Simulation of Business Systems
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Lecture – 07
Monte- Carlo Simulation

Good evening everyone. Today we are and into yet another lecture of the simulation of business systems.

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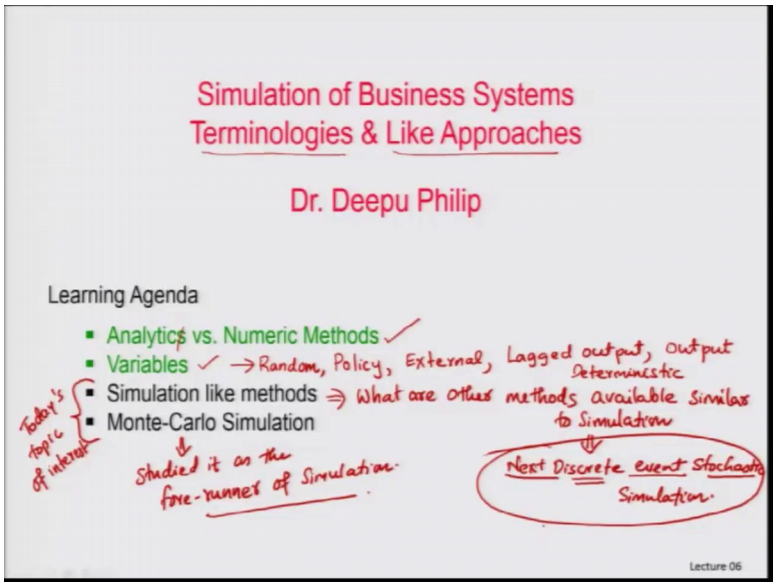

And it is a important lecture because we are now going to come to study a new approach in simulation called Monte Carlo simulation today's class and we will try to work an example also, but before we get into this let us get into a quick review of what we are done so far. So, if you are looking through we are doing the lectures on terminologies and like approaches ok. And the terminologies and like approaches we have already looked into what is called as analytic versus numeric methods what was the importance of this. And we also look into what are the different type of variables that are used in the simulation.

In the variables that are used in the simulation we talked about what we call as random variables, we talked about what we call as policy variables, we talked about what we call as external variables also similarly there was lagged output variables. And we also had output variables and more than that we also had other things about deterministic

variables as well. And we saw what each one of them and how they are important in the simulation. Now we are getting into these 2 topics today the simulation like methods.

So, this will be today's topic of interest. So, we will be looking into these 2 things simulation like methods which implies that, what are other methods available similar to simulation. And then remember here we are talking about next discrete event stochastic simulation. So, this is a next event simulation which is focusing on discrete system. And it is stochastic which means it is random and we are using a simulation.

So, the it is an event based simulation that we are focusing on. So, what are the approaches that are similar to this similar to this approach is what we are going to study today. And one of the most common one is Monte Carlo. And we studied this as the studied it as the fore runner the beginning point of simulations which was used in the atomic bomb studies I mentioned at the beginning of the slide. So, we are going to see what this simulation is all about.

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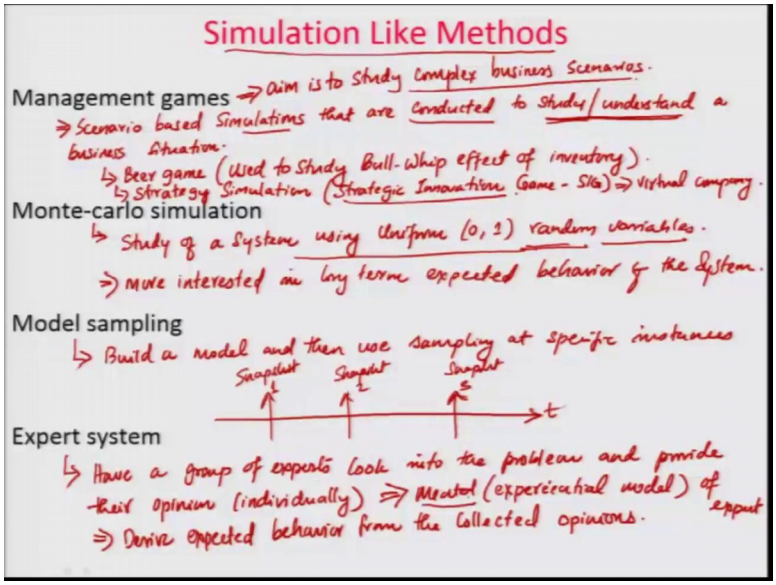

So, let us get into the first topic that we talked about which is called as the simulation like methods. What are those methods that are available which are similar to simulation?

So, the first one we talk about it does management games ok. Management games are you know these are scenario based simulations that are conducted to study or understand a business situation. For example, there is people use this, these are simulations that are

conducted to study or understand to get deeper understanding or to study the phenomena of a business situation. So, like for example, is the beer game is an example which is used it to study what is called as bullwhip effect of inventory.

So, that is an example of a management game. Then we also talked about various strategy simulations. For example, the game that is developed by IIT, Kanpur which called strategic innovation game or popularly known as SIG is another example of a scenario where you are running a virtual company. It is a virtual company and we are studying the impact of long term impact of various strategies using this particular strategic innovation game.

So, these are type management games which are interested. So, aim is to study complex business scenarios ok. So, rather than really conducting the experiment with the real system, you create a simulation business simulation and then use that simulation to study. Monte Carlo simulation on the other hand is what we are going to talk about now in a brief sense we will study more later it is a study of a system using uniform 0, 1 random variables ok. Let us always talk about this for the time being you use uniform 0 1 random variables and study the behavior of the system.

You are interested in more interested in long term expected behavior of the system ok. So, we are interested in long term expected behavior of the system. And we study the system by v simulating using uniform 0 1 random variables and a random variates and then you sample that you scale that we will see how that scaling happens today then go from there. Then we have something called as model sampling.

So, here what happens is you build a model and or and then use sampling at specific instances. So, like let us say you are basically you have like a long time frame to study a particular time is going like this. And you take you are using a model and you take particular snapshot of the system at different places at different time intervals. And then use that. So, the here is a snapshot 1 and another snapshot and snapshot. And these snapshots you take sufficient number of snapshots and then use the snapshot to study about the system.

It is not a very popular methodology, but some people still use it. And the expert system is kind of there are many many variations of this, but in the simplest sense is have a

group of experts look into the problem and provide their opinion individually. So, then derive expected behavior from the collected expert opinion collected opinions.

So, if I want to study what will be price of or what will be the growth in the agricultural land in India I might end up getting 20 different experts talk to each individual expert and each expert has a mental model about the agricultural land pattern usage patterns in India. And he or she might give individual opinions. and if I take all those 20 opinions and from there find a commonality out of the opinion or find the factor that is most commonly obtaining out of it or the highest suggested opinion out of the people, it has a very high chance of that is going to happen because each expert has a mental model.

So, here the model that you are going to use is mental model of the experts mental or experiential model of expert. So, the expert has some mental model. He has something in his mind or he has something in his mind.

