then subsequently you can draw conclusions and make action decision, now coming to the advantages of simulation you will find that it is very straightforward and flexible. So these are the 2 keywords straightforward and flexible. Now some of the recent advances that have taken place in the context of simulation software it has made the simulation models or other modelling very easy to develop.

You can carry out the analysis of even large very complex and real-world situation, you can answer what if questions using simulation, you will see in our examples further it does not interfere with the real-world system, you can study the interactions among variables associated with your simulation problem, you can carry out the time compression exercise, you can also include the real-world complications as you will see subsequently.

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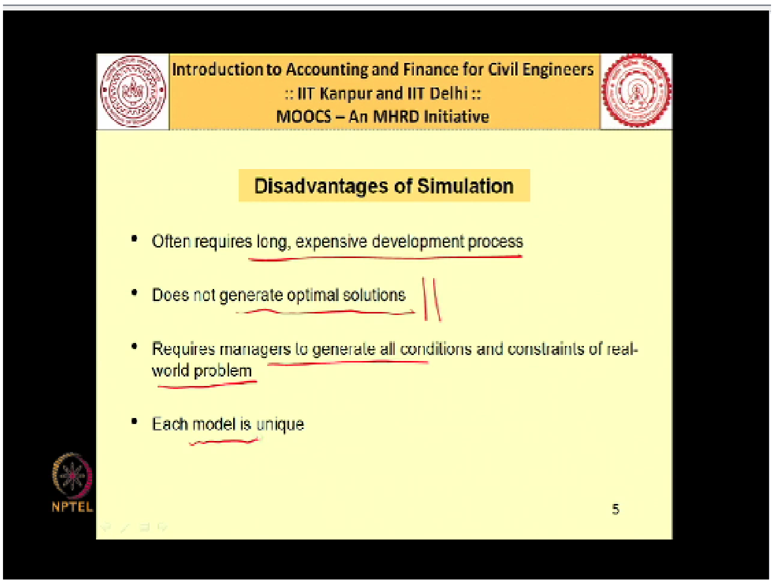

However you will also notice that simulation also has certain disadvantages for example you will require long and expensive development process especially for the complicated problems, one of the major drawbacks of simulation is that it does not guarantee you an optimal solution. So whatever solution that you obtain using simulation they may not be optimal. Now the simulation requires managers to generate all conditions and constraints of real-world problem.

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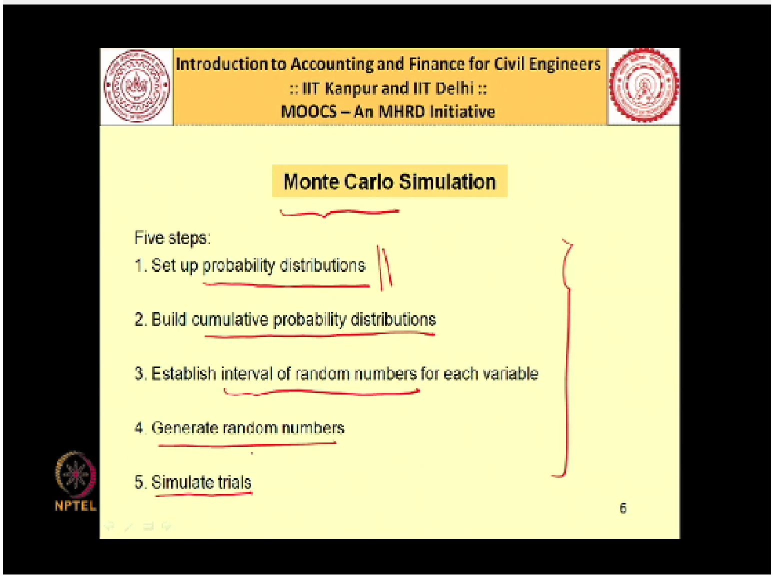

And another disadvantage you will find that every simulation model is unique in nature. So these are some of the disadvantages of simulation. Now there are different types of simulation, Monte Carlo simulation is one very widely used simulation methods available to us. We can carry out Monte Carlo simulation for solving our problem using these 5 steps. So step 1 what we do it probability distribution.

How do we do this is by virtue of collecting a large set of data from our past experience and from our past knowledge, subsequently I built cumulative probability distribution, we will see how it is done, then we establish an interval of random numbers, will see what random number means we generate random numbers and then we simulate trials, after doing all these 5 steps you can carry out similar analysis for some other conditions.

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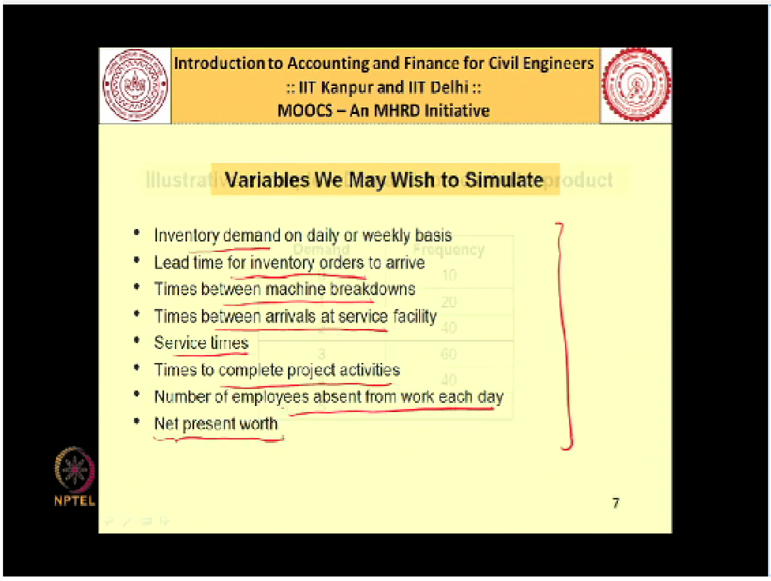

And depending on the answers that you get you can choose a particular strategy for your problem. Now we try to illustrate you these particular steps for a number of problems but before that you may like to know what are the type of problems you can try to solve using simulation, you can carry out the inventory analysis it could be on a daily basis or it could be on a weekly basis, you can find out the lead time for inventory orders to arrive.

