Project Management

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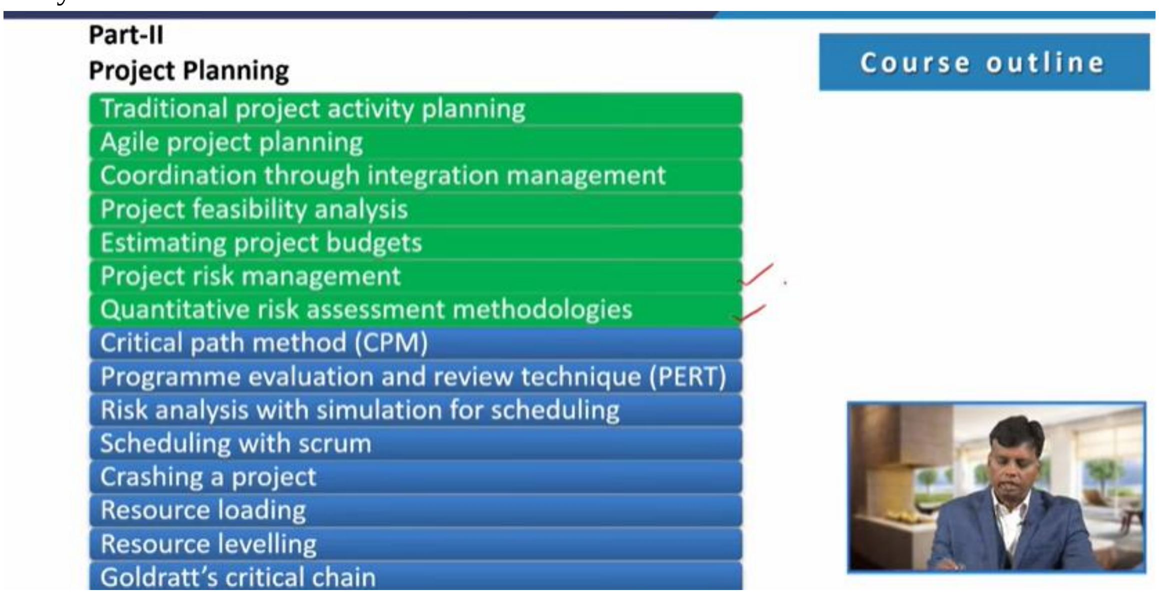
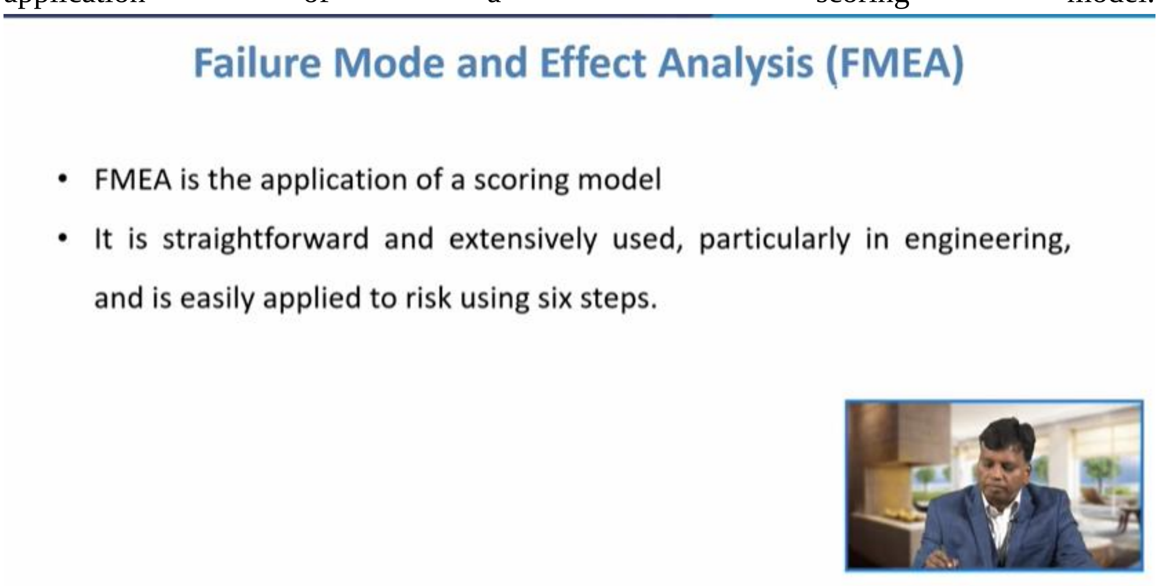
Week: 4