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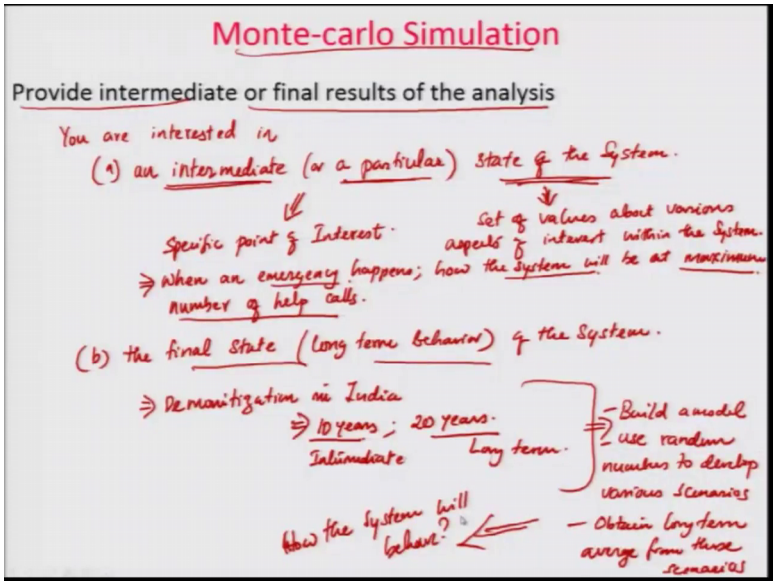

Or there based on their experience they have derived a certain model in their mind and using that model is when they are actually giving you the feedback and the concept and the using that concept, you are trying to find the average behavior of the system. Now from here what we will now try to do is or we will try to pick what is a Monte Carlo simulation and we will try to work through an example to see how Monte Carlo simulation can be used to study various types of systems. We will use a simple example in the class and once this example is worked out so that you see the nitty gritty details,

then I will present an appropriate excel spreadsheet to demonstrate to you how excel can be used to study want your develop Monte Carlo simulations in a simple fashion.

So, excel will be the tool that you will finally, end up using the to develop Monte Carlo simulations, but the mechanism of the Monte Carlo simulations will be worked out in the class step by step so that you understand what we actually try to do. And how this uniform random number numbers get scaled into what we actually expect out of it. So, Monte Carlo simulation as I mentioned earlier, what it is used to is provide a intermediate for final results of the analysis.

So, you are interested in a, an intermediate or a particular state of the system. You are interested in a very particular or an intermediate state of the system. State of the system again remember set of values about various aspects of interest within the system. So, what we are trying to do here is we are trying to study the state of the system at an intermediate point or at a particular point of interest. So, this is a specific point of interest.

You are interested in a very specific aspect of the system. a classic example of this is like you know like, if you look into a system when an emergency happens. How the system will behave how the system will be at maximum number of help calls. So, if an emergency is going on emergency is happening, and then you are keep on getting people calling you for help keep on calling you for help. And when this number of calls are at a maximum point a very large number of points.

Then how will the system will behave? What will be the condition of the system? How many of those calls you will be able to address? How many of those calls you will not be able to address? What will be the average response time? And those kind of aspects if you want to study for a particular instance of it you can use Monte Carlo simulation. The other part are the interested in the final state of the system. This is kind of a wrong usage instead of the final state you can say long term behavior of the system.

So, if you say that for example, if you want to study what happened if we did like the demonetization in India? What will be the impact after some people say in the long term this will benefit that country? So, how did they study? They developed the Monte Carlo simulation. So, if you want to study after 10 years, what will happen or after 20 years what will happen something like this.

So, this 10 years could be can think about this an intermediate. And this could be a long term. And then people use different way to study this in a and you replicate and then you say that you build a model, then use random numbers to develop various scenarios. Obtain longtime average from the scenarios. So, these 3 aspects you build the model the news random numbers to develop the scenarios and obtain long term average from the scenarios. Using these you can basically say how the system will behave.

So, the best way to understand this is to do a simple example ok. Make a simple system and then study that simple system work through the different aspects of the system. And then you will a same way as I demonstrated the queuing example we will work on a very simple Monte Carlo example. And with the Monte Carlo example where you will work through individual aspects of the examples so that you can understand how the system will behave.

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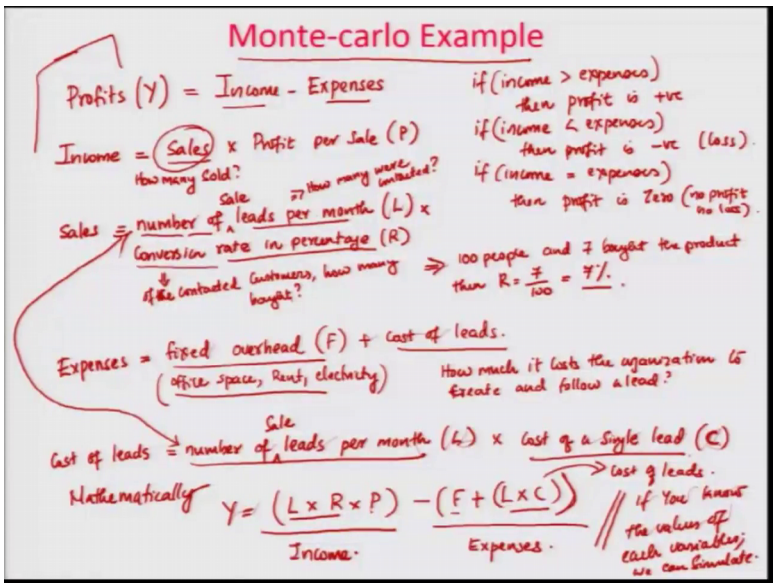

So, let us work a small example Monte Carlo example in the class.

So, I am going to give you a scenario where profits ok, profits let us denote that by variable Y is given by the simple equation income minus expenses. So, you know that if income is greater than expenses, then profit is positive right. If income is less than expenses, then you can say greater than or equal to in the then profit is negative or you are in loss. So, we define profit task profit Y as income minus expenses in a very simplistic model. And then we define income let us define income; income assuming that

you are so the income comes from sales. So, income is given by sales multiplied by profit per sale. Let us call this as P.

So, if you have if you sell many units. So, sales this implies how many units you are selling. So, this means how many sold ok. And with that if you multiplied by profit per sale ok, how much profit you are making per sale you multiply that, that will give you your income ok I hope you understand this much. So, profits are defined by income minus expenses, if income is greater than or equal to expenses in the profit is positive, if it is equal to it will become 0. If income is less than expenses then the profit is negative then you are running at loss. If income is equal to expenses, then the profit is pretty much 0, which means you are operating on a no loss no profit. So, let us clarify that otherwise you might have a confusion. If income equal to expenses, then profit is 0.

No profit, no loss that kind of a system. So, these are the 3 possible aspects of it. An income is purely from sales and how many items at your sold that is the sales. You multiply by that profit per sales that will give you the income. And these factor sales can be further given by number of leads or sale leads per month. Let us call this as L number of sale leads per month L multiplied by that the conversion rate in percentage which we call it as R.

So, what happens is how many so, this part number of sale leads per month this part answers the question how many were contacted. So, if you contact 100 people then that will be the number that you get here ok. Then this one is this conversion rating percentage answers the question of the contacted customers how many bought. So, if you had here if you had contacted 100 people and 7 bought the product then R is equal to 7 over 100 equal to 7 percentage. Ok I hope you guys understand what is called as a conversion rating percentage.

So, this sales is given by number of say leads per month which is good naught by L or how many people were contacted which is denoted by L. And multiplied with the conversion rating percentage denoted by R or of the contacted customers how many bought that you know gives you in percentage. Then so now, you have the income aspect. Now we call the expenses aspect. The expenses let us assume that this is has a component called a fixed overhead, which we call it as F plus cost of leads ok.