You can find out the times between various machine breakdowns, you can find out the time between the arrivals at service facility, you can even calculate the service times, the time to complete project activities that means you can find this application in your CPA import analysis, you can even find the number of employees likely to be absent from work each day or each week.

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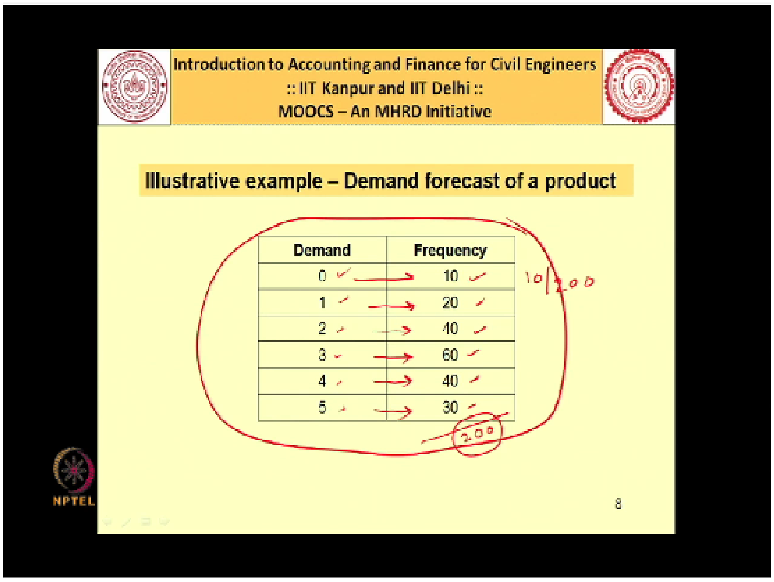

And in our case will also try to understand its application in the computation of net present worth. So to start with we will carry out the demand forecast of a particular product, let us say we are into manufacturing some product and the demand of that particular product where is on a daily basis. So what have done from my past record I have captured this data. I find that on 10 occasions I did not have any demand.

So that means demand is 0, occasion for 1 unit 140 occasion I have a demand of 2 units on 60 occasions I have a demand of 3 units on 40 occasions have a demand of 4 units and on 30 occasions I have a demand of 5 units. So you can see I have a record of 30+40 70, 130, 170, 190 and then 200. So I have the record of past 200 days and from this record I know what is the demand profile.

So you can see demand that on 10 occasions the demand was 0, on 20 occasions demand was 1, on 40 occasions demand was 2, on 60 occasions demand was 3, on 40 occasions demand was 4, and on 30 occasions demand was 5. So what I do is from this frequency value I can calculate the probability. So we can find the probability for 0 demand would be 10/200, likewise probability for 1 demand would be 2/200.

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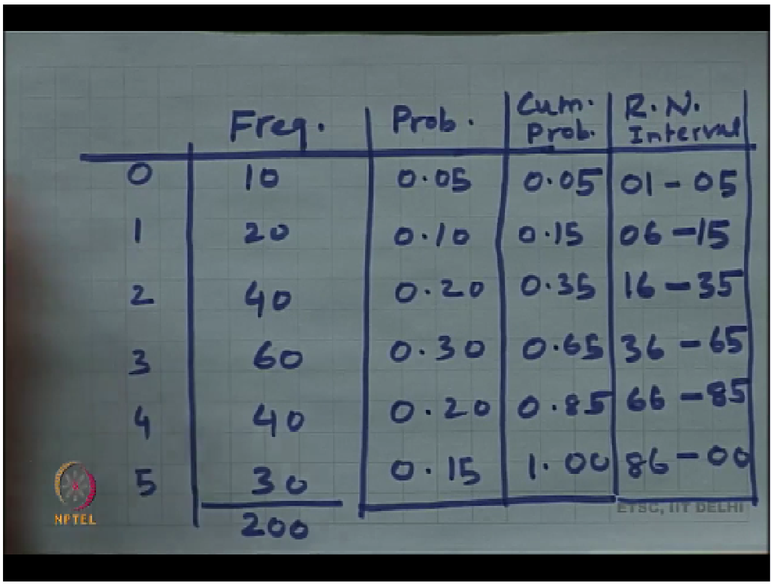

	Freq.	Prob.	Cum. Prob.	R.N. Interval
0	10	0.05	0.05	01 - 05
1	20	0.10	0.15	06 - 15
2	40	0.20	0.35	16 - 35
3	60	0.30	0.65	36 - 65
4	40	0.20	0.85	66 - 85
5	30	0.15	1.00	86 - 00
	200			

So what I do I can calculate the probability values associated with each of these demands. So let us say demand is 0, 1, 2, 3, 4 and 5, frequency is already known to us 10 here, 20, 40, 60, 40 and 30. So I can calculate the probability from this data demand of 0 probability, it is going to be 10/by this sum is 200 here. So I can calculate the probability it would be 10/200. So it is going to be 0.05, for this it is 20/200. So it is going to be 0.10.

Likewise this is going to be 0.20, this is going to be 0.30, this going to be 0.20 and finally this is 0.15. Now you can calculate the cumulative probability values, so this is 0.05, this becomes 0.15, this is 0.35, this is 0.65, 0.85 and finally this total probability is 1.00. So these 2 steps we have easily been able to do. Now what I do is I assign random number interval, so there is a term called random number.

I represent it with R.N. random number interval. So there are 2 ways in which this random number interval can be assigned. So let us say you know random number intervals, you can generate it with the help of even your small calculator also, scientific calculator also, in fact can we of 2 digit, 3 digit, 4 digit or any number of digits. As far4 as the interval is concerned I write it like 01 to 05. This is 06 to 15, 16 to 35, 36 to 65, 66 to 85 and 56 to 00.

