Project Management

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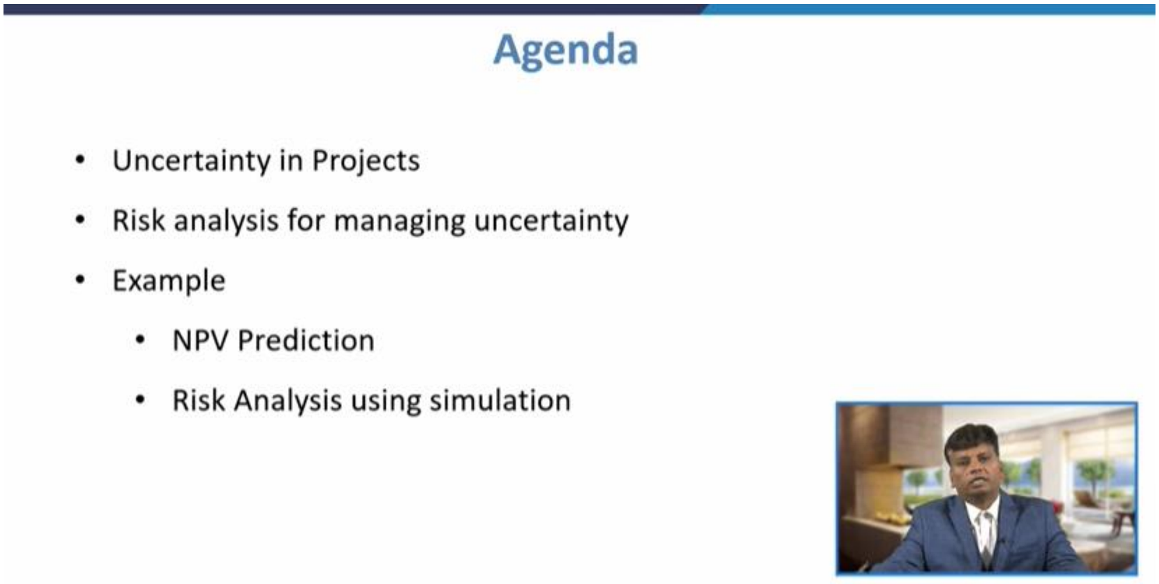
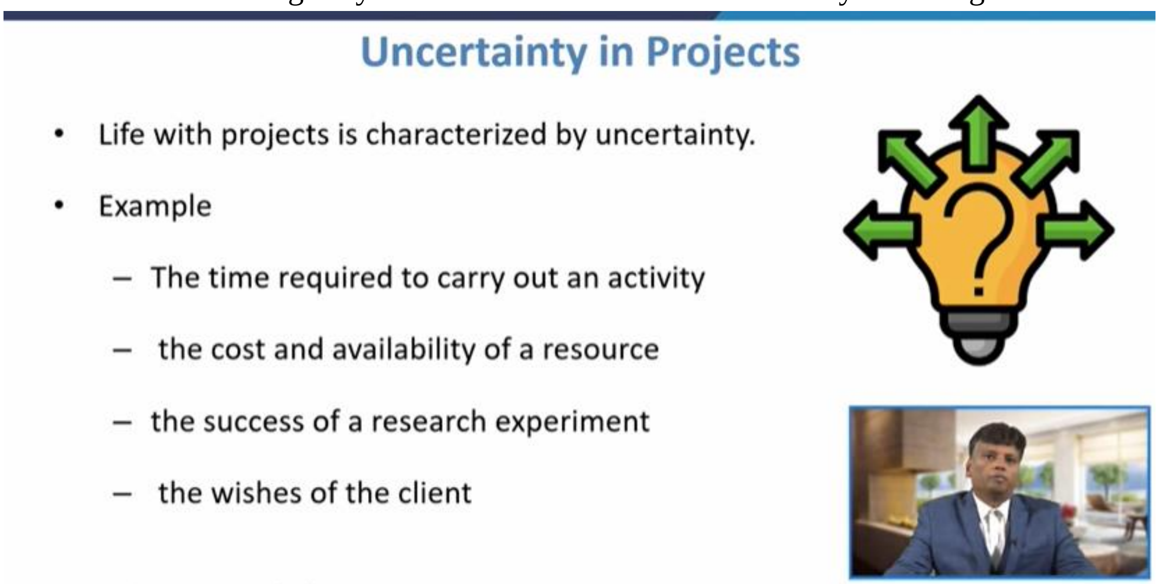
Week: 5

Lecture 22 Risk Analysis with simulation for scheduling

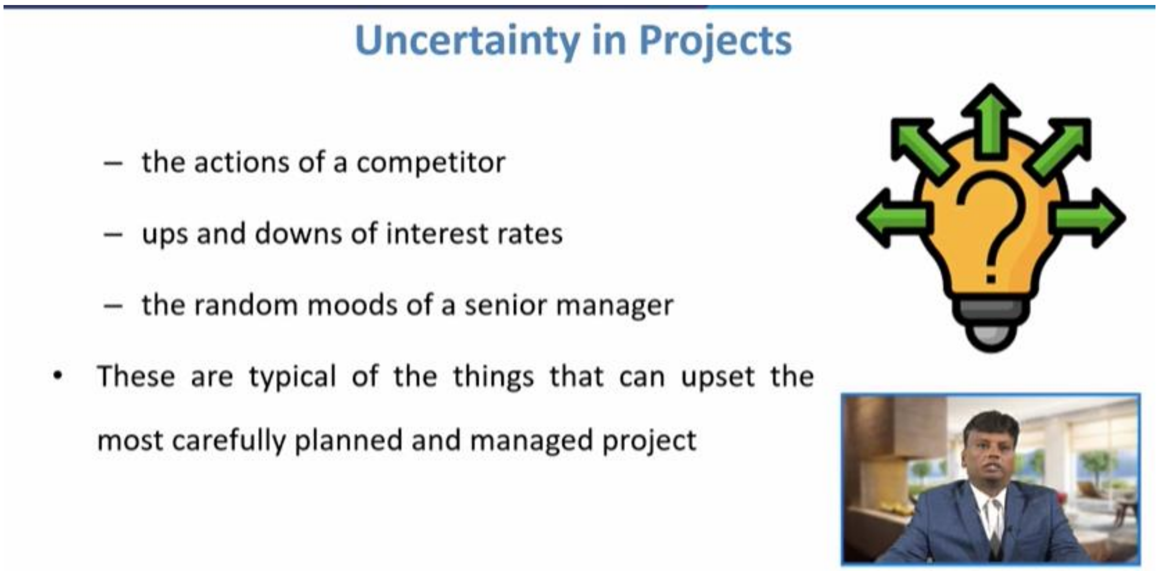
Dear students, in the previous class I have explained how to use PERT for scheduling. In this class, I am going to explain how to do the risk analysis with simulation for scheduling purpose. So, this was just to know the continuity I brought the slide. So, the previous class we are discussing about PERT. In this class, I am going to discuss about risk analysis with simulation for scheduling. So, the agenda for this lecture is what are the uncertainty in the projects, how that uncertainty can be minimized, then I will discuss about risk analysis for managing uncertainty.

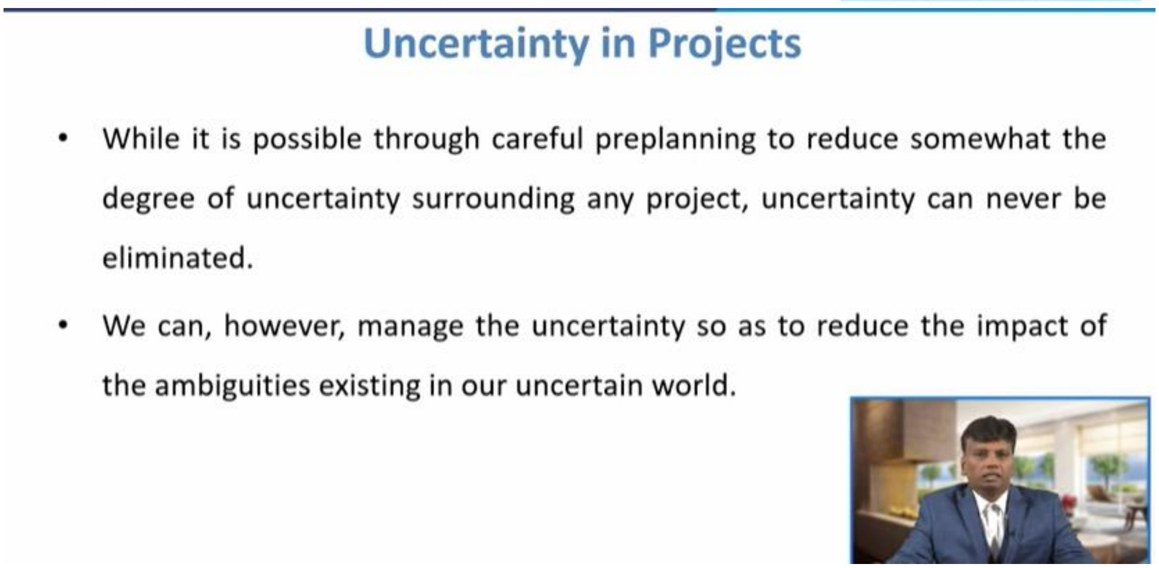


So, one of the way to manage the uncertainty is risk. So, that risk analysis I am going to use a software an add-in in excel called crystal ball. So, I have taken two example, one I will explain how to predict the net present value. The second one, I will explain how to do the PERT using crystal ball that is a risk analysis using simulation.