So, we are continuing on this. So, the expenses is given by fixed over heads. Whether you conduct sales on does in conduct any sales this overheads will come no matter what. So, this includes like you know office space and stuff like that, office space then what we call as rent, electricity etcetera ok. So, it is all part of this one whatever the fixed overheads. And for typically a sales expenses this is usually fixed. And then the cost of leads are something that will actually result in how much it costs the organization to create and follow a lead.

So, that is what is being discussed in this cost of leads. And if we explain exam we expand this cost of leads, cost of leads that is equal to number of leads per month ok we call it as L. And let us denote this well number of leads per month the same thing this particular L and multiply that by cost of a single lead. Let us call it as C. So, in this case when you have a cost of number of sales sale leads per month ok. The same are that of these 2 are exactly the same. They are the same another cost of single lead how much it cost you for a single lead denoted by the alphabet C.

So, if you have this then you can write mathematically you can write it as Y is equal to L times R times P minus F plus L times C. So, if you read what it is this L, L is the leads per month times R times P; R is this times P profit. So, this is your income ok. So, it is L is the number of leads per month times R is the sales conversion which will give you these 2 together gives you the sales aspect of it and then P is the profit per sale. So, that gives you the income side. This side on the other hand gives you the expenses. The expenses here is the first part is the fixed expense, F is the fixed overhead plus cost of leads; cost of leads is L times C.

So, this gives you the, this much component this part of it gives you the cost of leads. So, this total consideration, this consideration can completely be written in the form of a mathematical equation. Now if you figure this when you think about it, if you know the values of each variable, we can simulate. So, once you know these are the variables and if you study that these are the variables and we know the limits of the variables then from here we can actually simulate.

So, let us see what are the values of these variables ok.

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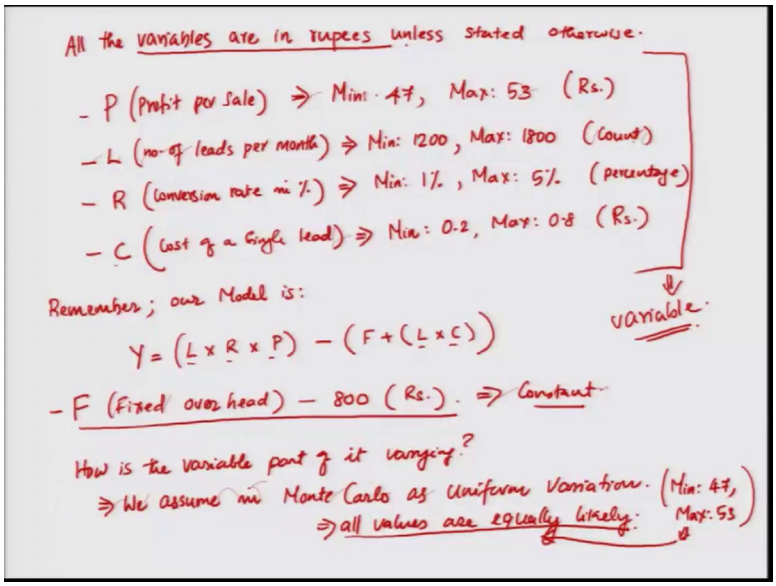

So, I am going to say that all the variables are in rupees unless stated otherwise. So, we are all variables are under P. So, let us take a P first variable as P, P is the what is called as profit per sale that we talk about it as minimum value of 47, maximum value of 53. Then the second variable that we are going to consider here is L. L is the number of leads per month we talk about it as minimum will be 1200 maximum will be 1800. So, number of leads per month. So, this is in profit per sale that is in rupees number of leads per month this is count not in rupees.

So, minimum is 12000 1200 leads maximum is 1800 leads these are the count. Then we talk about the next one as R, R denotes the conversion rate in percentage ok. So, here we talk about thus min minimum value as one percentage maximum value us 5 percentage. So, this is percentage alright. So, the profit per sale is 47 rupees 53 rupees minimum and maximum number of leads per month which is a count, which is minimum of 1200 maximum of 1800 conversion rate in percentage is minimum of 1 percent maximum of 5 percent the unit is percentage.

And the last one is C; C is the cost of a single lead. And let us assume this in this case as minimum is 0.2 maximum is 0.8 that is in rupees. Or we can think about the (Refer Time: 29:12) a ok. So, 0.2 rupees will be the minimum cost of the sale and 0.8 rupees will be the maximum cost of the sale. And remember our model is what is our model? Y

the profit is equal to L times R times P minus fixed the cost plus L leads times C cost of lead this is our model.

So, we have L we have R we have P we have C all the except what we have is F. F is the fixed overhead. And let us take this as 800 and that is in rupees. So now, we have a idea of the individual variables that are in the system. And how are we going to study the different aspects of the system. So, for each case we need to find out what will be the setup of the variable. So, we now know that F is no matter what this is constant. Ok all these guys they are variable ok.

One is constant other is variable. So, the thing is, how is the variable part of it vary. In this case what we do is, we use we assume in Monte Carlo; Monte Carlo as uniform variation. That is all values are equally likely.

So, here the variation is all these values so, if you say that minimum is 47 maximum is 53, then we are saying that all values in this are equally likely. That this where the uniform distribution comes into picture. So, let us do an example of this, how the uniform comes into picture.

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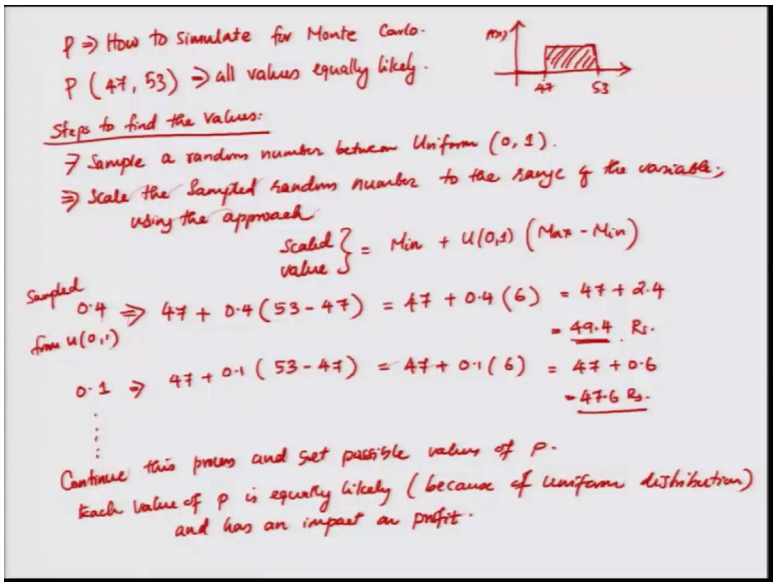

So, let us take the case of P how to simulate for Monte Carlo ok. So, the way we are going to do this will be, we just take P varies from 47 to 53, all values equally likely.

Or if you draw a graph it will be something like this. This will be 47 let us say this is 53. Up to this point the probability curve will be something like this with all values are equally likely ok. So, if you think about this is the probability of x. So, to do this what we do is steps to find the values. Ok what do we do is step 1 sample a random number between uniform 0 and 1 ok. Second will be scale the sampled random number to the range of the variable using the equation using the approach scaled value is equal to minimum plus uniform 0 1 multiplied by max minus min ok.