So let us try to work it out with 2 digit random number, in fact in some of the textbook you will find there is a table which gives you the random number. So I will show you one such table and then we come back to this problem again.

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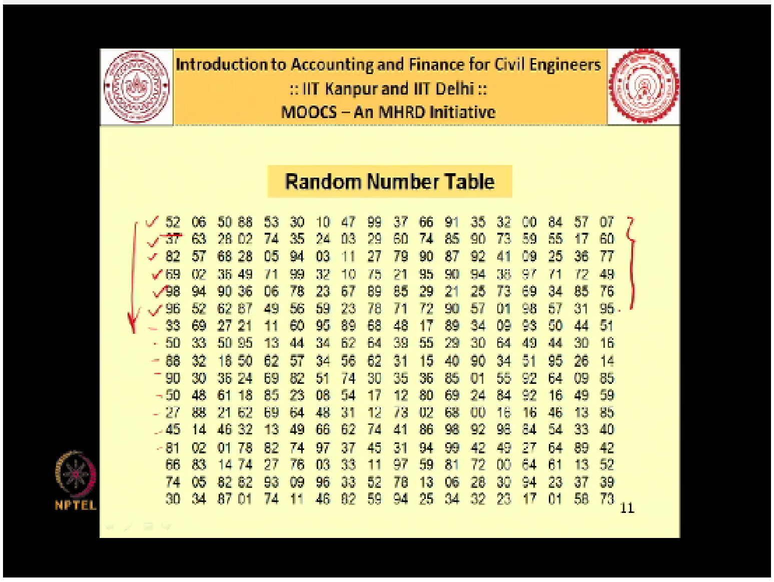

52	06	50	88	53	30	10	47	99	37	66	91	35	32	00	84	57	07
37	63	28	02	74	35	24	03	29	60	74	85	90	73	59	55	17	60
82	57	68	28	05	94	03	11	27	79	90	87	92	41	09	25	36	77
69	02	36	49	71	99	32	10	75	21	95	90	94	38	97	71	72	49
98	94	90	36	06	78	23	67	89	85	29	21	25	73	69	34	85	76
96	52	62	87	49	56	59	23	78	71	72	90	57	01	98	57	31	95
33	69	27	21	11	60	95	89	68	48	17	89	34	09	93	50	44	51
50	33	50	95	13	44	34	62	64	39	55	29	30	64	49	44	30	16
88	32	18	50	62	57	34	56	62	31	15	40	90	34	51	95	26	14
90	30	36	24	69	82	51	74	30	35	36	85	01	55	92	64	09	85
50	48	61	18	85	23	08	54	17	12	80	69	24	84	92	16	49	59
27	88	21	62	69	64	48	31	12	73	02	68	00	16	16	46	13	85
45	14	46	32	13	49	66	62	74	41	86	98	92	98	84	54	33	40
81	02	01	78	82	74	97	37	45	31	94	99	42	49	27	64	89	42
66	83	14	74	27	76	03	33	11	97	59	81	72	00	64	61	13	52
74	05	82	62	93	09	96	33	52	78	13	06	28	30	94	23	37	39
30	34	87	01	74	11	46	82	59	94	25	34	32	23	17	01	58	73

So if you see on your computer screen this is from another text book that I have taken the random number table and here you can see it gives you the random numbers of 2 digit. So basically what is happening in simulation is we are trying to imitate a real-world phenomenon and in real world phenomenon you know that the demand could be random in nature. So I really do not know whether the demand for my product tomorrow is going to be 0 or 1, 2, 3, 4, or 5 I do not know.

So this I am trying to imitate with the help of random numbers. Random numbers do not appear in any sequence, it does not follow any arrangement. So you cannot really find any pattern when you are generating a random number. So in a scientific calculate you will find there would be a button, if you press you will different numbers at different point of time. So in the problem solving you can even take the help of your calculator.

If you do not want to do that you can refer to a random number table either of 2 digit or of 3 digit and accordingly we can try to solve our problem. So if you look at this particular table you would not really find, you would not really find that there is a pattern. For example here you can see the number 52, if you look at the computer screen you find the first number is 52 then you have 37, then you have 82, 69, 98, 96 and so on. So you can find there is no pattern at all, so right now it is 33, the next number is 50, the next number is 88, the next number is 90, 50, 27, 45, 81 and so on.

So basically you would not be able to find any sequence or other any pattern that let us see if right now this number is appearing, the next time some other known number would be coming no we are not at all sure and this is the reason we are saying that this is trying to imitate the real world phenomenon. So what I do after you have computed the random number interval we will refer to this particular table and we will try to find out the probability of that particular demand.

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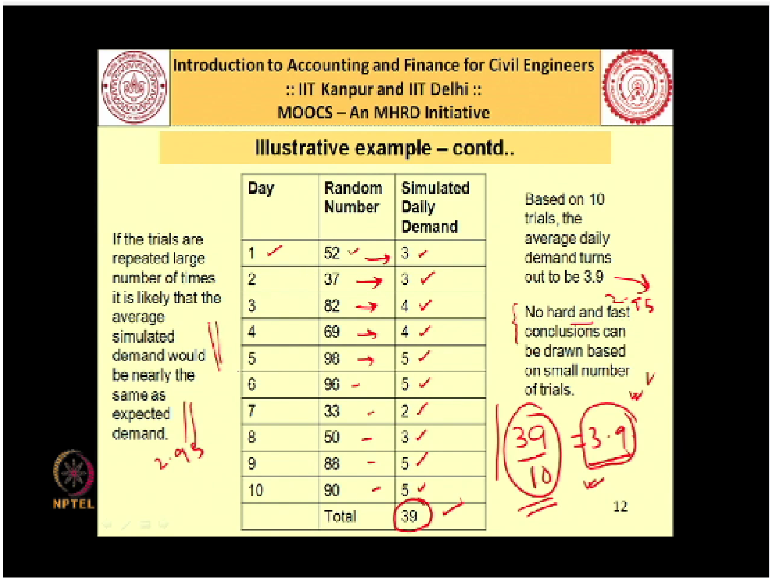

So this is captured in this particular slide, say let us try to do this simulation trial for 10 days. So let us say we are in day 1, now I picked up 1 random number from the random number table, if you go back the first random number was 52 let us say we are going in from this number in this manner, random number we are referring from top to bottom. So first I am referring first column, then I will go to the second column, third column, fourth column and so on.