Lecture 19 : Quantitative Risk Assessment Methodologies

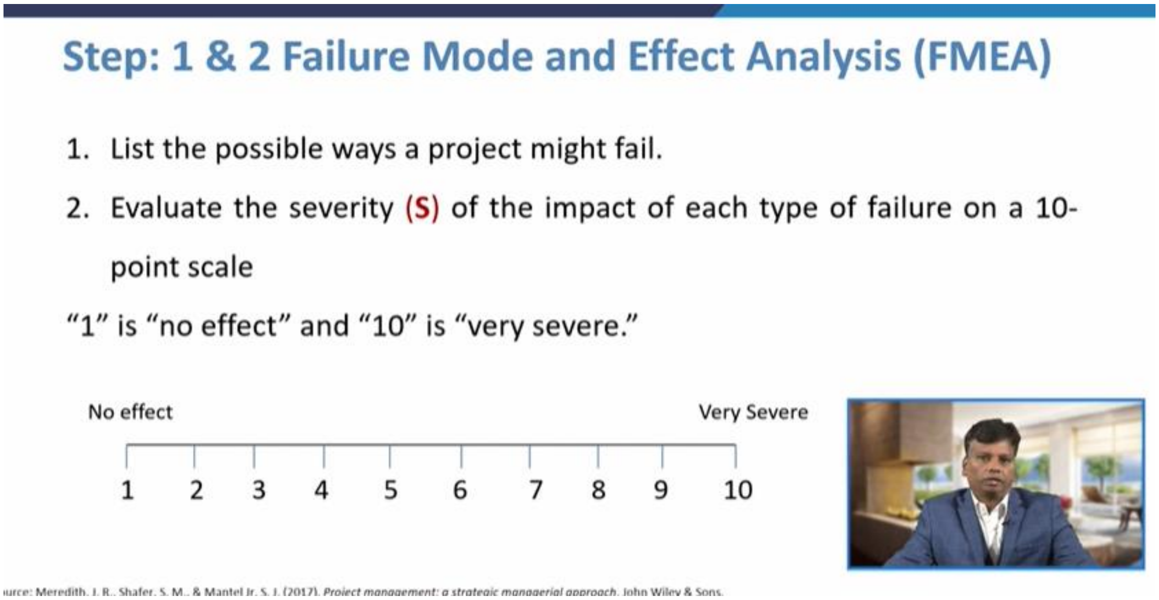
Dear students, in the previous class I have discussed about project risk management. In this lecture, I am going to discuss about quantitative risk assessment methodology. Last class we discussed about project risk management. So, in this lecture I am going to discuss about quantitative risk assessment methodologies. So, the agenda for this lecture is the first quantitative technique for assessing the risk is failure mode and effect analysis. The second techniques which we are going to discuss today is decision tree analysis.



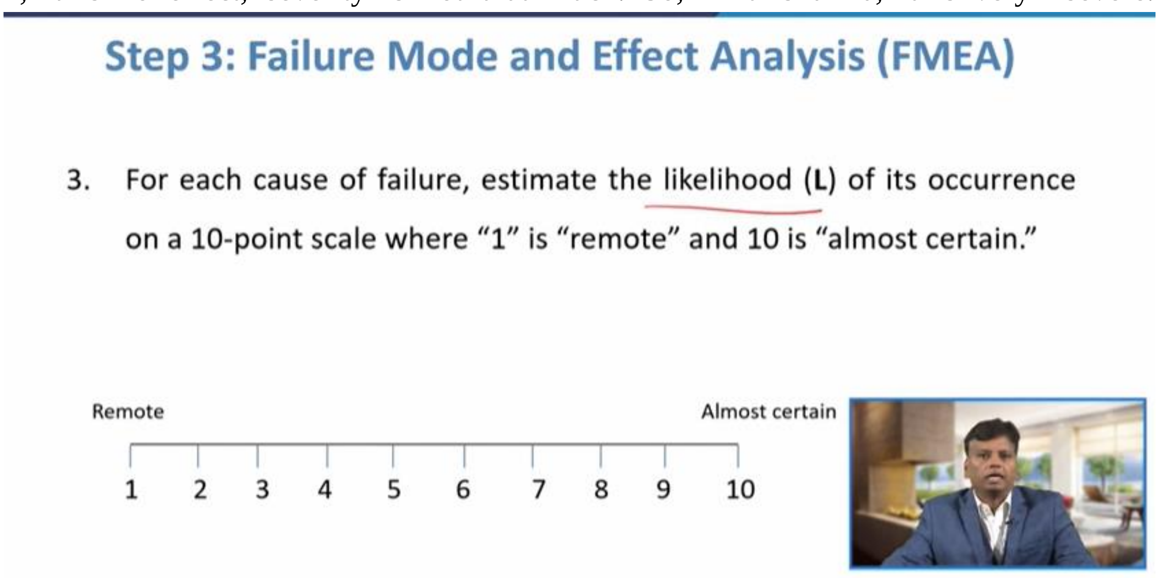
The third method is simulation, especially we are going to use Monte Carlo simulation to assess the project risk. Finally, I will discuss about what is sensitivity analysis and importance of sensitivity analysis for project risk management. The first technique is called failure mode and effect analysis, we shortly call it is FMEA. So, FMEA is the application of a scoring model.



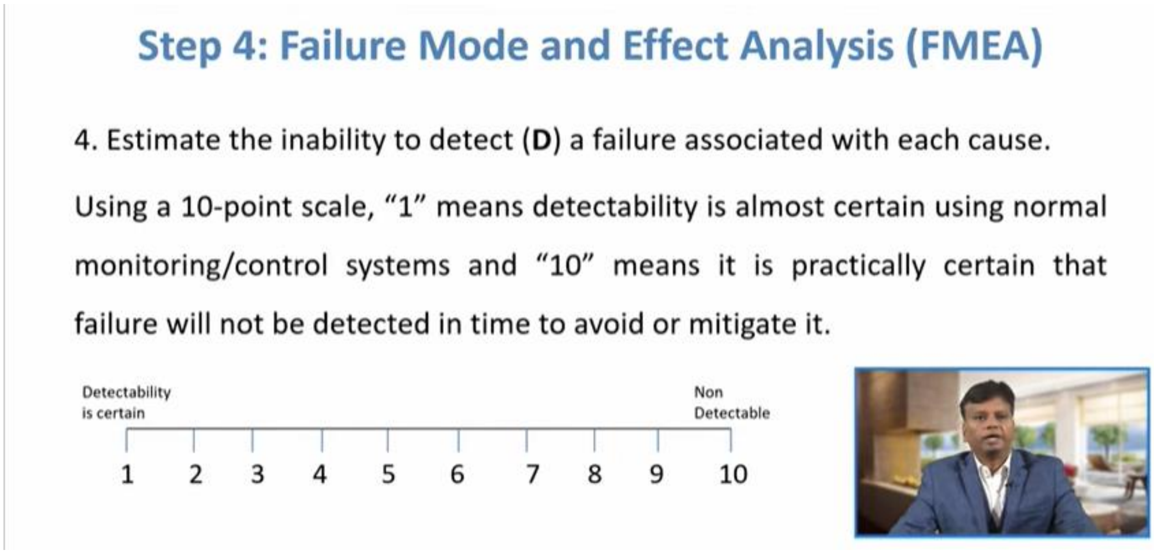
So, there will be three criteria, we will substitute or apply some value for each criteria, then we will multiply that we will get a score for different type of risk. So, whichever is having the higher risk that is most important risk that we have to focus on or we have to mitigate that risk. So, it is a straightforward and extensively used particularly in engineering and easily applied to risk using six steps. So, in the failure mode and effect analysis, there are six steps that we will discuss. So, the step one and two is, the first step is list the possible ways a project might fail.