So, let us say we sampled 0.4 ok. If the for a sample of 0.4 from uniform 0 1 which implies the minimum in this case is 47 plus 0.4 times 53 minus 47 ok. So, that will be equal to 47 plus 0.4 times, 53 minus 47 will be what will be that value? 6 right. So, that will be equal to 47 plus 6 times 0.4, that is 2.4 which will be equal to 47 plus 2.4 will be 48 49 49.4 rupees. So, this will be one case.

So now let us take another sample just to repeat this. If you take a sample of 0.1, then it will be 47 plus 0.1 times 53 minus 47 which will be equal to 47 plus 0.1 times 6, it will be equal to 47 plus 0.6, 47 0.6 rupees. So, we can keep on continue. So, we can continue this process and get possible values of P. And each value of P is equally likely because of uniform distribution and has an impact on profit. You will see how this impact will actually happen. So now, we look into what we call as the P aspect of it. We just saw how the P works ok.

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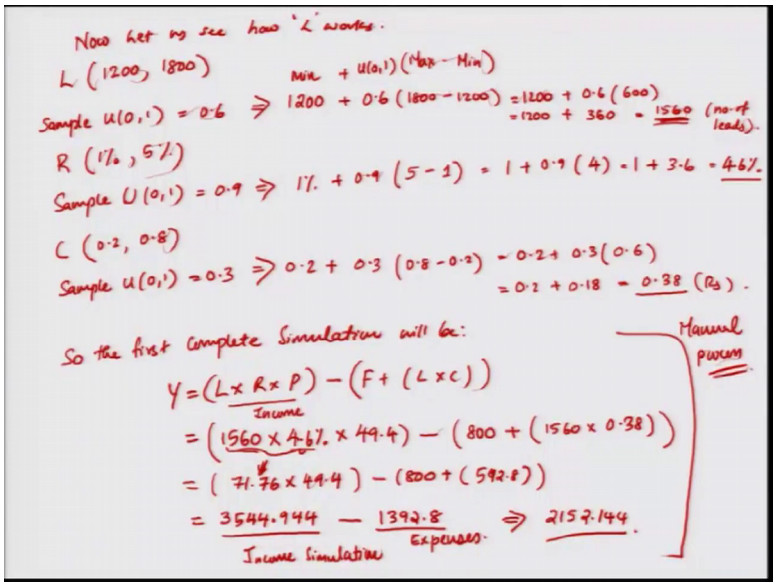

Let us do the second case of now let us see how L works. So, the way we are going to do this is, L we know that the values are between 1200 to 1800. And we sample uniform 0 1 let us say we sample 0.6. So, then it will give you minimum which is 1200 this is the minimum plus then 0.6 this is the u 0 1 multiplied by 1800 minus 1200 ok. So, that is the max minus min which is equal to 1200 plus 1800 minus 200 will be 0.6 times 600 right.

So, that will be if you multiply this, this will give 1200 plus 360 that will be 1560 will be the number of sales number of leads, this is a count right. Now similarly let us do R, R is supposed to vary between 1 percent and 5 percent and we do a sample of uniform 0 1, I apologize for this kind of tailing on this right because of is nonsense.

And let us say we get the value as 0.9 which implies again same equation minimum is 1 percent plus uniform 0 1 is 0.9 multiplied by minimum maximum minus min will be 5 minus 1 ok. That is 1 plus 0.9 multiplied by 4. That is equal to 1 plus 3.6, 4.6 percentage that will be the percentage conversion rate.

So, we got R and similarly we got C, C will be minimum is 0.2 max will be 0.8 ok. So, sample from uniform 0 1 and let us say we sampled 0.3 which implies it will be 0.2 plus 0.3 times 0.8 minus 0.2 is equal to 0.2 plus 0.3 multiplied by this will be 0.6 which will be equal to 0.2 plus 0.3 with it is 0.18 that is 0.18 which will be equal to 0 0.38 ok. So, that will be your C the cost of the cost of single lead this is also in rupees.

So now, if you take the first cases of the previous one, now we just take this case we this let us call this as the first case of this one and then first case of each one of this then we will be able to get our if we calculate. So, the first simulation first complete simulation will be, Y is equal to same equation L times R times P minus F plus L times C is what we talked about. So, if you look at the L the first value we got is, it will be 1560 times R the value we got was 4.6 percentage times P we calculated in the previous one as this 49.4 that is 49.4 multiplied by then we have is the F; F is fixed at 800 plus L the value of L is already calculated as 1560 multiplied by C is 0.38.

So now if we do the math it will be 1560 multiplied by 4.6 percent 1560 multiplied by 4.6 percent that is 0.046. that will give you what we call as the first value which should be 71.76 multiplied by these 2 together will give you this value multiplied by 49.4 minus 800 plus this is the other part of it. So, it is 1560 multiplied by 0.38that is 5 92.8 ok.

So, the first component you will get will be 71.76 multiplied by 49.4 will give you 3544.944 will be your income ok. This is the income part income simulation, minus this will be your, this is 800 plus 592.8 that will be 1392.8 this will be your expenses ok. So, these 2 put together. Now you can say that in this particular instance you will have the difference of 3544.944 which will give you a profit of 2152.144. This is one instance and depending upon how the number changes your profit loss all those kind of things will vary drastically.

So, this if you do manually manual process. This is what the manual example is.

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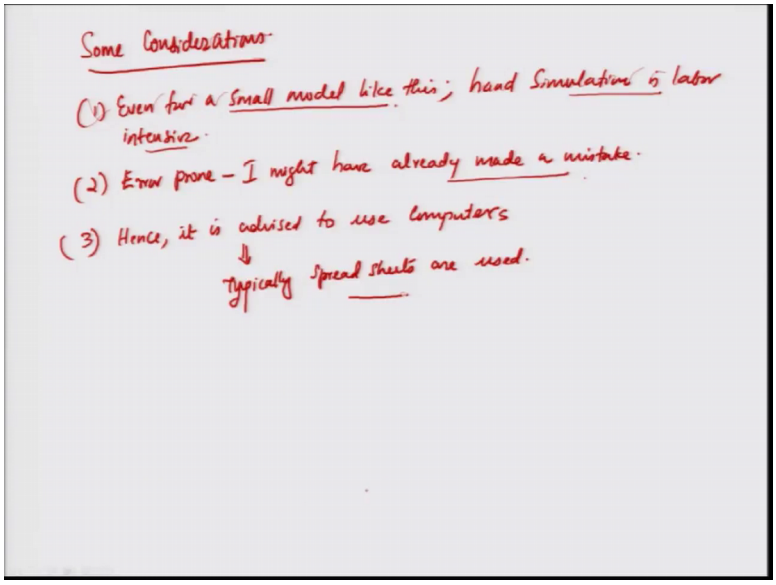

Now, some aspects I will say some considerations. One even for a small model like this hand simulation is labor intensive. Number 2, error prone ok I might have already made a mistake and got a value that is not even correct. That is quite possible you might have to recheck my calculation.

What am trying to say is even for a simple small model like this, doing it by hand is very intensive and you can easily make a mistake. Hence it is advised you to use computers typically. Typically, spreadsheets are used, we use spreadsheets to do these calculations ok. So, what am going to do now to you is you to show you how a spreadsheet can be setup in this regard so, that we can study what the Monte Carlo simulation is all about ok.