So first number is 52, so the moment I generated 52 you know my random number interval was like this, if you see here my random number table I had already shown you the random number interval is shown in this particular piece of paper. So I will locate where does 52 actually lie, so you will find that 52 lies in this interval that means the demand for that day is likely to be 3. You can see here 52 will lie in this interval, you can see between 36 to 65 any number that comes we will assume that on that particular day the demand is going to be 3.

Now the next random number is 37, 37 will again come here, so the demand for that second day also is likely to be 3, then the next random number is 82 so now you know the demand is going to be 4 on that day. So likewise if you see this table you can easily find out the daily demand. So corresponding to 52 my expected daily demand is 3, corresponding to 37 my daily demand is 3, 82 my daily demand is 4, 69 my daily demand is 4, 98 my expected demand is 5.

Likewise 196 it is 5, for 33 it is 2, for 50 it is 3, for 88 it is 5 and for 98 5 again, so you can find in next 10 days my total demand is likely to be 39. So on an average I am getting 39/10 which is about 3.9. So this is how you carry out the simulation trials, of course when you are doing it manually you will not be able to go 100 trials or maybe 1000 trails, however using the computer software you can very easily find it out that the number of trials can be increased.

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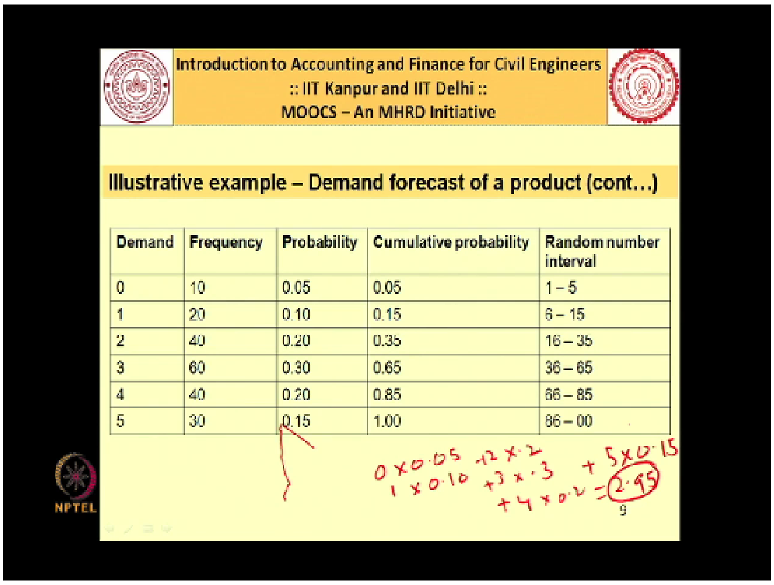

And the more number of trials you are performing you are more likely to be closer to the real life problems. Now what you can do is if I would have taken the expected value of this problem from this slide I could have calculated it like this, so for 0 demand the probability is 0.05, for 1 demand the probability is 0.1, for 2 the probability is 0.2, for 3 demand probability is 0.3, for 4 it is 0.2 and for 5 it is 0.5.

So if you calculate this it would be something like this, so you have 1*0.1, so it is 0.1+2*0.2 which is 0.4+0.9+0.8+0.75. So this is coming to be 2.95. So the expected value of demand is coming to be 2.95 based on the probability values that we have here, but when we did this trial for 10 times we are getting the expected value this we are calling it as simulated daily demand it is 3.9.

The difference is coming here is only on the basis of less number of trials conducted manually. If you try to go for large number of trials you will find that your 3.9 will come very close to 2.95. So the more you carry out the trial the closer you are with the expected value that you have obtained, just because our number of trials less we cannot take any hard and fast conclusion right, you cannot draw very hard and fast conclusions.

Because the number of trials are very less, that is why this problem you can just understand it for the purpose of illustration only, no hard and fast conclusions you can draw from here. Because the number of trials that we day was only 10. Now if you repeat the trials large number of times as I told you the simulated demand would be very close to the expected demand, expected demand in this case is 2.95 and it will be very close to that.

Now the real benefit of simulation can be derived when we take large number of variables and that to the problem is very complex. So will try to show you the complications when I take the 2 variable simulation at a time.

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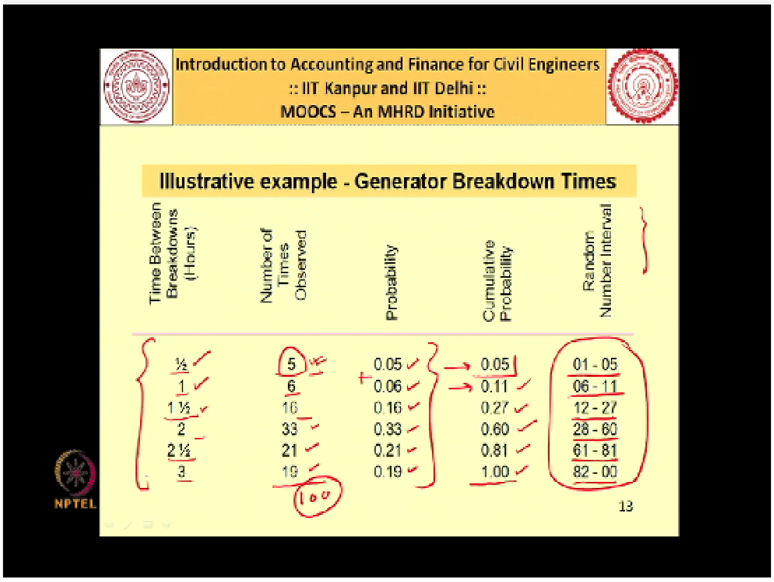

And this 2 variable simulation let us try to work it out for a generator breakdown problem. So what is happening in this particular problem is let us say there is a power producing company which is producing the power based on the generator. Now let us assume the company has got 15 generator sets and each of the generator sets are contributing to the power supply. Now as you know the power supply is from the generators, the company cannot effort to see that its generators are frequently under breakdown.