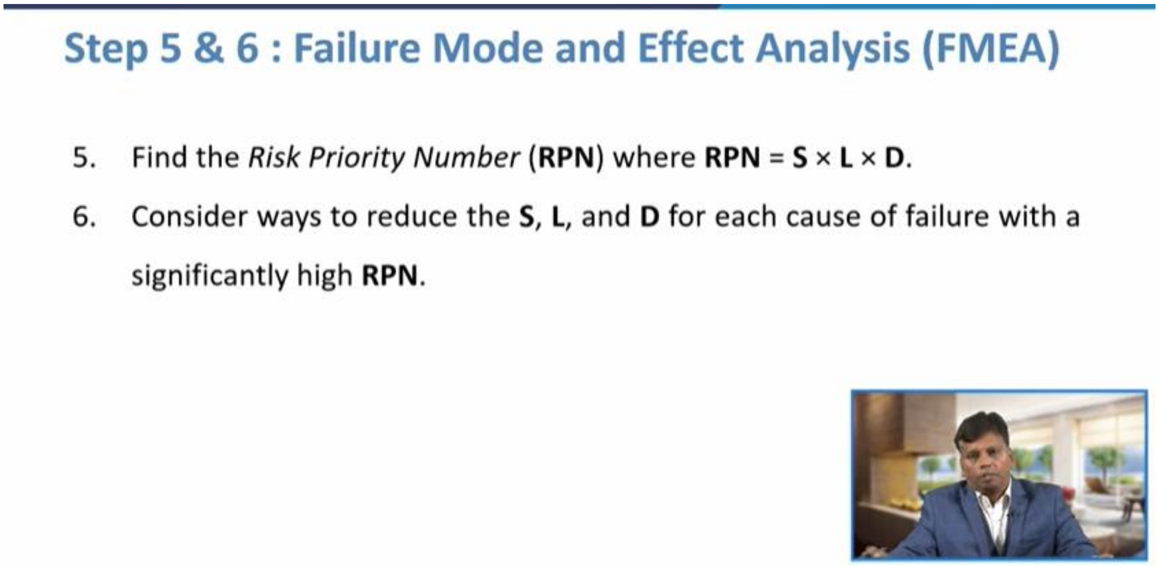
If you take a project say Chandrayaan 2, so first they might have discussed that was failed, they might have discussed that what was the, what were the possible ways that project was failed or if you are developing a new product, before launching the product, you have to look at all possibilities of failure of that project, that is a step one. Then we have to evaluate the severity of the impact of each type of failure on a 10 point scale. So, the second step is we have to assess the severity. So, how we are going to assess, if it is 1, it is no effect, severity is not that much. So, if it is a 10, it is very severe.



So, based on the severity of that risk, so we have to assess the score for the term yes. The third step is for each cause of failure estimate the likelihood of its occurrence "L" on a 10 point scale, where 1 is rarely occurs and 10 is almost certain. So, 1 represents, see look at this scale, likelihood is very less. So, 10 means the likelihood is more. The step 4 of failure mode effect analysis, estimate the inability to detect a failure, we call it is D associated with each cause.



So, we have to apply some score for this D. So, using a 10 point scale, if you are giving 1 means, detectability is almost certain. So, easily we can detect it. But if you are giving 10 means, it is very difficult to detect that risk. So, 1 represents, detectability is certain, 10 represents, very difficult to detect.



So, we discussed about 3 term, one is yes, severity, second is L, likelihood, the third one is D, detectability. So, find the risk priority number by multiplying these 3 term that is S, L, D. So, S represents severity, L represents likelihood and D represents detectability. So, we will get a score. So, then we have to consider ways to reduce S, L and D for each cause of failure with a significantly high RPN.

Failure Mode and Effect Analysis (FMEA)- Example

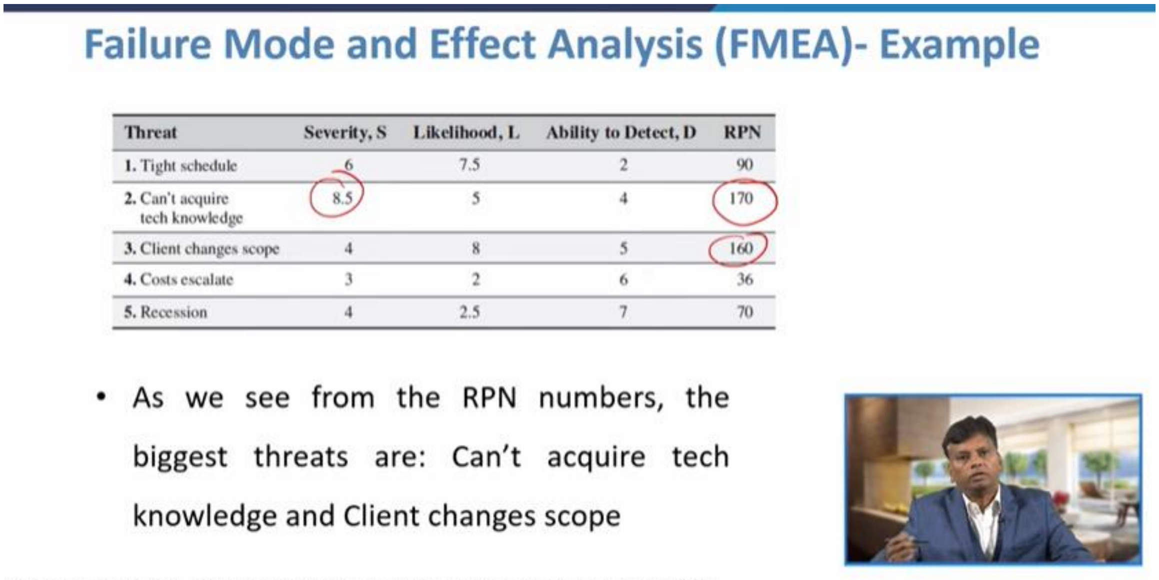
Threat	Severity, S	Likelihood, L	Ability to Detect, D	RPN
1. Tight schedule	6	7.5	2	90
2. Can't acquire tech knowledge	8.5	5	4	170
3. Client changes scope	4	8	5	160
4. Costs escalate	3	2	6	36
5. Recession	4	2.5	7	70