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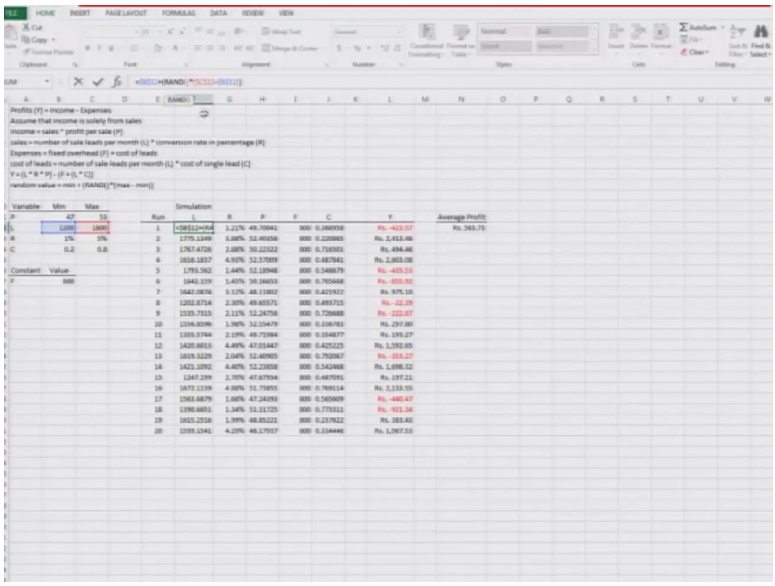

So, as I said to earlier to you guys that we have to use a spreadsheet to do Monte Carlo simulation because it is not how to it makes your life easy.

So, I have setup the spreadsheet for you guys, and I will walk you through what each columns of the spreadsheet is all about. So, the first column then we are going to talk about the basic definition we had profits y is equal to income minus expenses, same model. And we assume that income is solely from the sales; if that is the case, then income is equal to sales times profit per sale as I told it is a P that aspect. Then we talked about the sales is the number of leads per month sale leads per month, number of let us call it as sale leads per month, and then the conversion rate in percentages ok.

That is what we are talking about are ok. So, that will give you the in their income aspect and the expenses is the fixed overheads plus cost of leads. And the cost of leads of number of which is equal to number of sale leads sale leads per months times the cost of single lead. Then what we do is we know Y is equal to L times R times P that is L is your number of leads times R is the conversion rate, then P is the profit per sale minus fixed cost F times L is the number of leads C is the cost per lead.

And then the equation that, we are going to get the random estimate is equal to minimum plus R and value, this is the function that use in excel times max minus min. And we know that P varies from 47 to 53, you already set it up in these 2 page sheets, set up as

1200 to 1800, R is set up as 1 percent to 5 percent, C set up as 0.2 to 0.8 and F is fixed at a constant value of 800.

So, then let us take the one the first run of the simulation as an example. So, the value of L is calculated as, if you look into this formula, it is the first one says b 12, b 12 is what? B 12 is b is this column 12 is this row b 12, 1200 that is the minimum value. So, b 12 is the minimum value. Plus, rand; rand is a function of excel and what rand does? If you click on this excel will show you or if I write someplace else excel is just demonstrating what rand is.

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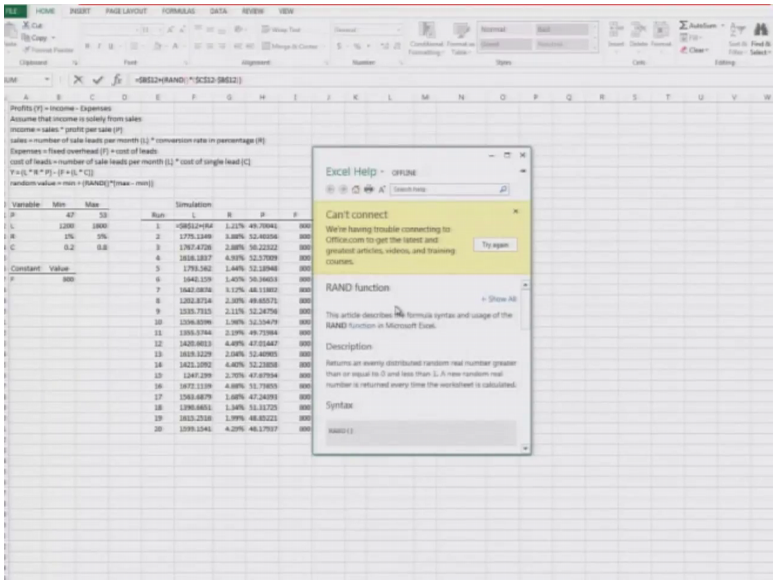

So, rand function, what does rand says?

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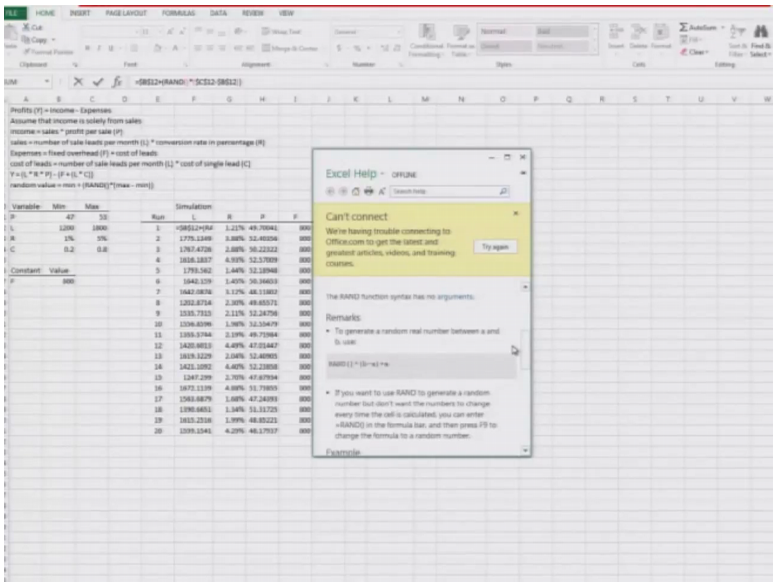

Rand determines a value gives you a value between 0 and 1.

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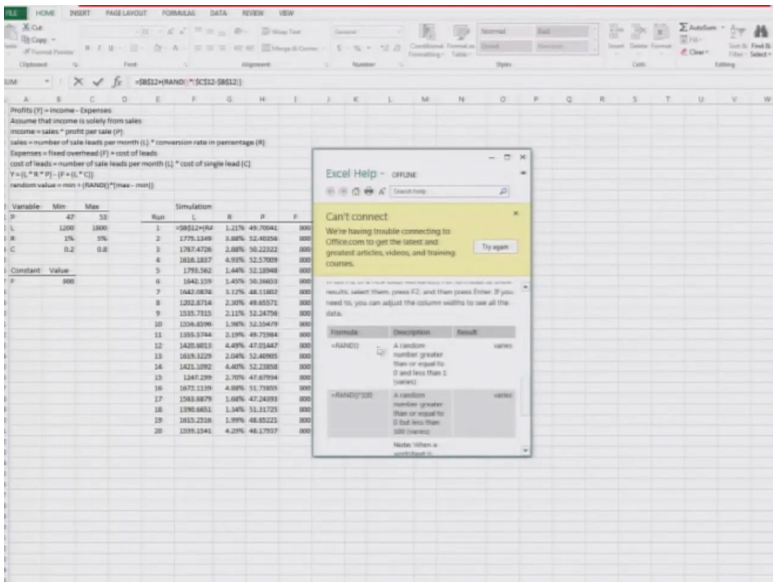

Rand gives a number greater than or equal to 0 and less than 1, it varies.