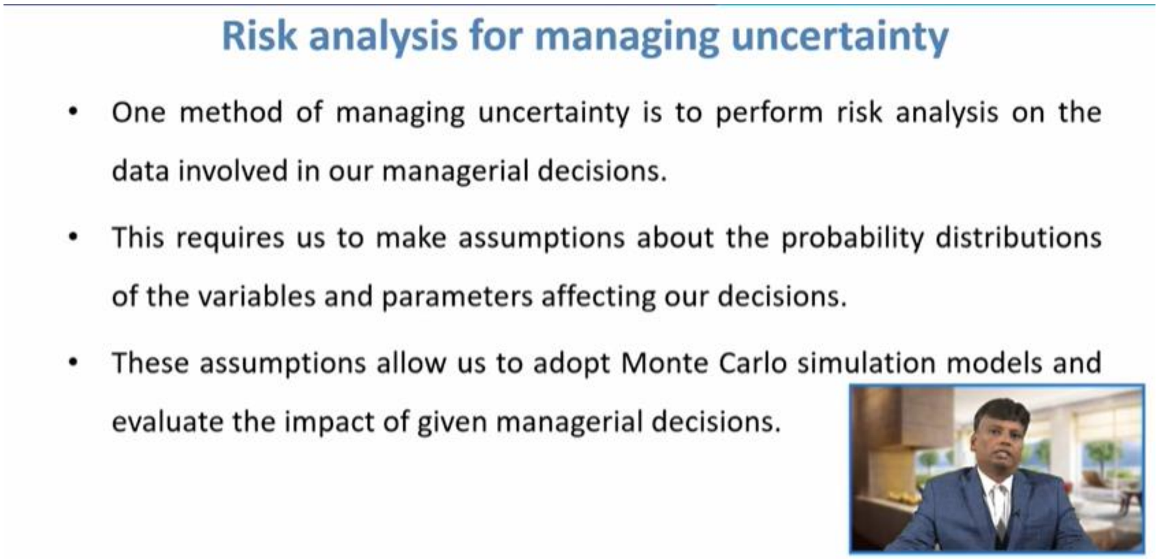


So, what are the uncertainty in the project? So, life with the project is characterized by uncertainty. There are so many uncertainties there in the project, for example, the time required to carry out an activity is uncertain event. The cost and availability of resource is another example of uncertain event. The success of a research experiment is uncertain event and the wishes of the client also uncertain, because they may keep on ask different requirement. The actions of the competitor is another example of uncertain event, ups and downs of interest rate and apart from that the most uncertain is the random moods of a senior manager.

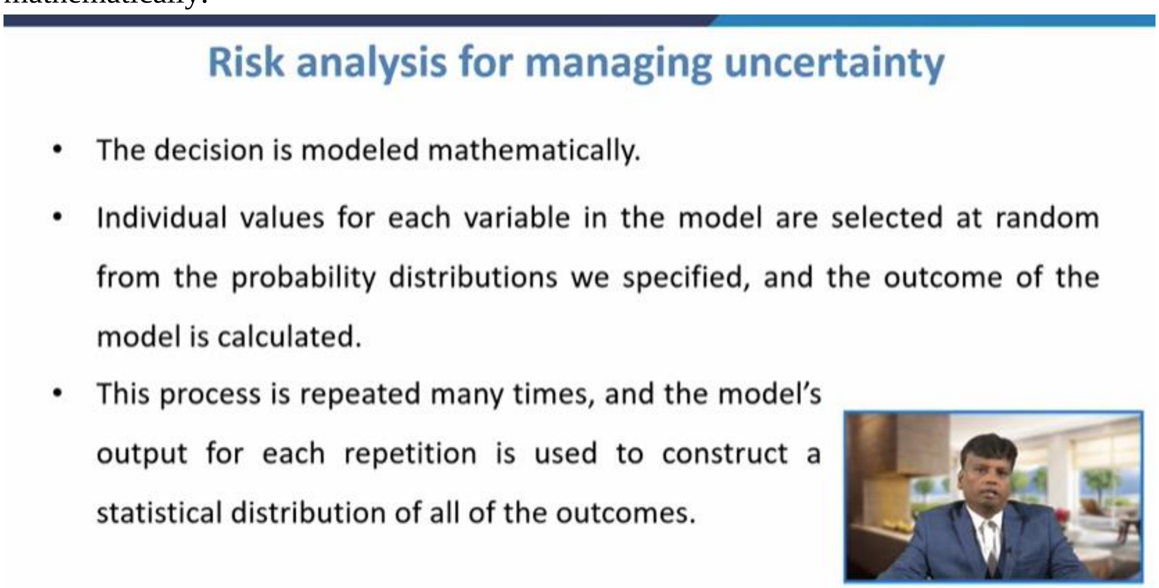




These are typical of the things that can upset most carefully planned and managed projects. While it is possible through careful pre-planning to reduce somewhat the degree of uncertainty surrounding by any project, uncertainty can never be eliminated, but we can however manage the uncertainty so as to reduce the impact of the ambiguity existing in our uncertain world. So, we have discussed so many uncertainties that cannot be completely eliminated, but the impact of that uncertainty can be minimized. One method for managing uncertainty is to perform risk analysis and the data involved in our managerial decisions. This risk analysis requires us to make assumption about the probability distribution of variables and parameters affecting our decision.

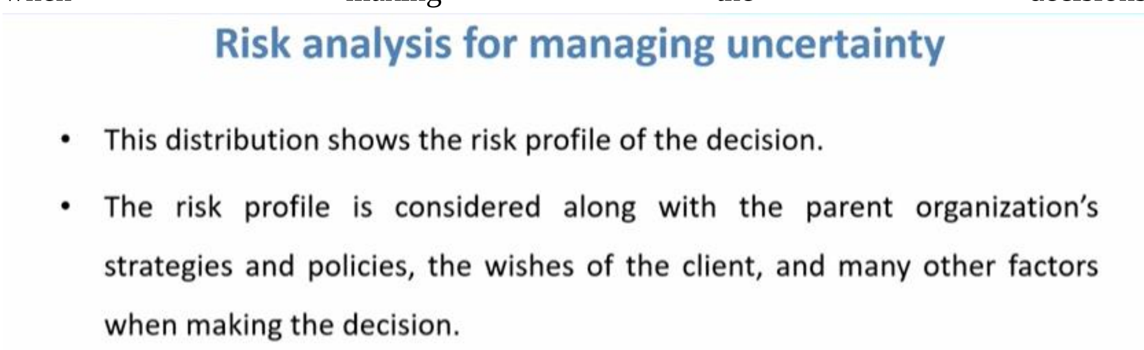


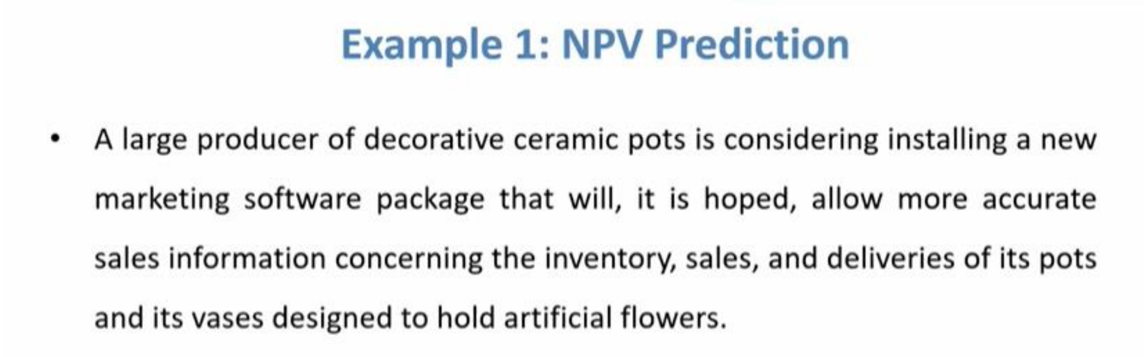
So, when we do the risk analysis, we have to assume certain probability distribution of our variables. So, these assumptions allow us to adopt Monte Carlo simulation model and evaluate the impact of given managerial decisions. In the previous lecture also before that I have discussed how to use excel for doing Monte Carlo simulation, but in this lecture I am going to do Monte Carlo simulation using an excel add-in called crystal ball. When compared to excel, this crystal ball have more options to choose different types of input which follow different distributions. Many time the risk analysis is done mathematically.



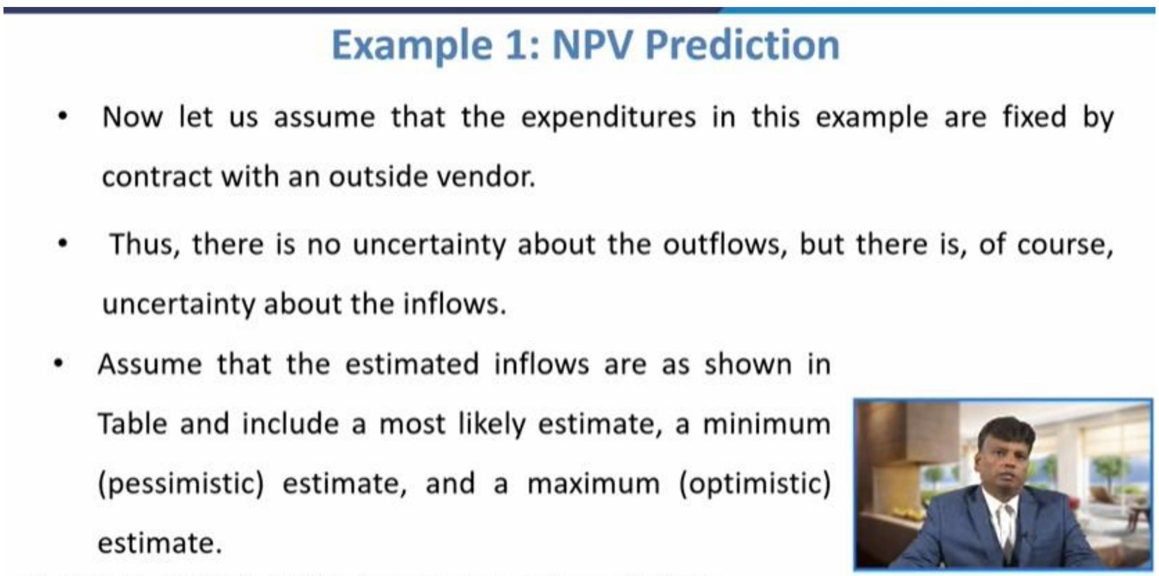
So, individual values of each variables in the model are selected at random from the probability distributions we specified and the outcome of the model is calculated. So, what will happen any simulation model there will be different input say x1, x2 assume that this y1 is output. So, the x1 may follow certain distribution, x2 may follow some distributions that has to be assumed it may be follow normal distribution, it may follow uniform distribution. So, the software what that does it takes randomly different values based on its distribution for x1 and x2 and it does the calculation by using some mathematical model and finally provide the output. So, this process is repeated many times and the models output for each repetition is used to construct a statistical distribution of all the outcomes.