- As we see from the RPN numbers, the biggest threats are: Can't acquire tech knowledge and Client changes scope

RPN here is called risk priority number. Now, I have brought a sample table to explain how we got this risk priority number. For example, say there is a project 1, the 1 first threat is tight schedule. Like that we have 5 possible threat for the project. The second threat is cannot acquire the technical knowledge.

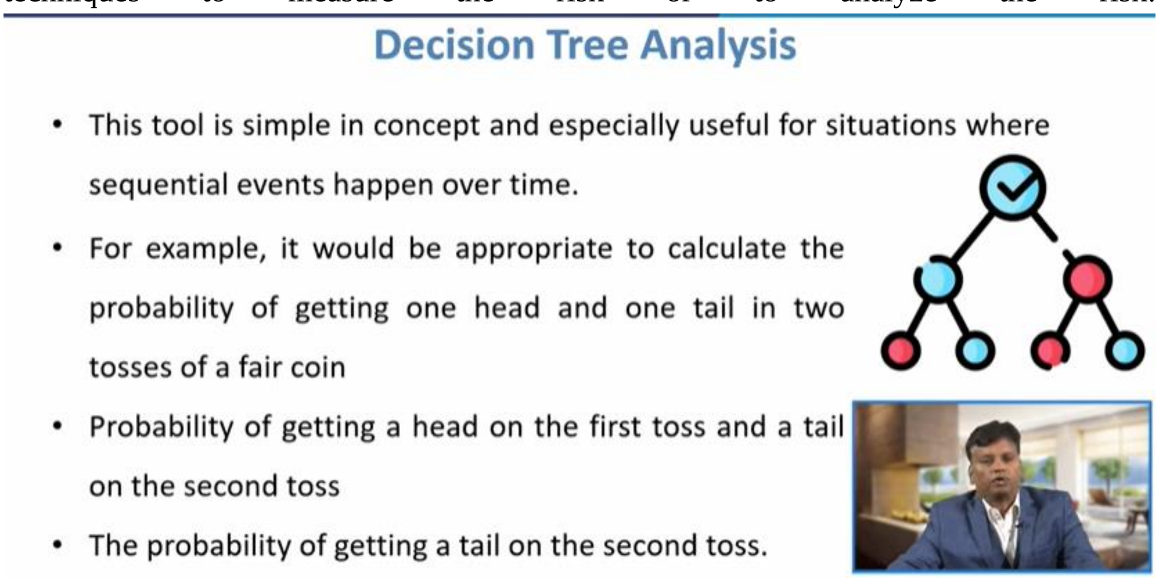
Third one is client changes scope, fourth is cost escalate, 5 is resistance. So, we have for S and L and D, we have supplied value. S means severity in the 1 to 10 scale. For example, with respect to severity, which threat is most severe threat, for example, this 8.5 cannot acquire technical knowledge that is having highest score.

So, with respect to likelihood, so which threat may occur, there is more chances to occur that is the highest score. Then ability to detect. So, when you multiply this, we are getting a score that score is called risk priority number. So, first we have to mitigate the risk which is having highest risk priority number, for example, 170. So, as we see from the RPN number, risk priority number, the biggest threat are cannot acquire technical knowledge.