So, that is what the rand function gives you. So, you are generating your uniform 0 1 random number using the rand function of excel. Then that is multiplied by C 12, C 12 is what? This is a column C and this is the 12th row 1800. So, that is e 12 that is the maximum value minus b 12; b 12 is 1200 which is the minimum value. So, this equation

translates to your minimum plus the uniform 0 1 times max minus min ok. When you do that it gives you a one particular value.

So, let me do one thing, let me delete this many columns out of here, ok.

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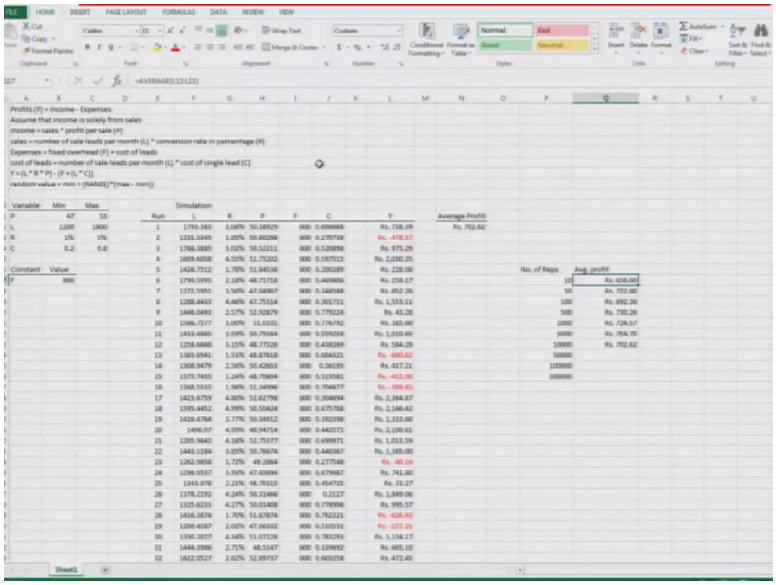

And then he will show you what it is all about. So, then, this is the case of your L. The next one is the case of your R, R is again if you look at the equation it is b 13, b 13 it is the same column as R which is one percent which is the minimum value multiplied by a plus, then random value rand gives you the 0 1 random number multiplied by C 13 is the this is C column 13 value this particular row. It is called as the maximum value of the R which is 5 percent.

So, it is 5 percent minus 1 percent. So, that is the b 13 which is smaller value, if you look into that that gives you in this particular instance is 2.24 you do not see that every time we do this, this actually keeps on changing ok. So, anyway we will change this for the time being. So, let me move this to L 16 for the time being. So, that it only calculates this particular value ok. Then P same way P is again if you look at the equation it is b 11 a P is b 11 is the minimum value which is 47 plus their uniform 0 1-rand value multiplied by the difference of max minus min max is 53 min is 47.

So, that gives the estimate of P. Then F is a constant value at 800. So, if we look at F, F is kept as 800 throughout. Then C is the cost of lead; cost of lead C is taken from this

particular case again. The minimum value is 0.2, plus the random value random 0 1-rand random variable we take out of this. And then you multiply that with the max minus min; which is C 14 minus b 14, C 14 minus b 14, you can see it right here and that gives you the value of the value of c.

So, then how do you calculate y? Y if you look into it y is a setup of the same equation that you see here, L times R times P. So, y is F 12, F 12 is this, this is the F column F 12 is this. Then that is L times R r is the g g 12 g column 12th row this particular row times h, h is the P value of P. So, L times R times P is the income side. So, the first part this parenthesis this bracket gives you this parenthesis gives you the income aspects of the study ok.

Minus income minus expense is what you need to do i 12 i 12 is the F value of F the i th column that is the value of F plus L F plus L times C L is F 12 the F column 12th row that is here the value of L times the j j is the value of C, the column j 12th row you take that particular value of j or value of C and you multiplied with L. And that gives you the estimate of your expenses ok. So, the first parenthesis this equation gives you the value of your income. The second parenthesis gives you the value of your expenses ok.

And when you do that it actually gives you the so, let me eliminate these ones to demonstrate to you what it actually means. So, the first instance that we studied this current value that you see 2 1 2 7 whatever you see here that is and if you see the average profit is average of this many columns ok. As of now there is only one value, hence whatever the value that you get here it gets the same value. Now if you think about this, if you extend this, if you increase this further, let me do this.

So, you take this much and excel and drag it extend it. So, then you can see that the first instance you got a loss of 111 rupees. Second case you got a loss of this third case you got a loss of this, 4th case also you got a loss of this. Fifth case you got a profit and then the average which is the average of this many values will actually become to a negative value. You can see that if you keep on every time I click on a new column, then this value changes.

So, if I selected this much and if I extend it further let us say 20 values ok, this profit is up to L 16, I am going to change it into L 31, 31 do that then you can see that the average profit is 768 ok. So, 20 instances if I do this.

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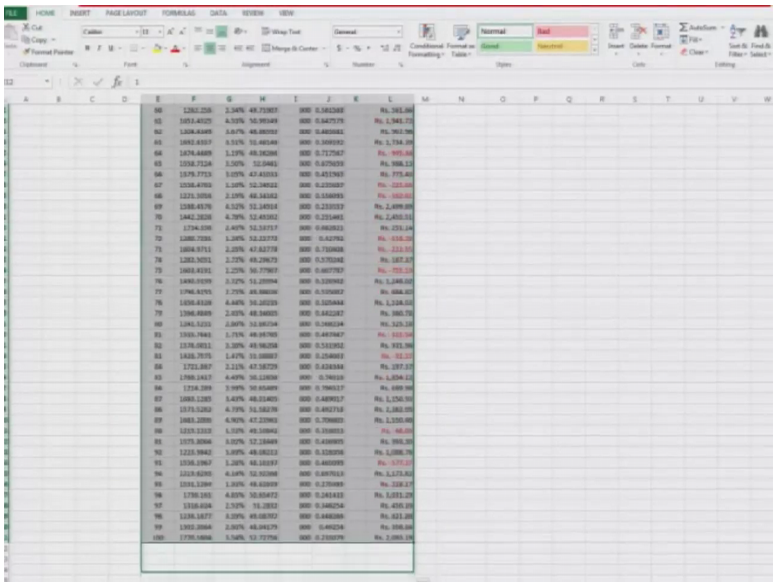

Now let me change this to ok let me pull it down further. Let me pull it down to 100 instances. And pulling it down we can see the columns changing to 100 instances, I rolled it down. And so, I have a 100 such simulations of this case ok. And sorry I have to change this. This should be 800 only; it cannot be more than 800 that is a small mistake. Sometimes excel will do this to you, you have to be very careful when excel does this.

So now if we pull it down, it should not change will just be 800 ok. So, everything is 800, now the equation is back to normal. You can see that none of the values are exceeding b or above whatever the values that is taken. And then the profit is still only 31, we need to enhance it to what is this column is 111. So, we make it as L 111. Now we get a number here ok. So, you have now 100 instances of this. Ok now if I make this 100 to something called as 100, I am going to roll it down further to let us say very large number of 1000.