So, there will be x1, x2 there will be set of values for each and every value of x1 and x2 there will be different y1. So, the output of that y1 is distributed in the picture form based on that output distribution then we can have some managerial inferences. This distribution shows the risk profile of the decision. So, whatever the output comes the output if you plot in the form of distribution we can get so many inferences so that is called our risk profile. So, the risk profile is considered along with the parent organization strategies and policies and the wishes of the client and many other factors when making the decisions.





I will take an example of prediction of net present value. This is an hypothetical example the example says a large producer of decorative ceramic parts is considering installing a new marketing software package that will it is hoped allow more accurate sales information concerning the inventory sales and deliveries of its parts and its vases designed to hold artificial flowers. Now let us assume that the expenditure of that project purchasing a new software in this example are fixed by the contract with outside vendors because that may be the maintenance of the software. So, what will happen that there is no uncertainty about the outflow but there is a of course uncertainty about the inflows. Assume that the estimated inflows are shown in the table, I will show in the next slide and include most likely estimate a minimum estimate and maximum and that maximum estimates called optimist there are three type of estimate most likely estimate, minimum estimate and maximum estimate.



1	**Hurdle Rate**	13.0%		
2	**Inflation Rate**	2.0%		
3	A	B	C	D
4	**Year**	**Inflow**	**Outflow**	**Net flow**
5	20X0*	$0	$125000	-$125000
6	20X0	$0	$100000	-$100000
7	20X1	$0	$90000	-$90000
8	20X2	$50000	$0	$50000
9	20X3	$120000	$15000	$105000
10	20X4	$115000	$0	$115000
11	20X5	$105000	$15000	$90000
12	20X6	$97000	$0	$97000
13	20X7	$90000	$15000	$75000
14	20X8	$82000	$0	$82000
15	20X9	$100000	$0	$100000
16	**Total**	**$759000**	**$360000**	**$399000**
17	**NPV**			**$17997**
18	**t=0 at the beginning of 20X0*			

Pessimistic, Most Likely, and Optimistic Estimates of the Cash Flows for Ceramic Sciences, Inc.

	A	B	C	D
1		**Minimum**	**Most Likely**	**Maximum**
2	**Year**	**Inflow**	**Inflow**	**Inflow**
3	20X2	$35,000	$50,000	$60,000
4	20X3	95,000	120,000	136,000
5	20X4	100,000	115,000	125,000
6	20X5	88,000	105,000	116,000
7	20X6	80,000	97,000	108,000
8	20X7	75,000	90,000	100,000
9	20X8	67,000	82,000	91,000
10	20X9	81,000	100,000	111,000
11				
12	**Total**	$621,000	$759,000	$847,000

Look at this figure this is the hypothetical example say the hurdle rate is given inflation rate is given many time the inflows see there are up to 20 x 9. This column shows the inflows this column shows the outflows this is the net flows that is the difference between inflow minus outflow. See this star * represents at the beginning of 0th year so the investment is 125,000 because there is no inflow there is no income from the project that is the buying the software. In the first year the investment is 100,000 that time also there is no inflow not the first year the beginning the end of the 0th year. Then first year it is 90,000 similarly third year 15,000 like that there is a various outflows and we are getting the benefit out of this project only from here onwards that is the x2 onwards 50,000 120,000 and so on. Now what will happen this portions we are going to consider an uncertain inflows obviously in practical you cannot exactly predict what is going to be inflow but these outflows are fixed because this was the requirement of the contractor anyhow we have we have to pay for that and the hurdle rate is fixed but we are going to consider the inflation rate is one of the uncertain cells.

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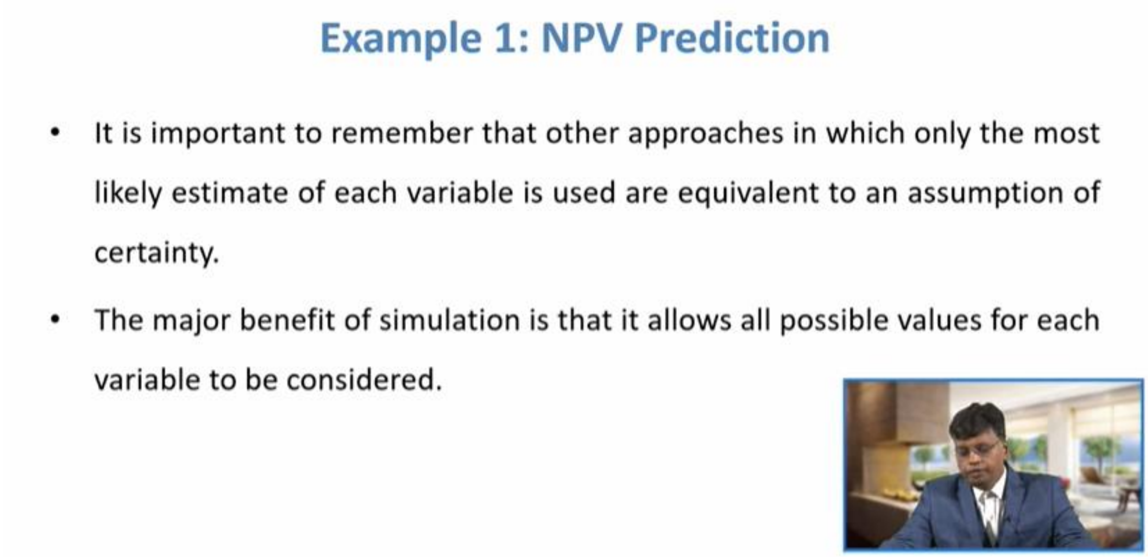
Source: Meredith, J. R., Shafer, S. M., & Mantel Jr, S. J. (2017). *Project management: a strategic managerial approach*. John Wiley & Sons

So, what is the setup for this problem is we are going to consider inflows in the form of uncertain so there are three time estimate is given for example year two so the minimum inflow is 35,000 most likely inflow is 50,000 and maximum inflow is 60,000. So, what we are what we are doing we are replacing this 50,000 instead of a single value we are supplying three values minimum most likely and maximum. Similarly, we are replacing 120,000 then we are going to provide minimum most likely and maximum. So, there are two uncertain input one is the inflow other one is inflation rate. So, the firm fixes the hurdle rate of return so the only remaining variable is inflation rate included in finding the discount factor.