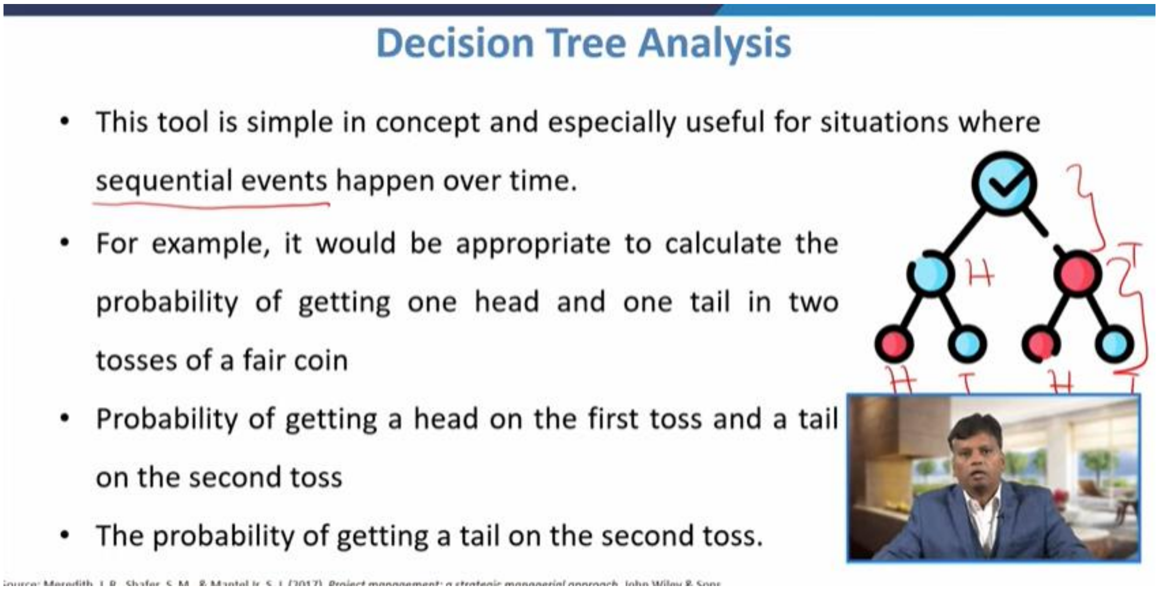


Threat	Severity, S	Likelihood, L	Ability to Detect, D	RPN
1. Tight schedule	6	7.5	2	90
2. Can't acquire tech knowledge	8.5	5	4	170
3. Client changes scope	4	8	5	160
4. Costs escalate	3	2	6	36
5. Recession	4	2.5	7	70

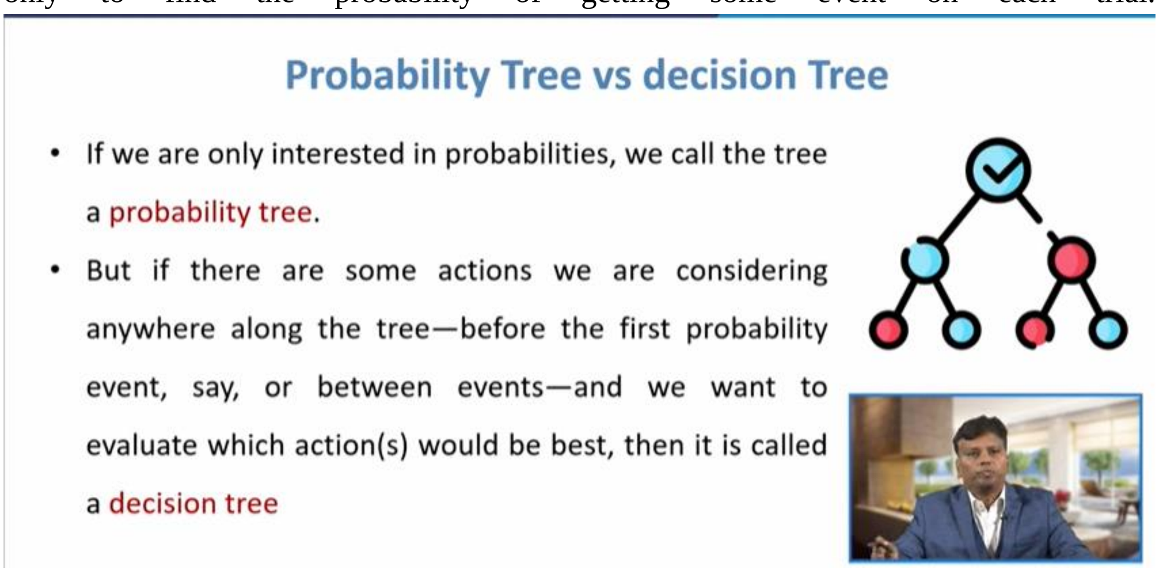
Next to that is 160 that is client changes scope. So, first we have to try to mitigate these two risk. How we can mitigate, we can look for how can we reduce the severity, then we can see the better methodology to predict that is likelihood of that threat, then we can develop a new methodology to detect that risk. So, the next tool is decision tree analysis. So, far we discussed about failure mode and effect analysis that is one of the quantitative techniques to measure the risk or to analyze the risk.



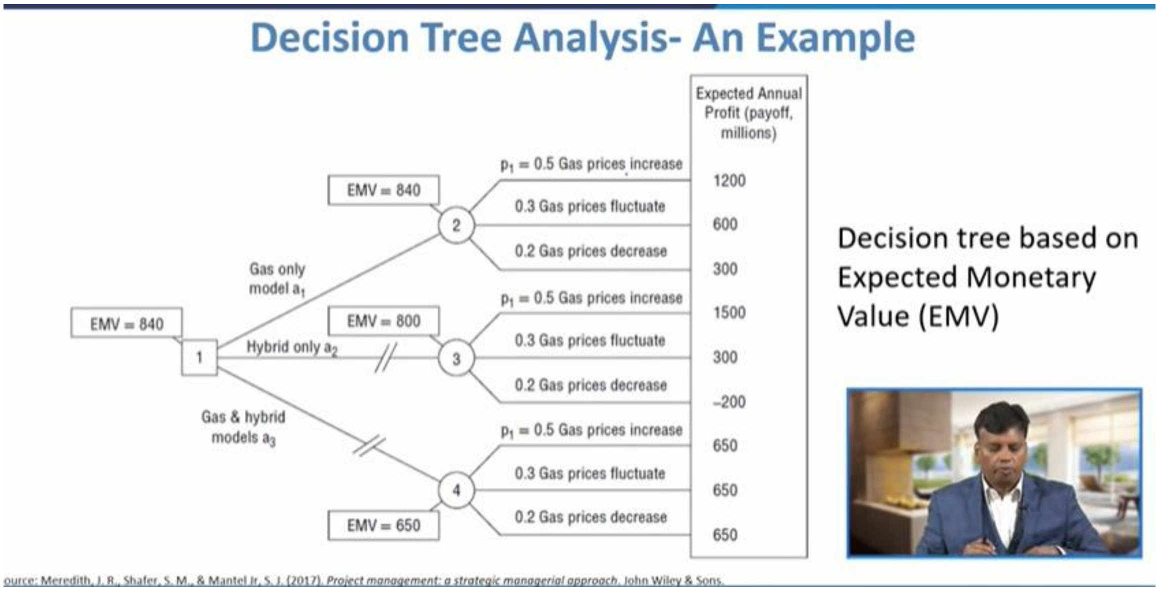
The second methodology, quantitative methodology is decision tree analysis. This tool is simple in concept and especially useful for a situation where sequential event happen over time. So, whenever there is a sequence of events, then we have to assess the risk of that each sequential event, then this decision tree is very useful tool. For example, it would be appropriate to calculate the probability of getting one head or one tail in two tosses of a fair coin. For example, the picture here is, this is trial 1, this is trial 2.