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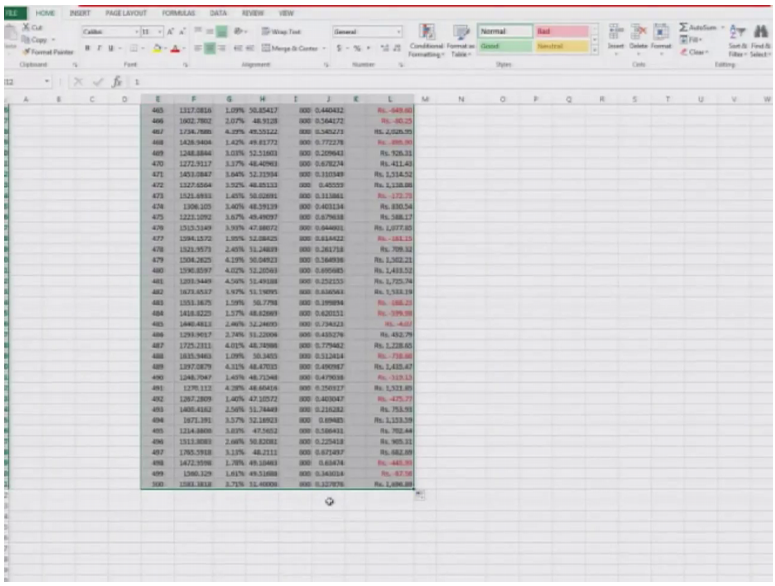

Let us call it just 500, let us make it to 500 simulations, 500 of them. And this column is 511 ok. So, if you now if you go up, you can see that 6 6 7 is the average. So, I change this to 511, 511. You can see that the profit will start to converge. So, if I click something and click this, you can see that the prof the variation of the profit will be very limited ok.

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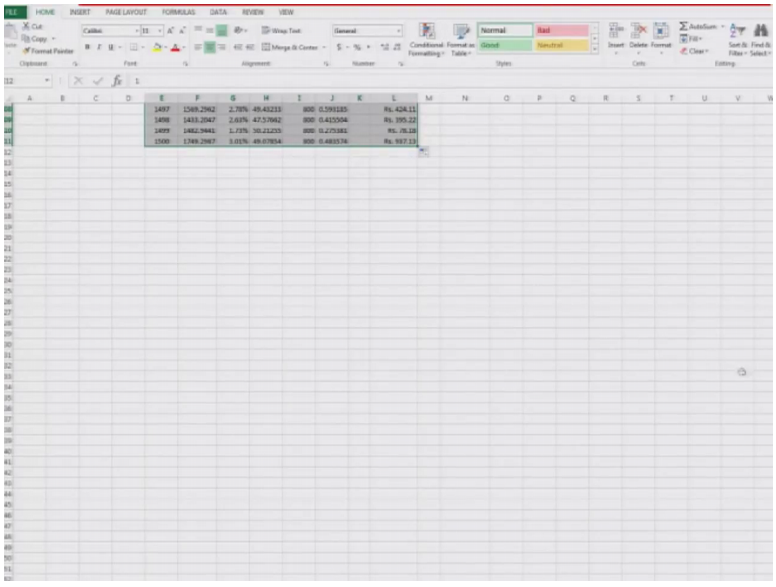

Now I make a change here, I select all the 500, 500 of them and am going to study make it a 1000 simulations ok. So, let me take it into something called, let me take you to the 1500, 1500 simulations. All of those who are these are used 1500, and the column is

1511. So, thousand more simulations were added. And we come here and write the average profit to be average of 1511, you look into this. Now you can see that the values will start to converge, if you change anything here and say that you will see 7693, 701 like this.

So, Monte Carlo simulation is like this pretty much. You simulate a large number of very large number of simulations of the particular behavior of the system. And from this you basically study the average. So, this particular value that you see is the average behavior of the system. If you have smaller number, this number will keep on varying drastically. You can see the individual instances. In one case it is a 100 rupees profit, another case it is a 900 rupees' loss 61 rupees' profit 896. Loss 200 rupees' loss 80 for profit 81 for profit 1700 rupees' profit, there is 2340 rupees' profit. So, the system demonstrates a large amount of variability as part of this study of the system.

So now if now let me give you an example of what was the so, let us see what happened when the let us so, let us see let us see the number of replications. And number of perhaps replications, am just going to change this ok. And average profit, average profit. So, I am first going to make this 10 replications, the number of replications only being done. So, we take change this value to 21, L 21 just this much, only 10 replications. And the average value average so, number of replications being 10, you get the average value of ok.

The current average value we are getting is 1134.88 that is the average value we got. Now we make this 10 to let us say make 50 reps. we do 50 so, what is the value of 50? 50 will be in this particular column which will be 61. So, if we change this to 61 and the value you are getting here is 565.60. Now let me make it as 100.

So, 100 in this case will be average will be 100 will be what will be 100? 100 I believe is 111 ok. So, I just make it as 111. So, for 100 I get a value of 720.48. Then let me make it value of 500. What will be 500? Let us see 500 will be 500 is somewhere here. 500 is 511 column ok. So, we go back and change this to profit will be 511, 511 average of that ok.

So, 500 you get a profit of 663.46 now let us do something for a thousand, we do thousand applications, what the value will be? So, do I have thousand here I think I do how thousand, thousand s set a column of this 1011. So, let us do that for 1011. Ok for

thousand I get an average profit of 702. Now I am not going to do for 1500, but let me do it for 5000, for the time being. and for excel the advantage of doing this in 5000 is that, I just do not need to do much, I just have to go down, am just going to scroll it down until I get to 5000. You are going to just overwriting those values, does not matters ok.

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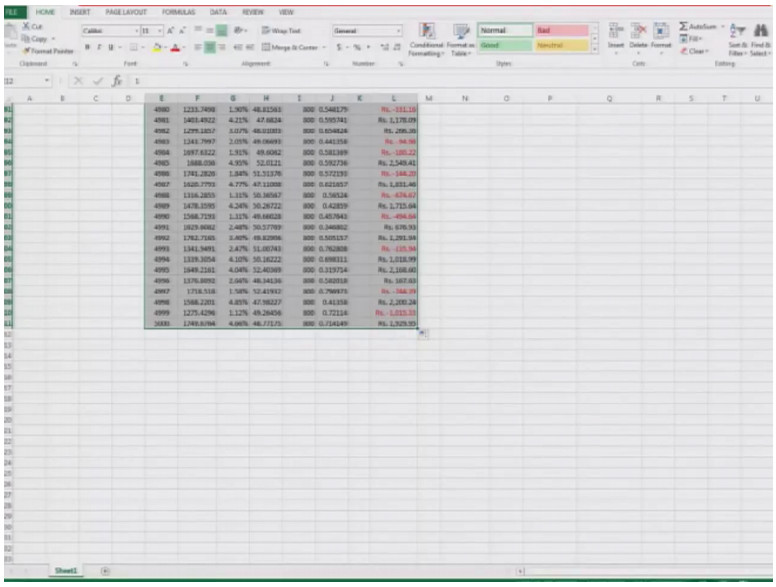

It is 1600, 1700, 2000 getting close to 2000.

So, if you manually do this it will take you a long time to compute all these many values manually. In a spreadsheet it is very easy for you to compute these values ok. I mean once you do this the rest of the calculation will be all done by the computer by in itself. So, you do not have to worry much about it. So, am just extending it am trying to run to 5000 simulations. You can do 2500 and all those kind of things, what I want to show you is the convergence of the simulation actually after some point of time. You can estimate the long term average, when you have a large number of values ok.

They want to demonstrate to you the large number of values I especially in the case of simulation. So, we are getting close to the 5000. We approach to 5000 somewhere here. So, 5000 is only here leave it here, all these values are calculated. The raw value is 5011 ok. So, let us go up and change this to instead of 105011. And you can see that it will be 697.83. So, if you look into this when you had smaller number of simulations, when you had 10 the value was 1100. When you are 50 their value is 565 it is huge variation.