So what it has done is it has collected that date from its past working regarding the time between the 2 breakdowns, suppose right now there is a breakdown after how much time the second breakdown took place, why it is interested in finding the breakdown because every breakdown is costing money to the company because in the event of breakdown the company has to borrow power from some other grid at a cost and then only it has to supply to its customer in uninterrupted manner.

Now the company has employed let us say 4 workers to make sure that whenever a generator is under breakdown it gets repaired quickly, now this workers are available round the clock, how it has been organised is like this, there are 4 workers in total on the role of the company.

Now every worker is spending 8 hours. So let us say in first shift one worker is there, second shift another worker will come and we are having shift of 8 hours.

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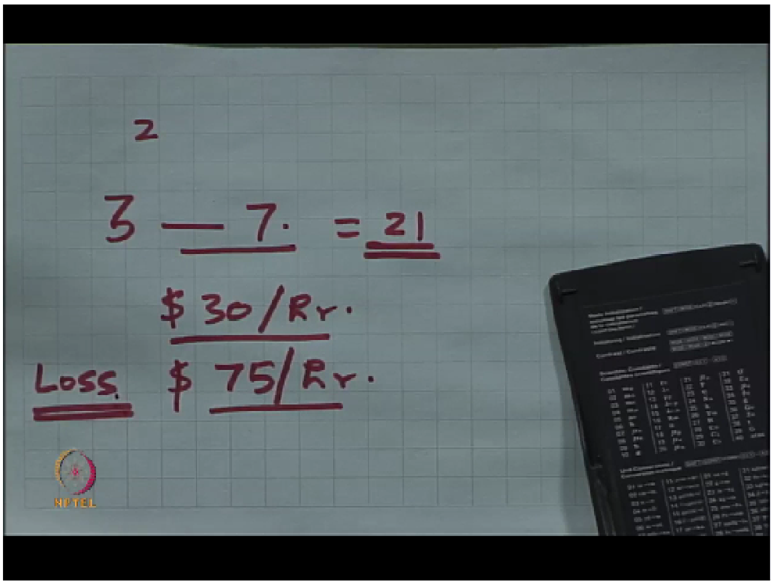

So we will find that these 4 workers in a weeks' time they will have about how many shifts, so total we require 21 shift, so you have 2 shifts per day of 8 hours tower that multiplied by 7. So 21 shifts are needed. Now the workers had been arrange in such a manner that all that 1 worker is available and the cost of hiring these workers is let us say 30 dollars per hour, and if generator is under breakdown let us assume that its cost of repair is 75 dollar per hour were that the lost to the company is 75 dollar per hour.

Now based on this we would like to know what kind of policy the company should follow, whether it should increase the number of workers, whether it should put new generator sets, whether it should try to replace those components which are showing faults on a regular basis. So these are the kind of decisions that we would like to understand. So what data the company has collected, it has collected 2 sets of data, 1 what is the time interval between the 2 sets of breakdown.

And what is the time to repair every time the generator is under breakdown. So from the past experience the company knows that the generator repair can take either 1 hour or 2 hours or it could even take 3 hours. So for that also the company has past record, and the company also has kept a record on the time interval between the 2 successive breakdowns. So in this particular slide if you see this is what is given here.

So you can see the time between breakdowns half an hour, number of times this was observed was 5, so that means between 2 intervals of outbreak half an hour lapsed and on such 5 occasions, likewise time between breakdown 1 hour on 6 occasions, time between 2 breakdowns 1 and half hour on 16 occasions, 2 hours 33 occasions 2 and a half hours between 2 breakdowns on 21 occasions.

And 3 hours between the 2 breakdown on 19 occasions, so you can see the total here is 5+6 which is 11 here, 5+6+16+33+21+19. So this is for 100 occasions the company has kept the data. So in the first step what I do is I calculate the probability associated with each of these times. So the probability that there would be half an hour time between the 2 breakdowns you can calculate it by 5/100.

So you divide this by 100 so you are getting 0.05, likewise you will get 0.06 here, 0.16 here, 0.33 here, 0.21 here and 0.19 here. So these are the probabilities now I can calculate the cumulative probabilities so this will be given by 0.05, this is 0.11 or 0.05+0.06 is 0.11. Then you have 0.27, 0.60, 0.81 and 1.0. I can generate the random number interval, so when a cumulative probabilities0.05 I am generating it like this from 01 to 05.

That means any time I am getting a random number between 01 to 05 I will assume that the time between the 2 breakdowns is going to be half an hour, likewise if any number is between 06 to 11 I will assume that the time between to breakdown sis 1 hour, likewise for this 12 to 27 any number appearing in this range will indicate that the time between 2 breakdowns is 1 and a half hour.

Likewise you can interpret it in this interval, you can interpret it in this interval or you can interpret it in this interval. So this is how you generate the random number interval. Now this is as far as the time between breakdowns are concerned right. Now this is 1 set of data.