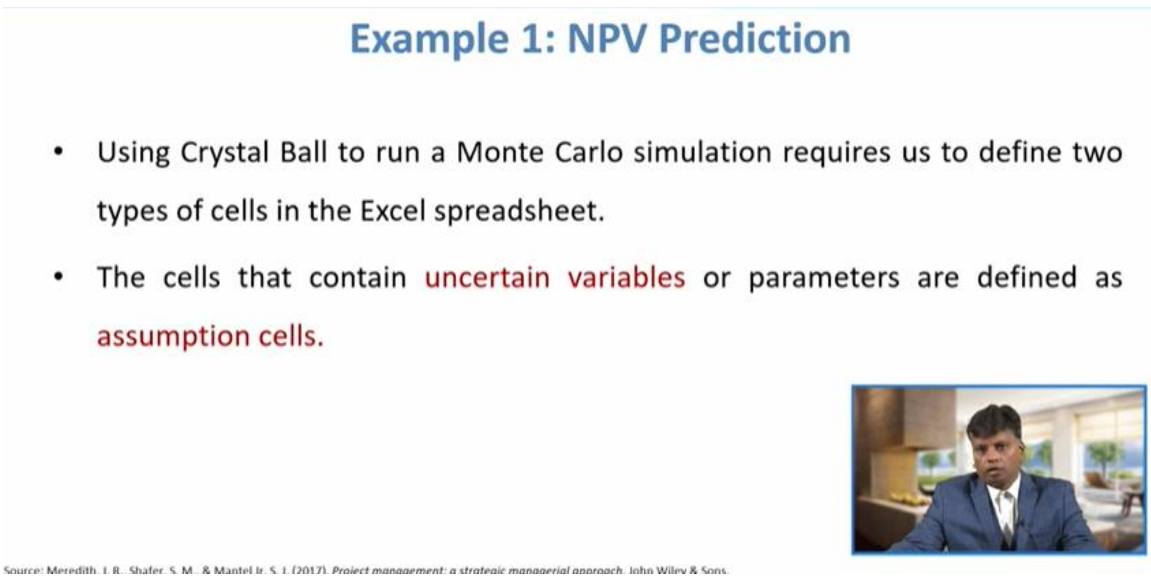
Example 1: NPV Prediction

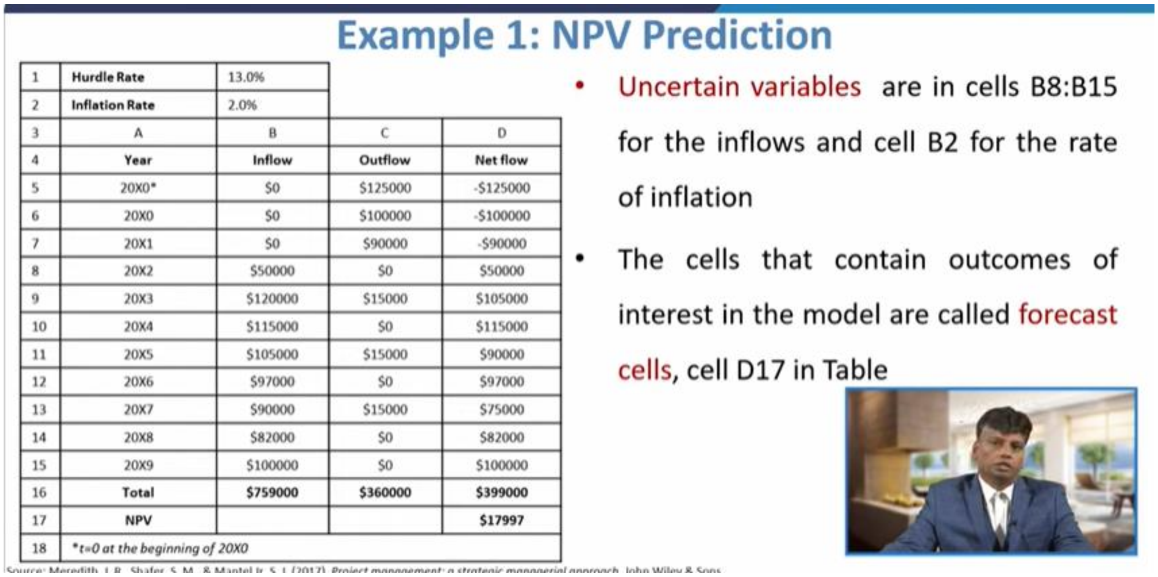
- The firm fixes the hurdle rate of return, so the only remaining variable is the inflation rate included in finding the discount factor.
- We have assumed a 2 per cent rate with a normal distribution, plus or minus 1 per cent (i.e., 1 per cent represents three standard deviations).

We have assumed that a 2% rate with a normal distribution plus or minus 1 percentage as the variation a tolerance we can say. So, the inflation rate follow normal distribution the mean is 2 percentage the variation is plus or minus 1 percentage this is the one input. It is important to remember that other approaches in which only the most likely estimate of each variable is used are equivalent to an assumption of certainty. What we can do instead of having three time estimate like minimum maximum and most likely but sometime some people may consider the most likely value as most likely value as a an approximate. So, the major benefit of simulation is that it allows all possible values for each variable to be considered instead of keeping it as a constant value like considering only the most likely value.



So, we can have all type of possibilities of the estimate that is the advantage of this simulation. So, using crystal ball to run a Monte Carlo simulation requires us to define two type of cell in the excel spreadsheet. So, two important things has to be declared when we use Monte crystal ball. The cells that contain uncertain variables or parameters are defined as assumption cells. The next one is uncertain variables the example of uncertain variable is here is.





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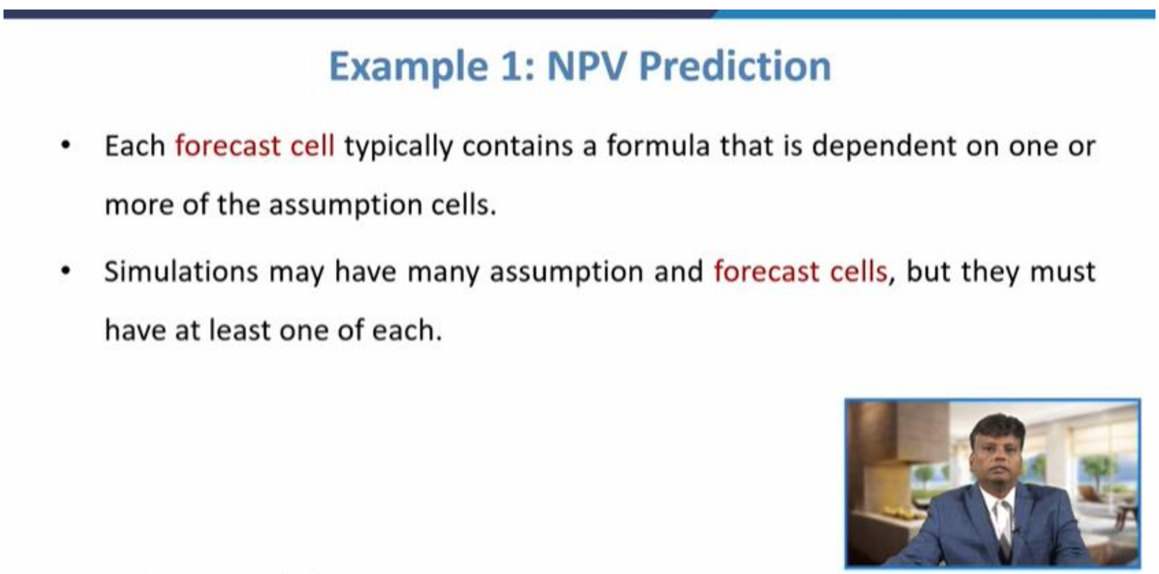
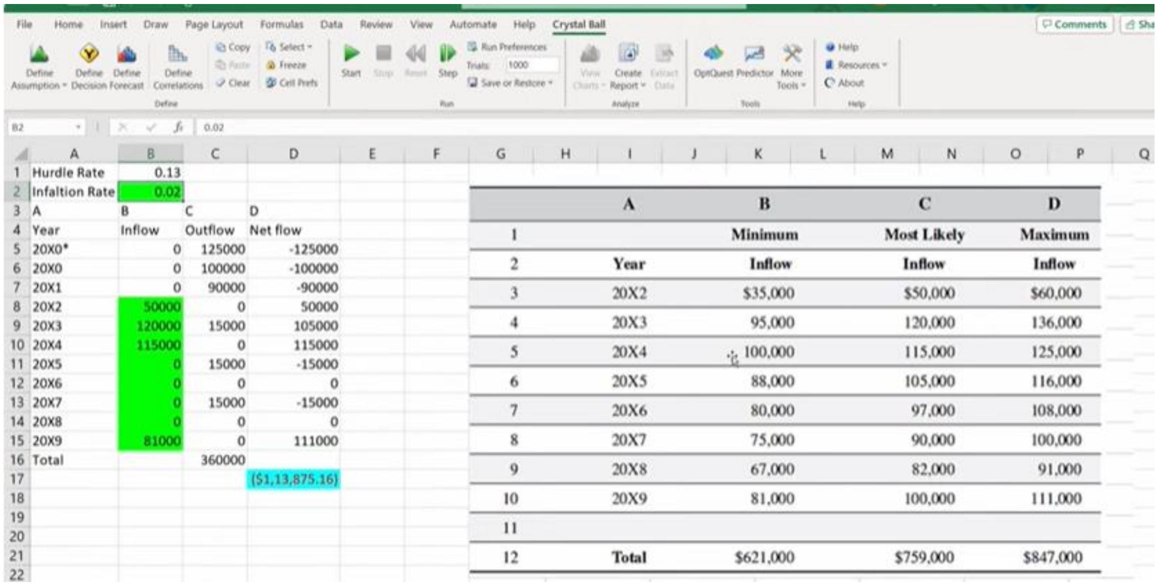
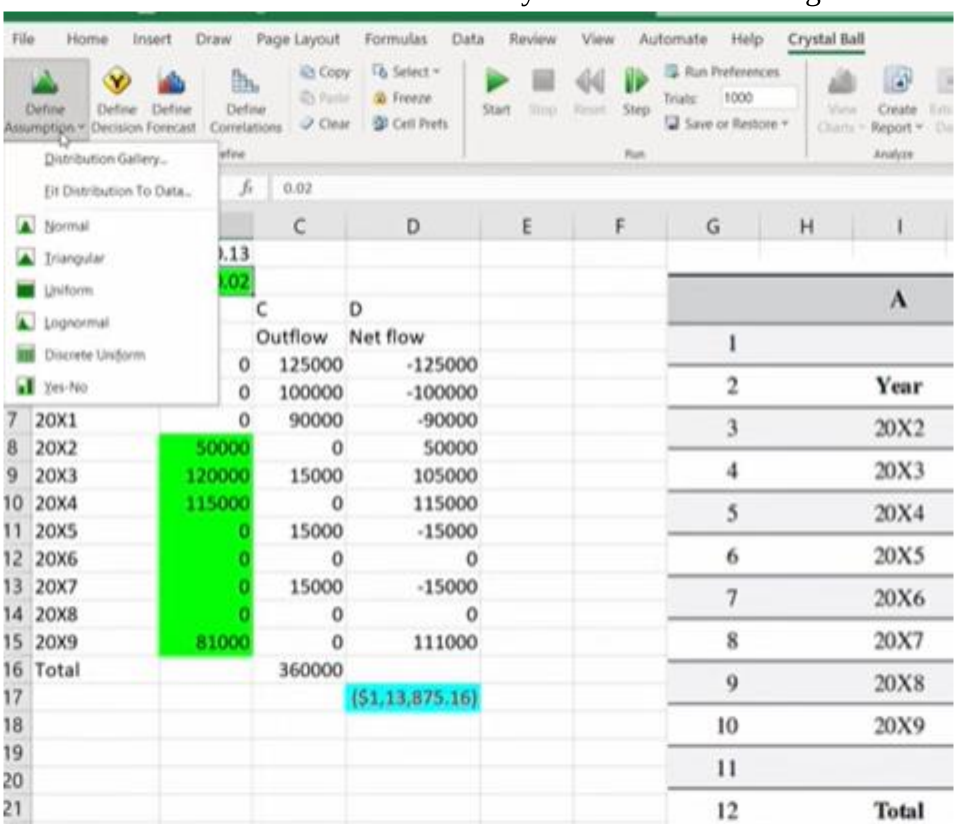
So, the cell B8 to B15 here this portion we are going to say is uncertain variables. The cells that contain outcome of the interest in the model are called forecast cells that is D17. And another uncertain cell is this inflation rate. So, each forecast cell typically contains a formula that is dependent on one or more of the assumption cells because that forecast cell should have some formula because that should be depend on our assumption cells. Simulation may have many assumptions and forecast cells, but they must have at least one of each.