So, the trial 1, there may be head or tail. In trial 2, here it may be head, here tail or here may be head or here may be tail. So, the probability of getting a head on the first toss and a tail on the second toss can be found by using this decision tree. The probability of getting tail on the second toss also can be found using the decision tree. If we are only interested in probabilities, we call the tree as a probability tree because our purpose is only to find the probability of getting some event on each trial.



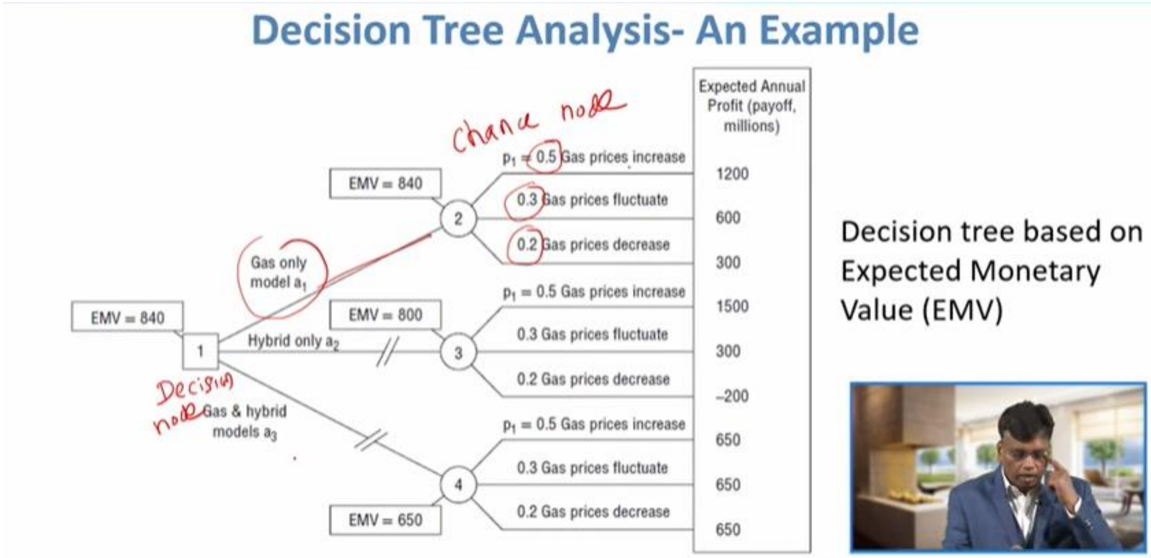
But there are some actions we are considering anywhere along the tree before the first probability event say or between the events and we want to evaluate which actions would be the best, then it is called decision tree. So, before each event if you are intervening the some action, then we want to know which is the best possible option. So, that can be found using this decision tree. Here our purpose is not to know the probability to assess the consequences of each action. Now, I brought a sample decision tree analysis.



So, here a company is looking for launching a vehicle, an automotive company. So, here the square represents the decision node, this is the decision node. The circle represents chance nodes. So, how to construct this decision tree analysis? Suppose, assume that that automobile company has the three option to launch a new vehicle. For example, they can go for gas only model, say A1 or they can go for hybrid only A2 or they can go for gas and hybrid model.

So, there are three options. So, we want to know the consequences or risk of these three options and which one we have to choose. So, suppose if the company goes for gas only model, so there are three possibilities. One is gas price increases, gas price may fluctuate or gas price decrease. So, what we have to see? We have to see the consequences of this action if the gas price is increasing or decreasing or the fluctuating.

Similarly, the company go for hybrid only. There are three possibilities market condition, the gas price may increase or fluctuate or decrease. So, there is a probabilities attached to each chance event. There is a 50% chance gas price will increase. There is a 30% chance gas price fluctuates.