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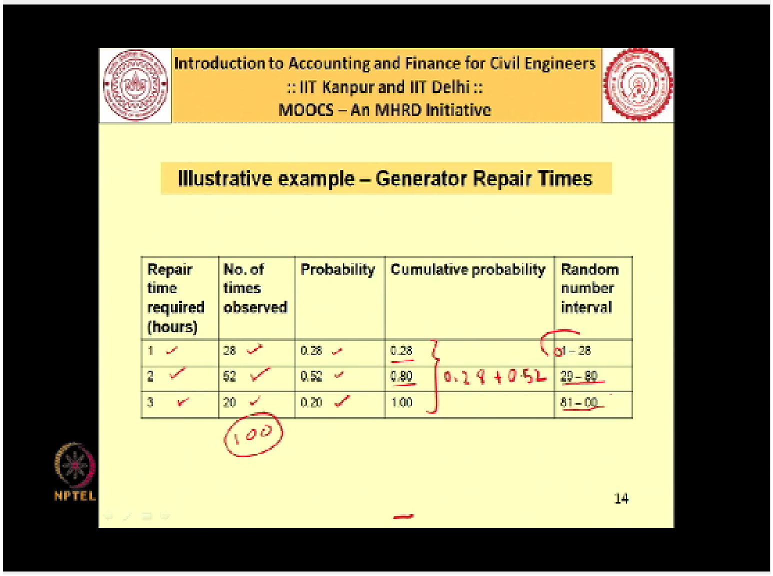

The other set of data that the company has observed is like this that the generator repair takes brother 1 hour on 28 occasion on 52 occasions hours on 20 occasions company observed is like this. It has observed that the generator repair takes rather 1 hour on 28 occasions, it took 2 hours on 52 occasions.

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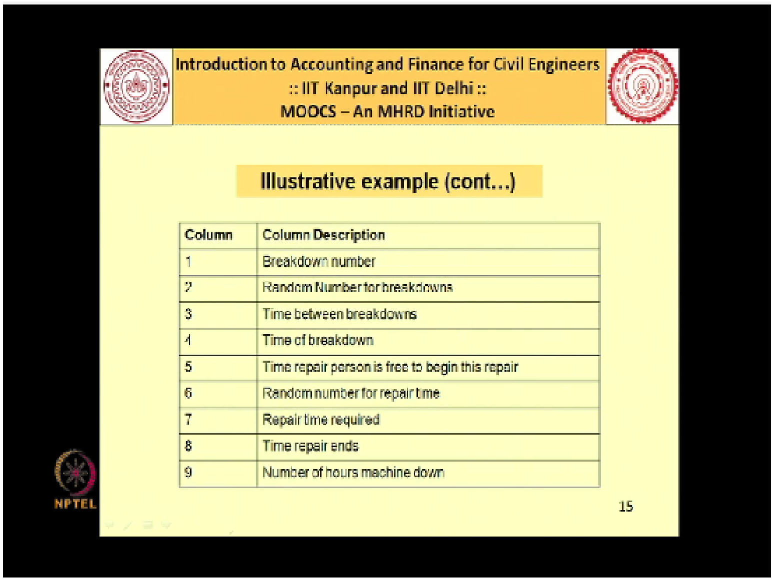

And it took 3 hours on 20 occasions. So you can see the company observed this on 100 occasions, now based on this you can calculate the probability that the repair time would be 1 hour. So it is 28/100, it is 0.28, 52/100 it is 0.52 and 20/100 it is 0.1. Again I can take cumulative probability for this. So this is going to be 0.28, 0.80 how I am getting 0.80 it is nothing but 0.28+0.52.

So this is 0.80, now you add 0.20 in this we are getting 1.0. Now you can easily find the random number interval associated with this. So any number which falls between 01 to 28 you will assume that the time to repair the generator would be 1 hour, if the number falls between 29 to 80 you will assume that the time required to fix the generator would be 2 hours and if it is between 81 to 00 you will assume that the time to fix the generator set is going to be 3 hours. Now based on this I do 1 small simulation here and it would be done like this.

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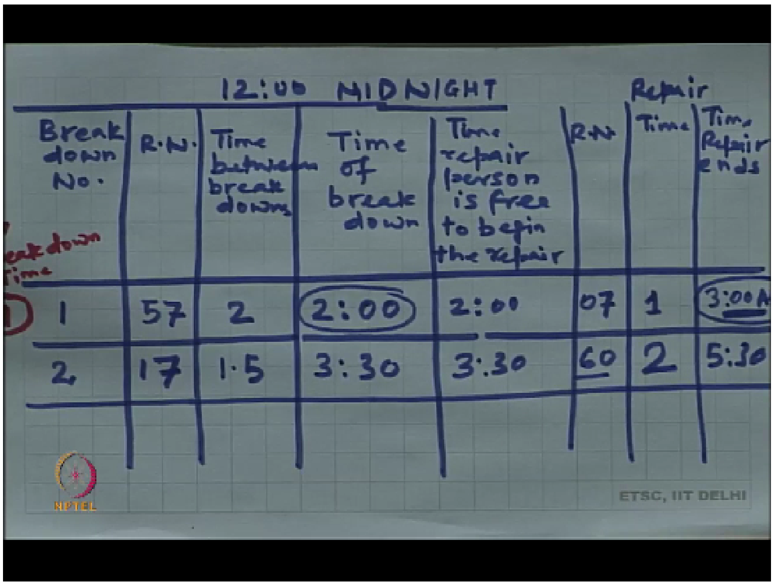

So you have to make various tables, the first table I will write the breakdown number it would be breakdown number, it could be 1, 2, 3, 4, 5, 6 and so on, then I will generate the random number for breakdown, then I will calculate the time between breakdown because the moment you know that random number is this I can easily refer to the table and find how much time you will take to see the next breakdown, time between breakdowns ok.

I can write the exact time of breakdown right, then I can calculate the time at which the repair person is free to begin this repair, then again I can calculate the random number for the repair time. So once you know this random number you will be able to find the repair time that would be needed, it would be 1 hour, 2 hour, 3 hour then the time at which the repair ends.