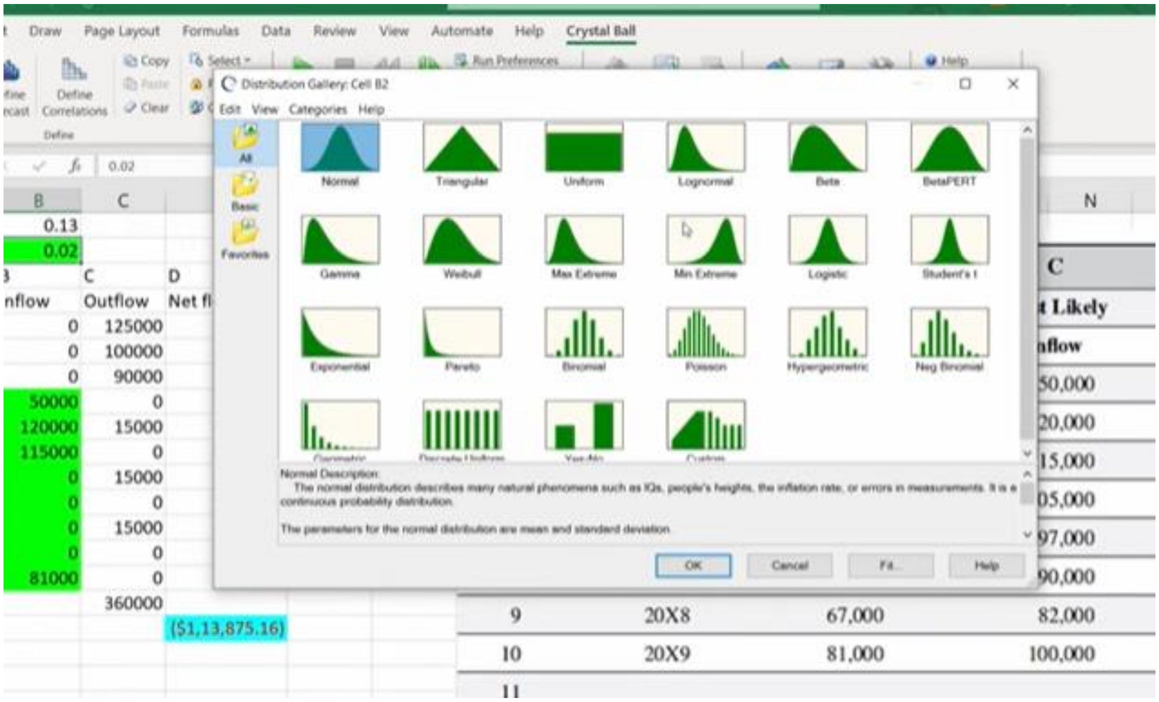




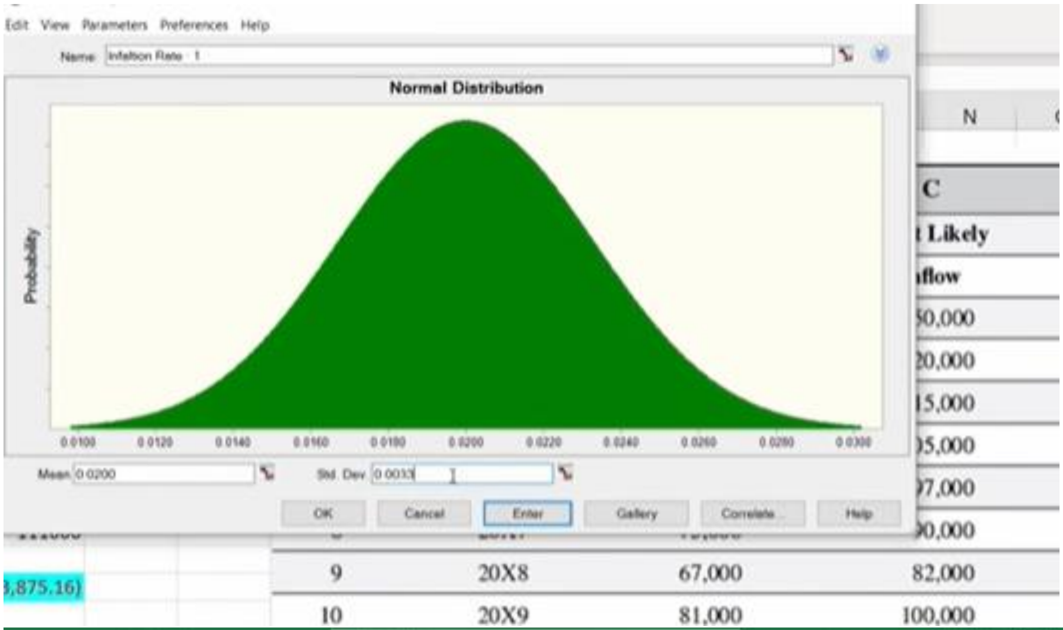
Now, we will go to crystal ball I will explain how to use crystal ball for predicting the net present value. Dear students I have installed the crystal ball in my computer after installing there is a tab appearing crystal ball when I click here I have already entered the data here hurdle rate, inflation rate, inflow, outflow and net flow. Net flow is difference between inflow minus outflow. Now, I am going to define all variable cells uncertain cells. The first one is inflation rate you click here then go to define assumptions.

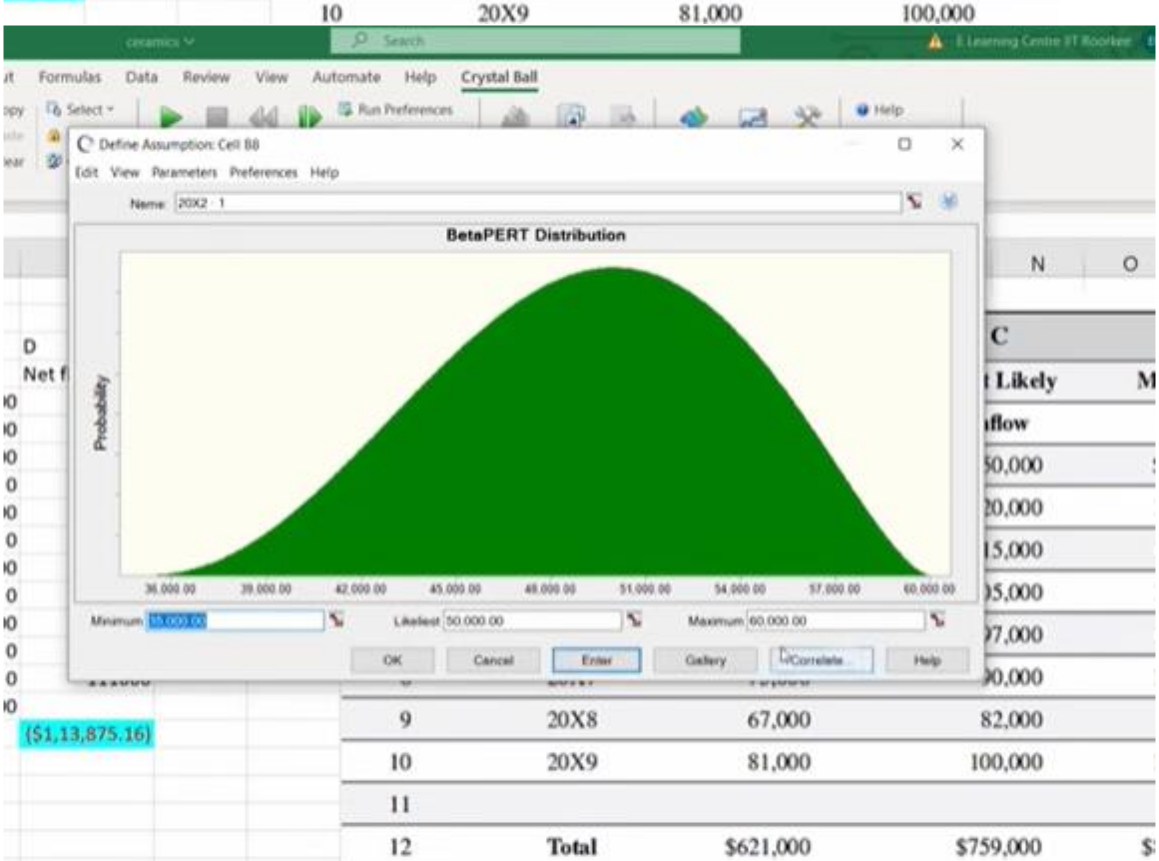


So, you have to choose what distribution that inflation rate follows. So, you can go distribution gallery when you click gallery there are so many distributions there. Suppose we go all you can get there is a normal, triangular, uniform, log normal it is up to you to decide based on the problem what distribution that uncertain variable is following. So, now I since now I am going to assume that that inflation rate follow normal distribution. So, I am going to choose normal yeah this is normal.



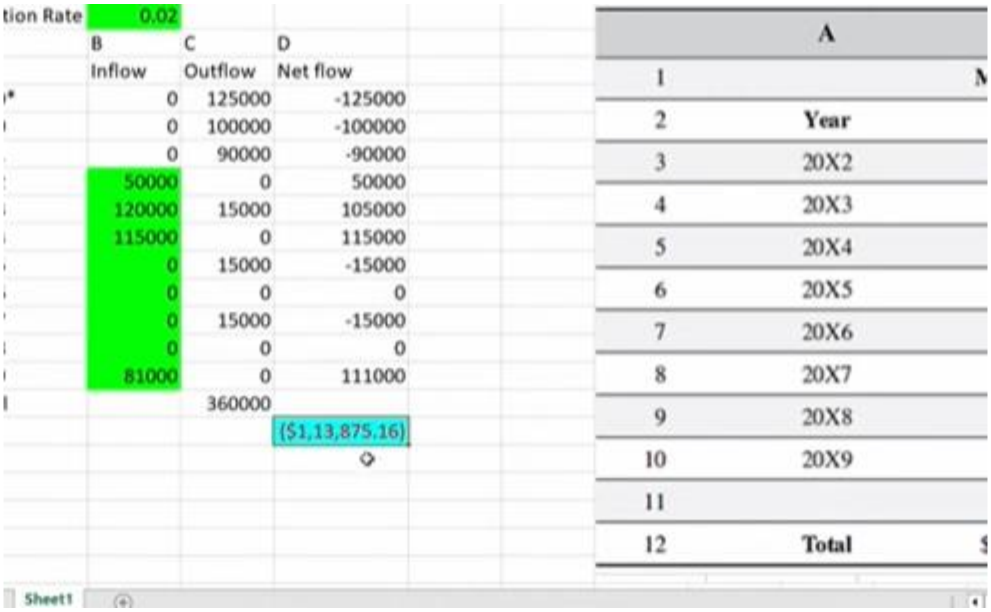
So, when I enter normal it is asking mean that I have to enter because 0.02 is the mean and the tolerance for that inflation rate is the variability is 1 percentage. If it is 1 percentage it will follow 3 sigma limit any normal distribution. So, 1 percentage upon 3 is 0.0033. So, that I have entered as a input. Now, I am going to choose this B8 here as I told it is going to follow beta distribution. So, define assumptions you go to distribution gallery. See here there is a distribution called beta part. So, I am going to click this one when I press ok it is asking minimum value, likeliest value and maximum value.