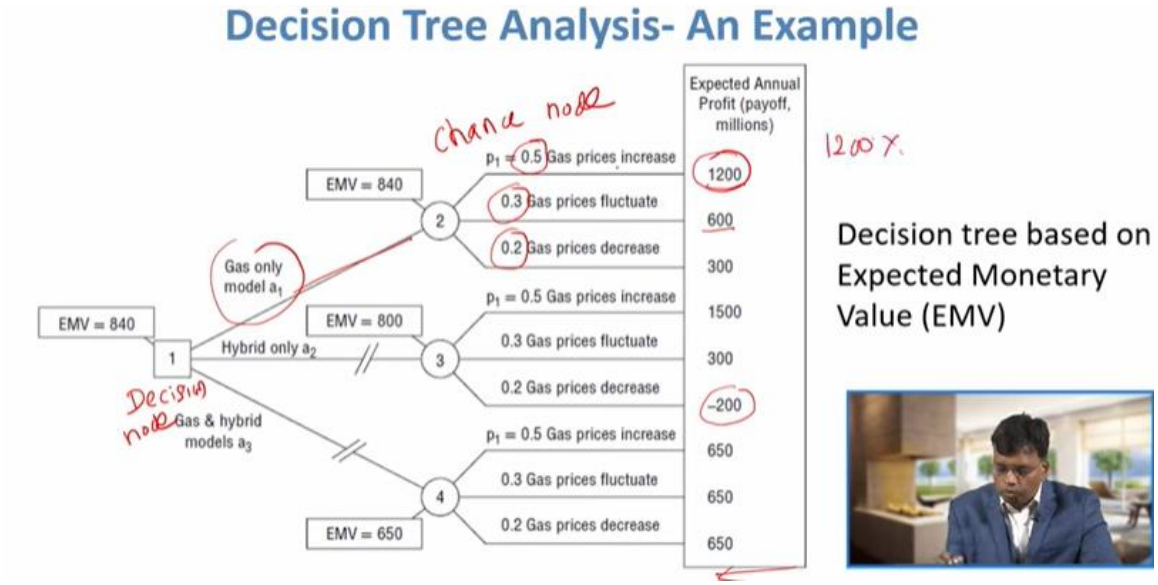


There is a 20% chance the gas price decreases. Similarly, for third alternative, a company can go for manufacturing gas and hybrid models. In that case, the probability is, look at here the probability is same for all these three actions, whether it is gas only or that is hybrid only or gas and hybrid only. Because the market conditions of the price of the gas is independent of our actions. So, the first and the last it represents the expected annual profit.

What this 1200 means? Suppose if you go for gas only model, if the market in the market, the gas price increase, there is a 50% chance. So, there are two possibilities go for gas only model, if the gas price increases, then the expected annual profit is 1200 million dollar. So, like that it is 600. So, now, if you see there is a loss here, what is the loss? If you are launching hybrid only vehicle, if the demand, if the gas price is decreases, there is a 200 million dollar loss for you, but which is the best option if you are an optimistic person, you will go for gas only model. So, there will be a 1200 million dollar you can get as a payoff.

So, this is a way of constructing the decision tree. But the calculation of the decision tree is done in the backward direction. So, first how we have to find out? We have to find out the expected monetary value of this action that is a gas only model. So, what do you have to do? You have to multiply this 1200 multiplied by 0.5 plus 600 multiplied by 0.3 plus 300 multiplied by 0.2. So, when you simplify you will get expected monetary value for gas only model is 840.

1200x0.5 +600x0.3 + 300x0.2 =840



Similarly, if you go for hybrid only model, so here 1500 multiplied by 0.5 plus 300 multiplied by 0.3 minus 200 multiplied by 0.2 you will get expected monetary value is 800.

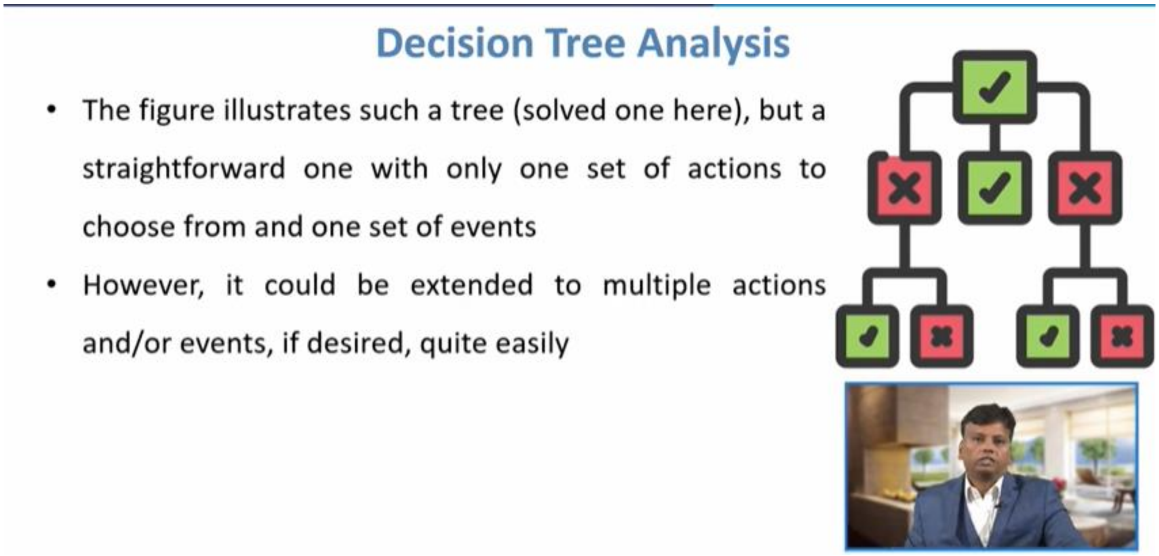
1500 x0.5 + 0.3x300 +0.2x(-200) =800

Similarly, for third option you will get expected monetary value is 650. So, you have to the calculation should go in the backward direction. Now, we have to see which one is having the highest expected monetary value.

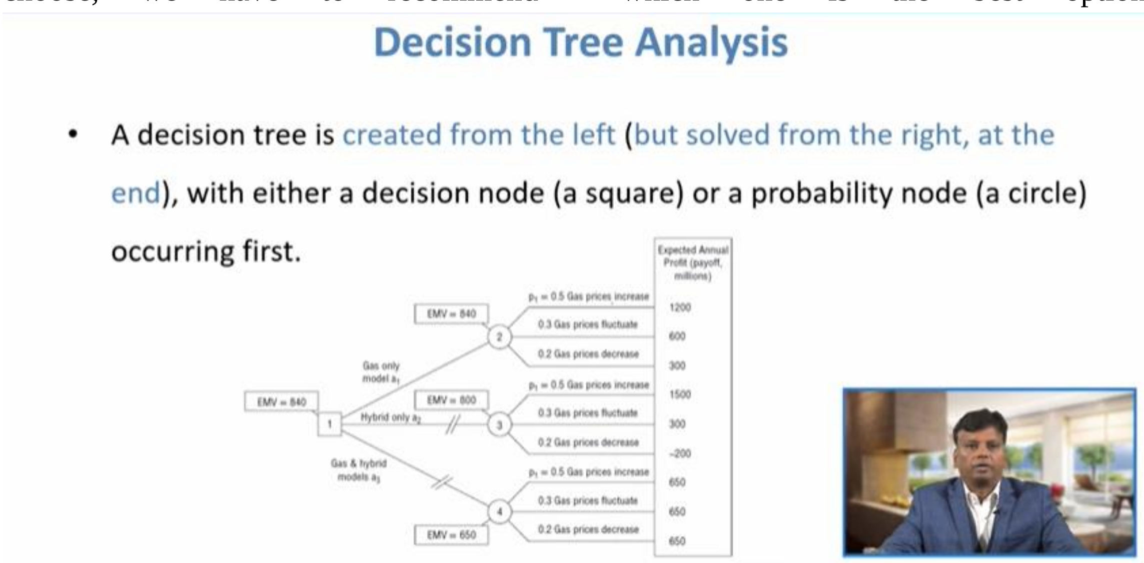
For example, the first option gas only model is giving the highest monetary value. So, the suggestion the recommendation for this automotive company is they should go for only manufacturing gas only model. So, they will get the expected monetary value in the sense average profit. So, average profit will be 840 million dollar. So, this is the way the decision tree works.