And the last column we can find out the number of times machine is down. So let us start with this first one, so let us say a breakdown number is 1, let us say and let us say we are starting this simulation at midnight, so 12:00 let us call it as midnight, so let us say we are starting the simulation at midnight. Now the first random number let us say we are generating it to be 57.

So the moment I have got this 57 the time between the 2 breakdowns will be 2, you remember from where we are getting this we are getting this form this particular table if you see the 57 here is in this range between 28 to 60 and that means this row you can clearly see the number 57 is falling in this row and it indicates that the time between the 2 breakdowns is going to be 2 hours. So what I do is I write 2 here.

Now you already know from where I am getting this 2 because I generated a random number 57 and corresponding to 57 my expected time between the 2 breakdance is 2. So you remember you started at 12:00 in the midnight so your time of breakdown is likely to be 200 that means at 2 a.m. morning your first generator is likely to be under breakdown. Now at this point of time since I have already told you that repair men are available round the clock.

So they had no pending work previously, so they are available at 2:00 a.m. itself or repairing this generator. Now we have to estimate how much time the repair person is likely to take in repairing this. So I will again generate a random number let us assume that random number is coming to be 07. So random number that we have generated is 07. Now what I do is corresponding to this 07 I will find out what is my repair time.

So I referred to this table, if you look at this computer screen 07 is coming here in this interval. So what does this mean, the time to repair is going to be 1 hour. So I simply write 1 hour here, so repair time is 1 hour right. So when it is 1 hour that means when exactly the repair would not it is started at 2 a.m. so it will end at 3 a.m. you understood. So how much time your generator was under breakdown you remember time of breakdown was 2 a.m. and it got fixed at 3 a.m.

So the time up to which this generator was under breakdown I will write it in some different colour and we call it here 1. So this column is basically the time up to which the generator is under breakdown. So this is breakdown time of generator I am writing it with red colour ok. This is because I do not have enough space there ok. Now I go for second trial I generate the random number again let us see my random number is coming to be 17.

So now I locate where does this random number appear in my table. So you can see this random number is 17 and this is falling in this 1 and half hour. So it is expected that the next will take place 1 and half hour after this previous 1 has failed. So what I need to write here I will write 1 and half hour here. So this is 1.5 I will right here time between 2 successive breakdowns 1 and half.

So remember first time it had broken down at 2 a.m. so the next it will break down at 3:30 a.m. Now you can see the worker is free at 3 a.m. itself because 3 a.m. itself the repair ended. So he is available at 3:30, so there is no time gap, so the moment he comes to know that the generator is under breakdown he will rush to that particular place and immediately start fixing the generator set.

Now I again generate the random number let us see what is the my next random number it is coming to be 60. Now if you go back to the table you will find repaired time corresponding to this 60 is coming to be 2. So when exactly my repair would end for this generator set 330+2 hours so this is going to be 5:30. So how much time this generator was under breakdown, we can find it out by subtracting 330 from 530. So because 330 it broke down and 5:30 it got fixed. So you are getting 2 hours right.

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Now in the same manner we can perform the analysis and the remaining analysis is shown in this particular slide. So you can see here now this is third trial now the random number generated is coming to be 36. So corresponding to this I find that if you go back to the previous slide corresponding to 36 my time between 2 breakdowns is 2 hours. So you can see it is 2 hours here.

So 3:30 it has broken down the previous generator now at 5:30 another breakdown will take place and you remember at 5:30 the previous generator was fixed, so this worker is free at 5:30, so immediately he will take up this challenge. Now again I am generating random number this time it is 77 I find at this time the generator repair will take 2 hours. So 5:30+ to 7:30 it will get over, so how much time the generator is under breakdown.

So 7:30-5:30, so 2 hours. So this last column is giving you the time in which the generator is under breakdown one of the generator is under breakdown. Now you can see I am going to the 4th trial here the random number is 72. So if you go to the 72 is coming in this range, so it is 2 and a half. So you can write here it is missing here 2.5 here.

So you remember the last time breakdown took place at 5:30, so after 2 and half hours means that is 8 hours this generator will be under breakdown. Now 7:30 the repair work ended so the worker is available to repair is at 8:00 a.m. how much time it will take to repair will be decided by the random number that we are getting. So this time it is 49 and so it is corresponding to 2 hours of repair time.

So 10:00 a.m. the repair ends, so here also you find that the generator is under breakdown for 2 hours. Now you can carry on this analysis I have done it for 15 trials and in the 15 trials you find that the number of hours in which the generator is under breakdown is 44. So if you submit a for all 15 cycles you are getting 44. So that means whatever trails we have done so far in that trail period for 44 hours my generators are under breakdown.

Now one more thing you can notice here that towards the end of simulation you can see your generator breakdown time is 11 here, repair starts at 11 find no problem, generator is breaking down at 13, repair starts at 13, generator breaks down at 15, but the repair starts at 16 hours. So there is a time gap you can see here. So that means there is a backlog likewise if you see the generator got breakdown at 5 hours.

And you can see the repair start only at 18 hours that means 1 hour difference 17 hours it was under breakdown but repair started at 18 hours, next breakdown 18:30 but repair started at so that is 19 hours, here 19:30 is breakdown but repair started 20 hours, here 21:30 repair it got under the breakdown and repair started at 23. So here also you can see 23 and once 2 hours gap, here 1 o'clock it got under breakdown and 4 o'clock repair started.

Here 4 o'clock it gotten the breakdown and 6 o'clock the repair started. So what you find likewise here 5:30 itself generated was under breakdown but repair started at 8. So what you find as we are going towards the end of this simulation process you find is a lot of backlog. So workers are not immediately available to take up the repair work. So this is the problem and thus the reason you can find towards the end the time of breakdown is very high compared to the initial once.