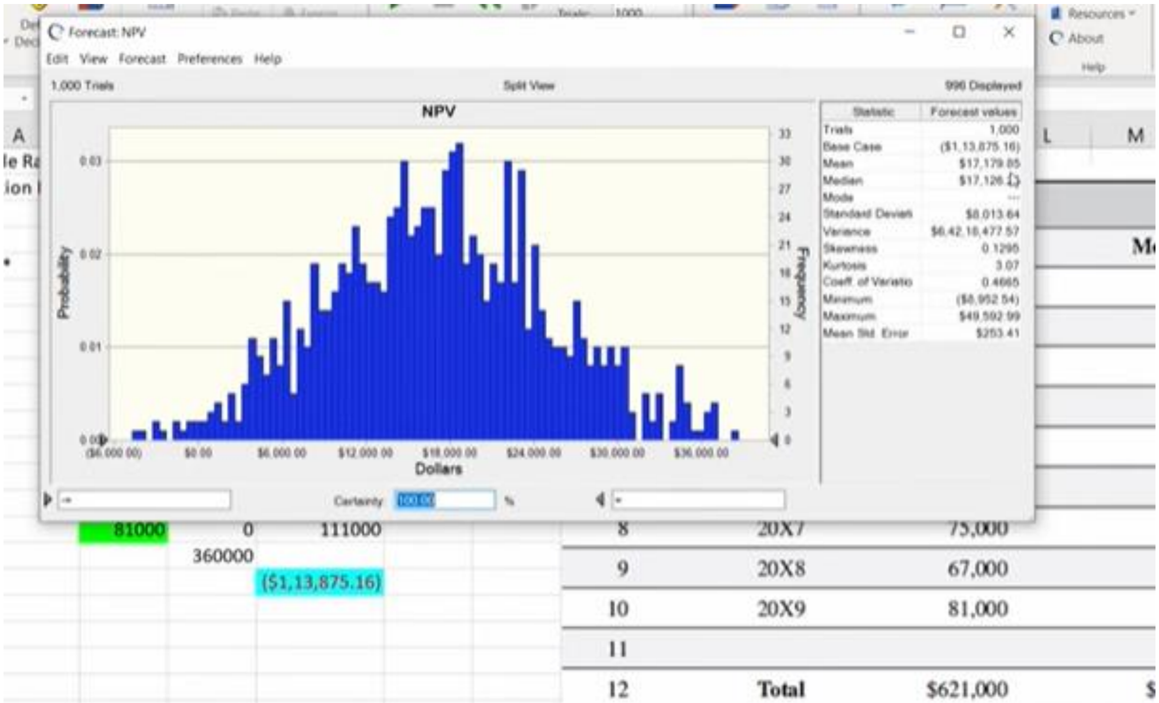
So, once you enter ok. So, as soon as you define the distribution the color will change to green. So, here already I have defined minimum, maximum and most likely value for the uncertain cells. Similarly, for this cell also B9, B10, B11 for example, B11 if you go here already defined it. So, minimum is 88 it is based on from this table for example, X5, X5 is minimum 88 most likely 105000 and maximum is 116000. So, this value already entered it.

The next I have find the net flow that is inflow minus outflow. Then here I have used NPV formula. So, what is NPV formula? The beginning of the year the investment is 125000. So, D5 plus the end of the 0th year my investment is first no in the NPV formula I have to define what is the interest rate. So, interest rate is B1 plus B2 hurdle rate plus inflation rate, then I have to choose the net flow that is D6 to from this to D6 to D15.



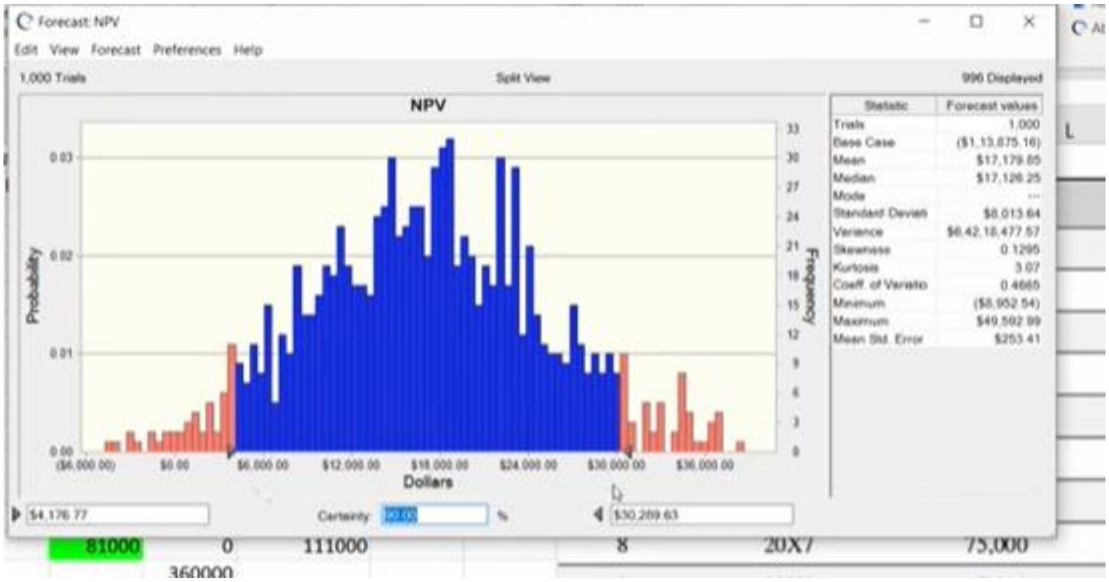
B Inflow	C Outflow	D Net flow
0	125000	-125000
0	100000	-100000
0	90000	-90000
50000	0	50000
120000	15000	105000
115000	0	115000
0	15000	-15000
0	0	0
0	15000	-15000
0	0	0
81000	0	111000
	360000	
		($1,13,875.16)

So, that is the formula for NPV. So, after getting that I am getting 113875 at present it is a it is the value is coming in the negative. So, now I have fed all the value. The next what I have to do is I have to define what is the forecast cell. So, click here then define forecast here I have to say name of that cell I say NPV then unit what unit say assume that it is a dollars then you press ok. Now, when you start this you start our simulation starts.

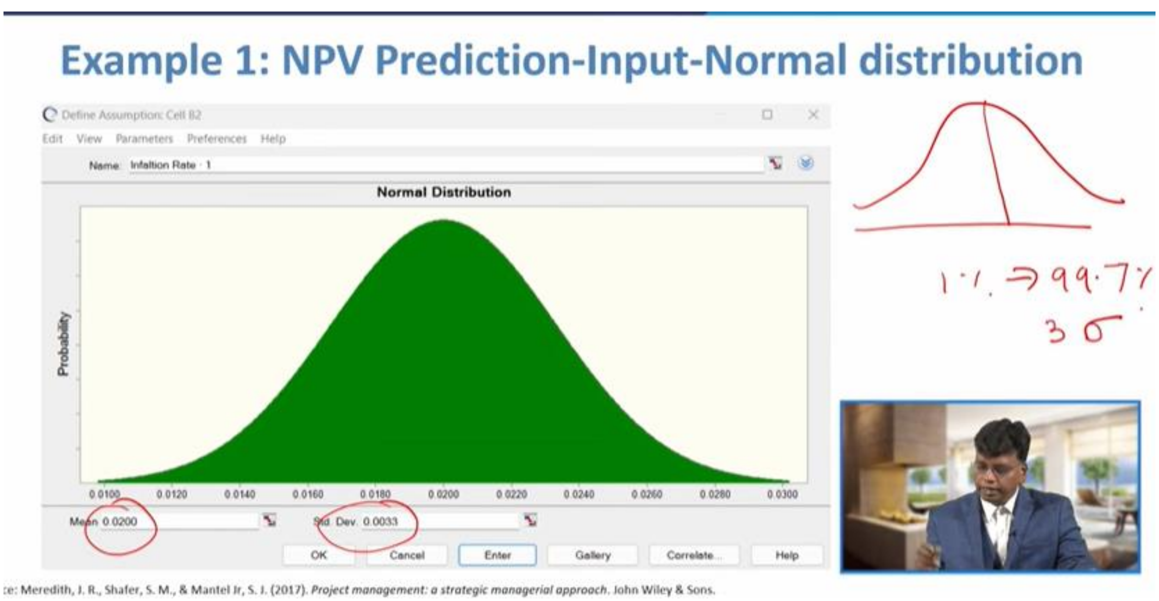


Yeah our simulation is completed look at this picture here. Yeah this one now the mean NPV value is 17179.85 dollar median is 17126.25 standard deviation is 8013 variance is given skewness is given. So, now what we are what we are predicting out of the simulation is so the NPV value for this problem is 17179.