So, it will be very hard for you to convince a person that no other profit can the profit is the expected profit is, in the first case if you only do 10 simulations. You will get 1100 value whatever it is. I mean the value will change depending upon what is a random number it is using. If you do only one simulation, you can get a wide variety of values. If you do 10, you get a different value get 50 another value, 100 you get a different value, 500 another value, but if you see be above 100, 500, 1000, 5000; in between 1000 and 5000 you see the variation in the values are very small. So, if you take these then if you do 10,000 you will get a different number 50,000 it will be a different number.

So, if you do these I my suggestion to you guys ease do the simulation for now 10,000, then you do it for 50,000 ok. Then you do it for 100,000 or what we call it as a 1, 00,000 ok. And then you do it for what we call as say 500,000. That much simulations you do and you pull those values here and see how these values, whether this converges to something.

And if the values converges to something then you can easily say that so if you do this like for example, we took this all thing to what 5000 simulations, this was the 5000 simulations we did.

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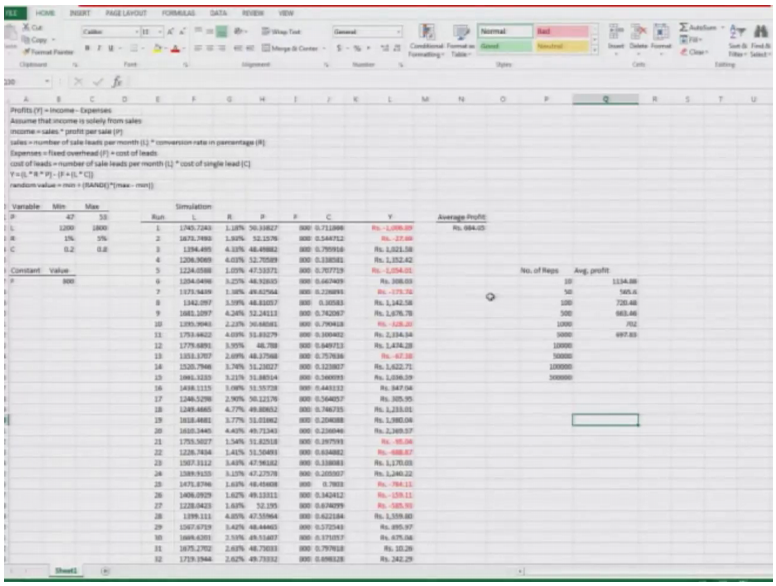

If we pull it down to 10,000 I just wanted to demonstrate the last 10,000 value. So, this is 6000 so, the good advantage of the computer is that, it will do the calculations for you, you do not have to worry about doing the calculations. This is excel big makes the life

much easy for you to do these kind of Monte Carlo simulations whereas, manually if you try to do this, it will become a complicated issue for you. So, here is the 10,000 simulation present, 10,000 right here and the column value is 10,001.

So, let us go up and do the simulation you change it in to instead of this we make it as 10001 to the average and 10,000 simulation it shows it does 694.39. Now you can see that as the number of simulations have increased, you can see this average profit value starts converging to something. And this convergence is what we actually are interested in studying of a simulation. In realistically if you think about a system, it will take you to study 10,000 simulations or 50,000 simulations you will take you a long time period. So, to avoid that, you actually use Monte Carlo method.

Now, we can see for 50,000 you will see this value starting to converge and if you plot this number of reps with again as this average profit, and you can see the graph of that and as well. So, one of your assignments after of this is to do these 3 simulations, set it up this excel spreadsheet, and then submit the graphs of the simulations exactly doing up to 5 lakh simulations. And see what is the average profit ok.

And how the average profit has become converging to a specific value. So, I hope now you have seen what is the Monte Carlo simulation, you understood the mechanism of Monte Carlo simulation how it works internally by using uniform 0 1 random variates, all values being equally likely. And you study between the minimum and maximum level of each variable. Now one more thing that I wanted to demonstrate here is, now one of the analysis in simulation, remember I told you is what we call as alternate analysis or sensitivity analysis.

So, if I want to say that fine the value of R, R is the conversion rate in percentage, now your sales crew changed, and the lower conversion rate is no longer one percent instead of it is 2 percent ok. How will this impact the profit? So, if you use that then you know you can immediately see that by changing this to 2 percent this average value has changed; 2 percent. So, the if you change this to this 5 percent becomes let us say it does 6 percent, 1 percent or 5 percent if it changes immediately the profit will change.

So, studying different values ok studying different setups using this ok is called what we call us if it is one percent to 6 percent what the profit will become ok. Or if it is one

percent to 5 percent what or general case what it becomes, you can see the change in average profit how does it actually varies.

So, by changing the C the value of 0.2 to 0.8 if you make the value of 0.2, if you make this 2.3 as minimum what will how will the profit will be changing. You can see that the profit will change this particular fashion. The profit will actually reduce. If you make this as 0.1, what will happen to the profit, then the profit or limit in the average profit you will start to increase.

So now you can play around with the values of different factors and decide which factories of most importance to you. This is what we call us the alternative analysis or significant analysis. And from here we can decide whether this value to which value mean to pay more or more focus to, do we need to pay if focus to F P or L or R or C. Can we what will be the impact if this F will be reduced from 800 to 600 how will the profit change. So, or if it is increased then what happens ok. All these studies can be done with the help of this.

So, and one way to do this also in so, I just copied the values and showed it to you. But one way to do this is you can write actually this and the same equation you can copy and write it here. You can write it as equal to average; average of L 12 to L 10 will be L 10 is here L 21. You can do it this fashion, sorry, my bad L 21 ok. So, same way you can do it as you can copy this. And then be here and L 12 to L 21 instead of this you can find where is this 50, where the value of 50 is you find out where 50 is. 50 is implies in 50 is here L 61.

So, you go up and change this to L 12 to L 61 ok. So, then you can do the same except process what happens. So, then you can see now more realistic values showing up here ok. So, then you take this case of again equal to average of L 12 to 100 will be it was 10 was 21. So, it would be 111, I believe to L 111 believe. So, what was L 111? Think it was 111 was 100, I believe yes, 100 was 111.

So, then similarly you can do for 500 as a thousand will be 100 is this, for 500 equal to I have a range of L 12 to L 511 ok. So now, you see the different value. Same way 1000 will be equal to average of L 12 to L 12 to L 1011. To do this then you get a different average, how is this completed? Not comma I believe it should be column, my bad, alright. The number should be column, not coma the in between is a column, this is

column, that is correct, this is should be column, this should also be not comma what I call ok. Then 500, then 5000 will be you can scroll down and do the same thing, average of L 12 to L 5011 I believe, ok.

So, you get done same way equal to average of L 12 to L 100 to 11 ok. Do that you can see that these values will start to change the minute you do something the values will change differently ok. So, different values are used and then you can see different averages coming up in different time, and you will see that it will start to converge as such.

So, do that and you will get an idea of what we are talking about. Hopefully this makes you make you understand the importance of Monte Carlo simulation. And how can you study different averages and look into what the average numbers are and then go from there. So, thank you very much for your patient listening. And I would request all of you to set up an excel spreadsheet like this.

And study accordingly, you are already been shown what are the importance of the excel spreadsheet. Use the video set up your excel spreadsheet, do this and complete take this kind of an analysis as your basic analysis. And once it is completed, please submit your keep that results in handy, because it will help you in as your homework another aspect ok.

Thank you very much, and thank you for your patient listening.