So you can see 4 hours, 4 and half, 5, 5 3 and half 3 now. So much of breakdown hour is occurring here right. So the total breakdown time is 44 hours and what is the total number of hours we have done here. So if you remember the simulation begin at midnight it continued for next one day and it continued for some more time up to 10 a.m. So total we are having 34 hours of simulation.

And in 34 hours of simulation of course we had 15 set of generator here and that is the reason you can see here that this is the 15 generator sets we can say DG sets, diesel generator sets and this is giving you total breakdown time of 44 hours in a 34 hours simulation. So what exactly we do from this simulation study.

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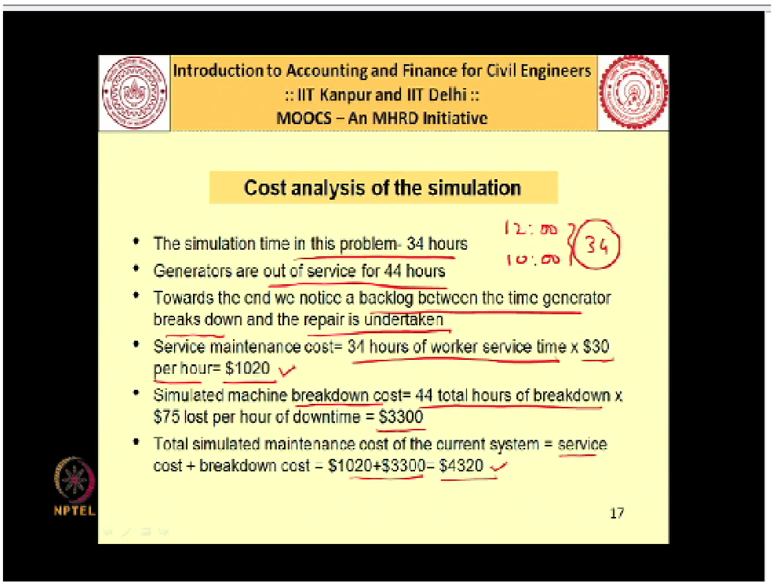

As I told you the simulation time in this problem is 34 hours how you started at 12 hours midnight on day 1 and ended it at 10 a.m. on the next day. So total of 34 hours simulation and generators are out of service for 44 hours as I showed you in the previous slide. We also notice the backlog between the time the generator breaks down and the repair is undertaken especially towards the end of the simulation.

So if you try to calculate the service maintenance cost you can see 34 hours of worker service time this analysis was carried out for 34 hours and you can remember that workers are available round the clock and they are available at a cost of 30 dollar per hour. So the total maintenance cost is coming to be as far as the labour cost is concerned 1020 dollar and when it comes to the machine breakdown cost 44 hours of breakdown and 75 dollar lost per hour.

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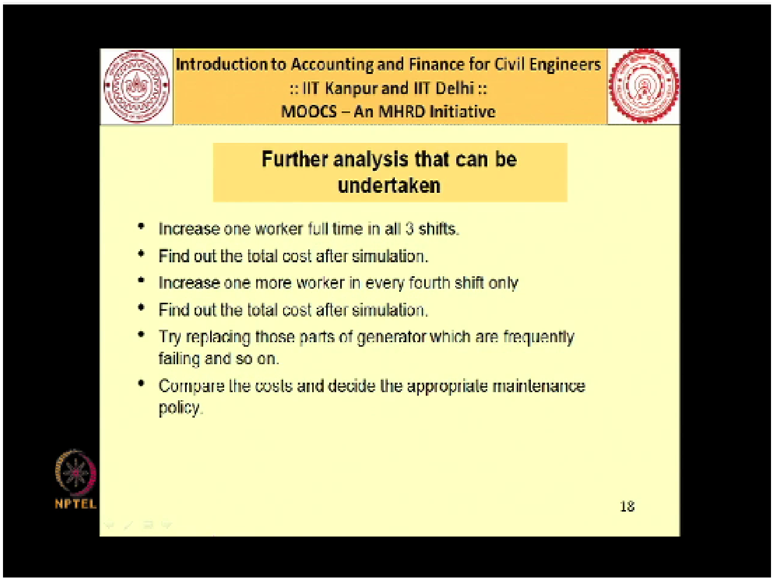

So that will give you a sum total of 3300, so the total simulated maintenance cost of the current system which is the sum of service cost+breakdown cost is coming to be 1020+3300. So which is coming to be 4320. So the question is what do we do from here onwards, so we will find that for the given set of arrangement we are finding certain cost. Now what I will do I will change the situation.

For example instead of only this 4 worker for whole 1 week that means 1 worker present in every shift I can try to increase 1 more worker and then I will like to run the simulation again and then will try how to see whether this has resulted in a lesser cost, like wise I can simulate another scenario what I will do I will try to replace all those faulty parts which are showing frequent breakdowns.

So what you can see here is that depending on the different arrangement I am likely to get a certain cost, I am going to choose the least cost out of that and that is how I will run my production plan. So these are the applications you can think of simulation in civil engineering context. For example you may have a large number of concrete production plants at your site. Now many of the equipment must be failing at regular interval.

So whether it is ways to put more number of workers to take up that repair work quickly or whether to repair those faulty parts for once for all. So these are some of the situations we would like to simulate. We will see more examples of peoples of simulation especially in the context of let us say the net present worth computation in the next lecture. So what I will do it is I will quickly summarise what we have learnt in this particular lecture.

We started with understanding simulation, we understood its advantages, we understood its limitations , we understood the various steps we take up in Monte Carlo simulation you remember you are too first developed the probability distribution table, then you have to find out the cumulative probability, then you have to have the random number interval, random number you can refer it from either the text books or you can generated from your calculator.

And you can forecast let us say single variable or you can carry out the simulation of more than 1 variables, the power of simulation you will realise when your problems are complex and we have more number of variables to be simulated. So with this we stop at this particular point, thank you very much.