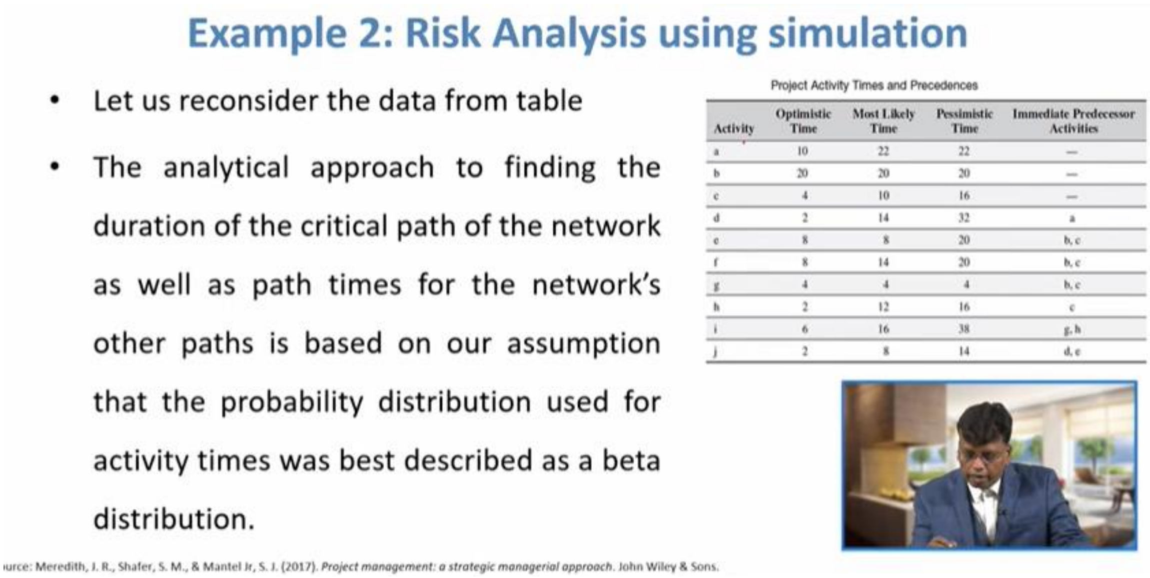
Here one thing what you can do suppose if you want to know 95 percentage 95 percentage confidence level what will be the mean predicted NPV value. So, here it is certain so you change to 90. So, when you change 90 so this area that is 6000 to 30000 that is our range of predicted NPV value. So, this certainty says based on level of certainty you can choose what is the predicted NPV value. So, this is the way to simulate a problem using crystal ball and if you want to know more options about the output go to view you can check frequency cumulative frequency you can check percent percentile and so on.



Then you can click there are many tab references there go to chart then you can say what are the other things which you want from the chart that also can be done. I have explained how to use crystal ball for doing the simulation and there this is the list of various distributions that can be considered for our uncertain cells it can be normal triangular uniform log normal and so on. Here we use the normal distribution for the inflation and for the inflows we use this beta parts distribution. Here this is another input for the inflation we have you chosen as inflation follow normal distribution mean this one standard deviation is 0.003. You should remember that if it is a 1% in your normal distribution 1% represents 99.7% of the normal distribution that is indirectly representing the 3 standard deviation that is why we are dividing 2% plus or minus 1% so instead of this 1% we are writing only standard deviation here. How it is 1% upon 3 so that will be the equal to 0.0033.

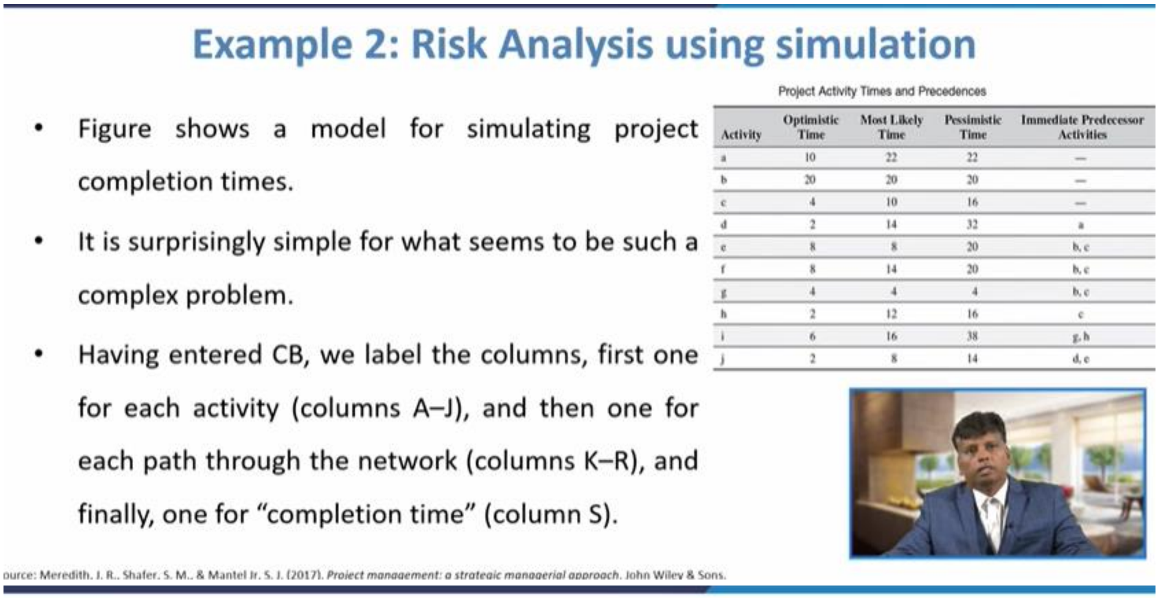


The next input which have given to predict the NPV was beta distribution that also explained I have what is the minimum value what is the likeliest value and the maximum value. This was our output so what is the inference from this output is we are getting the mean NPV value as 17815 with certainty of 100%. You can change this certainty level and we can see what is the corresponding chances of probability of getting that NPV value. Suppose if you want to know 95% chance what is the 95% confidence level what will be the range of my NPV then we can say that it may be come like this so this must this will be the lower limit this will be the upper limit. Now we will go to another example of using crystal ball for using risk analysis.



Activity	Optimistic Time	Most Likely Time	Pessimistic Time	Immediate Predecessor Activities
a	10	22	22	—
b	20	20	20	—
c	4	10	16	—
d	2	14	32	a
e	8	8	20	b, c
f	8	14	20	b, c
g	4	4	4	b, c
h	2	12	16	c
i	6	16	38	g, h
j	2	8	14	d, e

So this problem is a part problem so what is given is here the activities are given optimistic time is given most likely time is given pessimistic time is given and what are the immediate predecessors are given. So the analytical approach to finding the duration of the critical path network as well as the path times for the networks other path is based on the assumption of beta distribution. Now that same assumptions we are going to follow that the different activity times is going to follow beta distribution using that assumptions we are going to find out what is the total completion time for the project. The figure shows a model for simulating the project completion time it is surprisingly simple of what seems to be a such complex problem you might have seen previously if it is a beta distribution we have used mean formula for converting three time estimate into single time estimate but here it is very simple. So after entering all the values in crystal ball we can label the columns so the first one for each activity so we have activity A to J we are going to write all activities and then we are going to enter all the possible path and finally we are going to find out the total completion time for completing all this activity.



Project Activity Times and Precedences

Activity	Optimistic Time	Most Likely Time	Pessimistic Time	Immediate Predecessor Activities
a	10	22	22	—
b	20	20	20	—
c	4	10	16	—
d	2	14	32	a
e	8	8	20	b, c
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g	4	4	4	b, c
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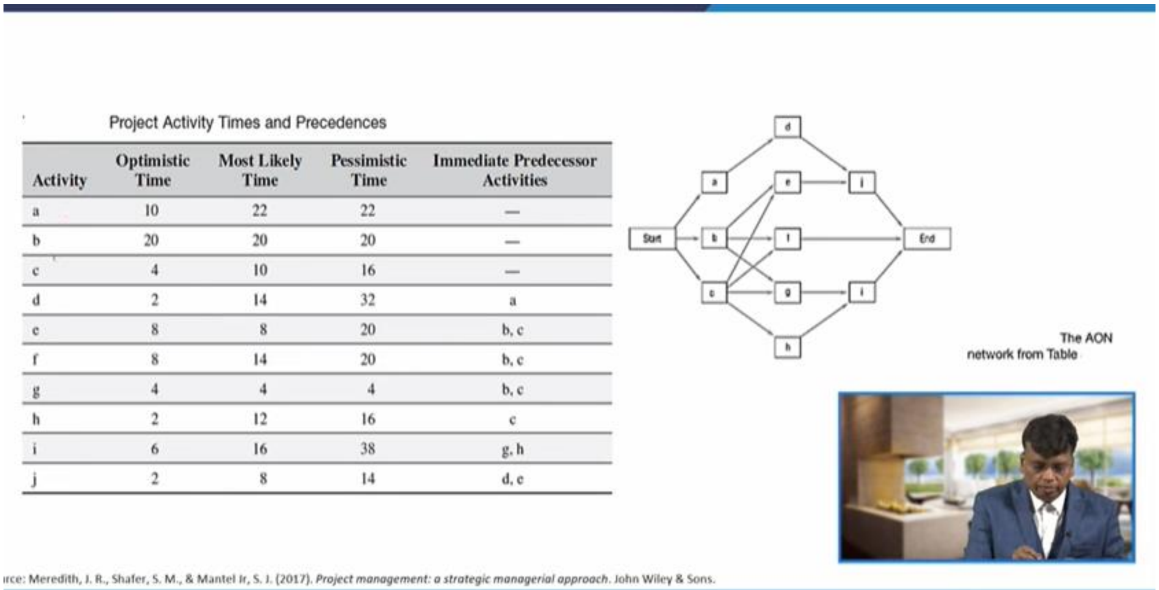
i	6	16	38	g, h
j	2	8	14	d, e



Project Activity Times and Precedences

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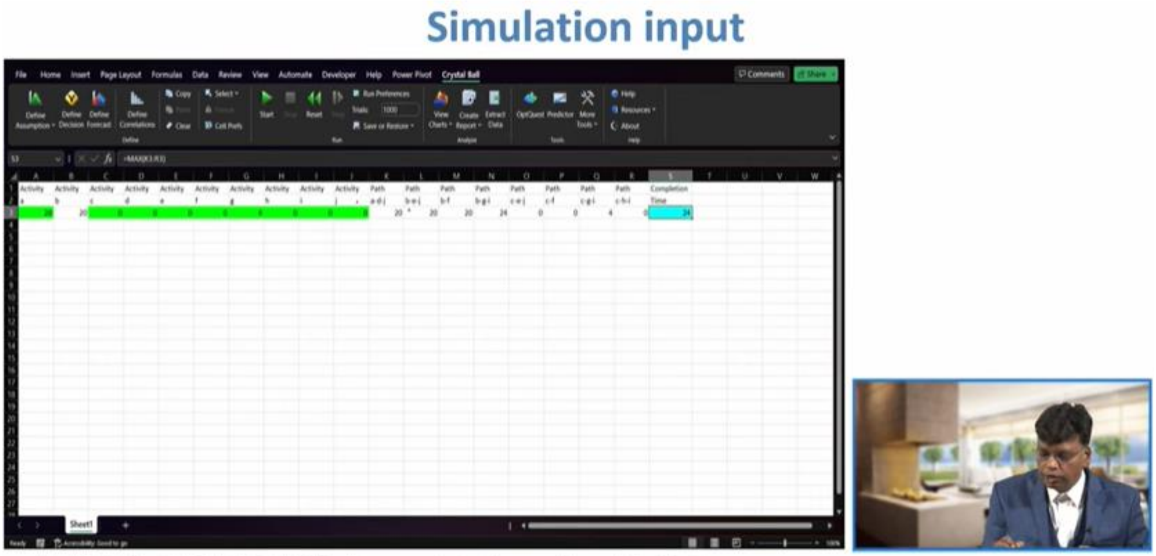
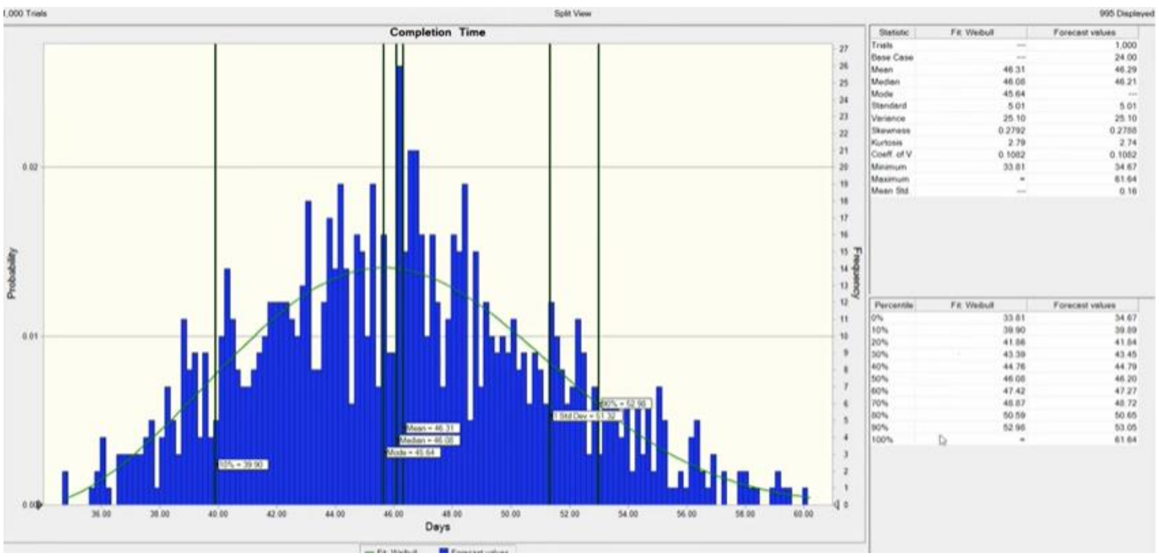
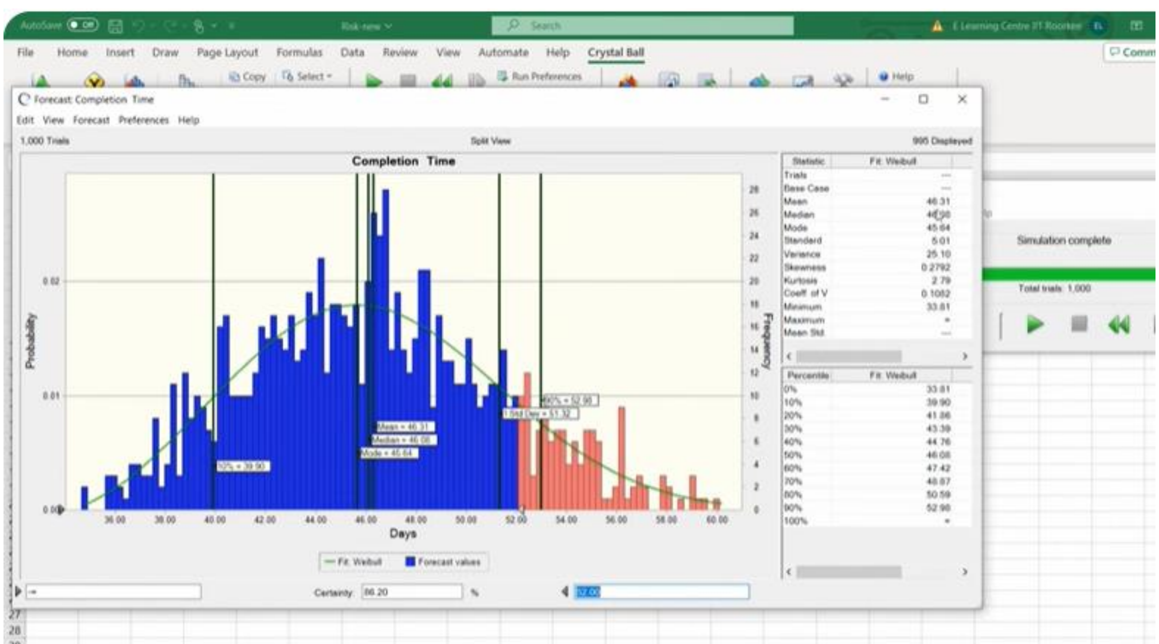
d	2	14	32	a
e	8	8	20	b, c
f	8	14	20	b, c
g	4	4	4	b, c
h	2	12	16	c
i	6	16	38	g, h
j	2	8	14	d, e

So what I have done for the given table for example there is a various activities are given activity a, b, c, d, e, f, g, h, i, j and optimistic time is there most likely time pessimistic time and the immediate predecessor of that activity is also given. So by considering this predecessor I have drawn a network. So what are the possible path here we can you can go A DI is one path then bei is another path then BGI is another path then CEI is on one path then CI is one path then CGI is another path then CHI like that all possible path we can find out so that path also has to be entered as a input. So the most difficult job one faces is identifying all possible paths to be evaluated for small network for example what they are showing for illustration purpose this is not difficult but for large network identifying all possible path may be difficult so instead of using crystal ball you can go for some other software for that. So this is the input for our simulation when you look at this input you see activity a, b, c, d, e, f, g, h, i, j up to that I have written then I have written all possible path a, d, j, b, e, j, b, f, b, g, i, c, e, j, c, f, c, g, i, c, h, i.



So here the bottom I have entered the because for example activity a we are going to have three time estimate that we are going to enter activity b also because all three time estimates are same we are going to use as a constant then only c, d, e, f and for g also we need not specify the probability distribution because all the three values are same then what you have to do we have to find out the path duration how we got this value is you have to define a formula so you have to add the duration of activity a activity d and activity j similarly here you have to add the duration of activity b e j then so for this all the path you have to find out the maximum values of different path that is going to be our project completion time so maximum path is the critical path and corresponding duration is our project completion duration. Now I am going to use crystal ball to simulate and predict what is the completion time for this PERT network. So here I have entered all the activities all the path and here also I had defined that activity a it followed beta distribution so go to crystal ball then define assumptions then choose beta PERT here I have entered minimum likeliest and maximum then press ok for second activity all the values are same you need not define it for example activity c click this cell define assumption go to beta PERT press ok then you will get the where this picture here you have to enter the minimum value likeliest most likeliest value and the maximum value like that you have to define for all the activities for example here k3 what I have done I have added a3 plus d3 and j3 it is summation of all individual activities for example bej so added b3 e3 plus j3 like that I have entered for all the path I have used formula to find out the total duration. Now the completion time for the whole network so what you have to do it is a maximum of k3 , r3 so we are considering all the path whichever path is taking longest path that is going to be by duration. Here only the uncertain cells are all the activities so now go to define forecast so I have cell I have chosen this S3 I define completion time then press ok then start the simulation yeah now this is the output of our crystal ball so the mean completion time is 46.31 and the median is 46.08 this is 86 percentage certainty suppose you can change it you put 100 percentage yes so when you you can enter the certainty level and another interesting thing is that you can see here the percentile value is given so what the percentile value says the probability of completing this project less than 61.64 days is 100 percentage for example probability of completing this project within 43.45 days it is a 30 percentage so this interpretation can be obtained from the percentile chart. Here I have brought the screenshot of the output here it says that the mean completion time is 46.12 and we are also getting this percentile chart it says that so 45.84 for completing this project less than 45.84 the chance is 50 percentage because it is a median it is a median value.





So in this lecture I have discussed about possible uncertainties in your project so that uncertainty can be managed with the help of managing the risk so how to manage that risk I have used a software called crystal ball so I have taken two problems one is for NPV prediction the second one is our PERT problems. So I have defined how to give the input and how to choose various probability distribution for the input then how to choose the forecasting cells then I have run it then I have shown the output thank you. Thank you.