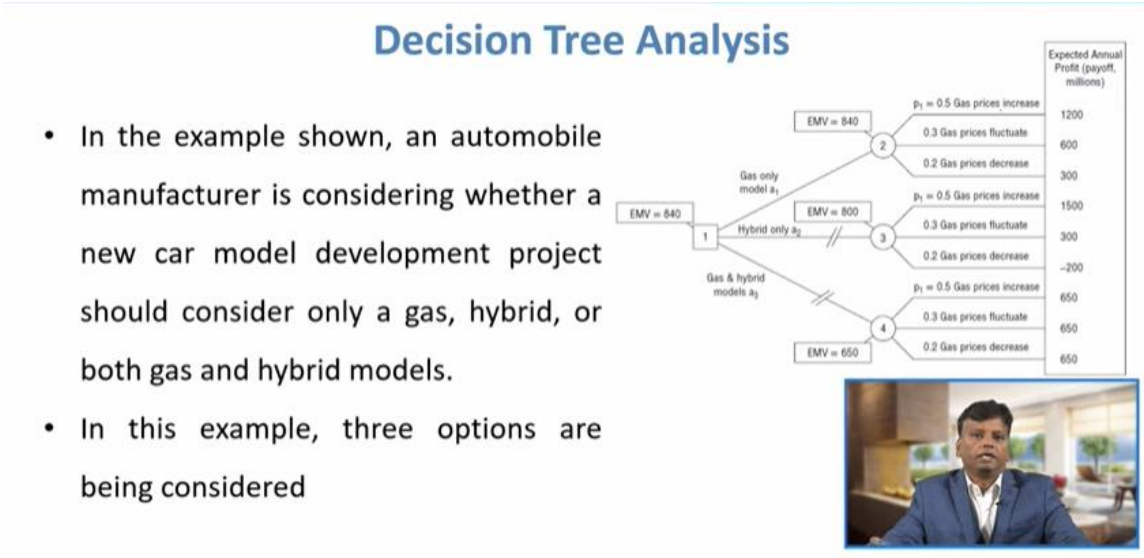
What is the point here? The construction of the decision tree is done left to right, but the calculation of the decision tree is done right to left. So, here square represents the decision node, circle represent the chance nodes and the probability for all the alternative and corresponding chance node will be same.

For example, 0.5, 0.3, 0.2. So, here also 0.5, 0.3, 0.2. The third option also 0.5, 0.3 and 0.2. So, this will explain in detail. Now, we will come back to the some more basics on decision tree analysis. The figure illustrate such that a tree is solved on here, but a straightforward one with only one set of actions to choose from one set of events.

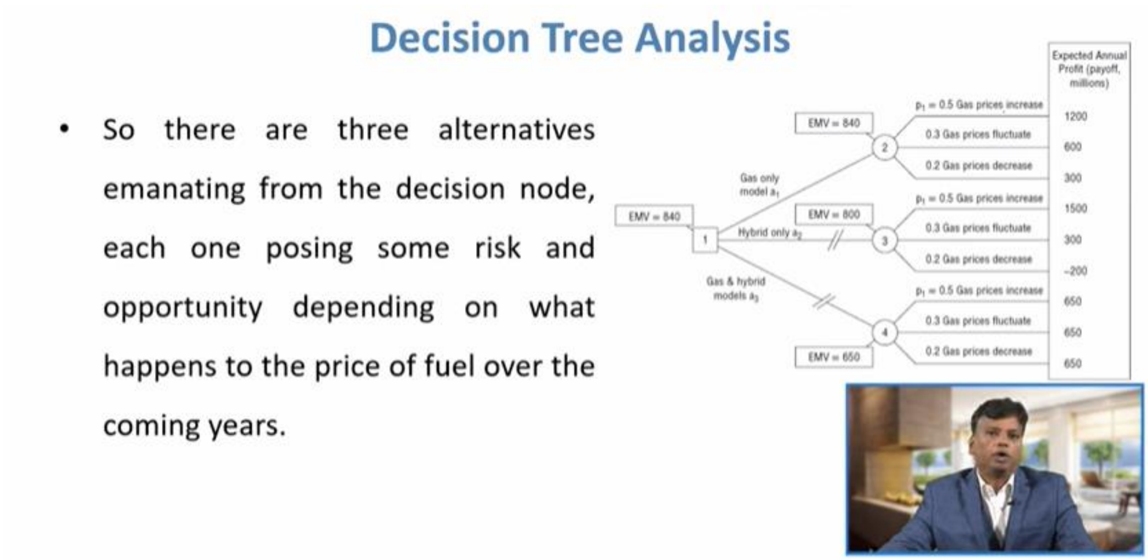


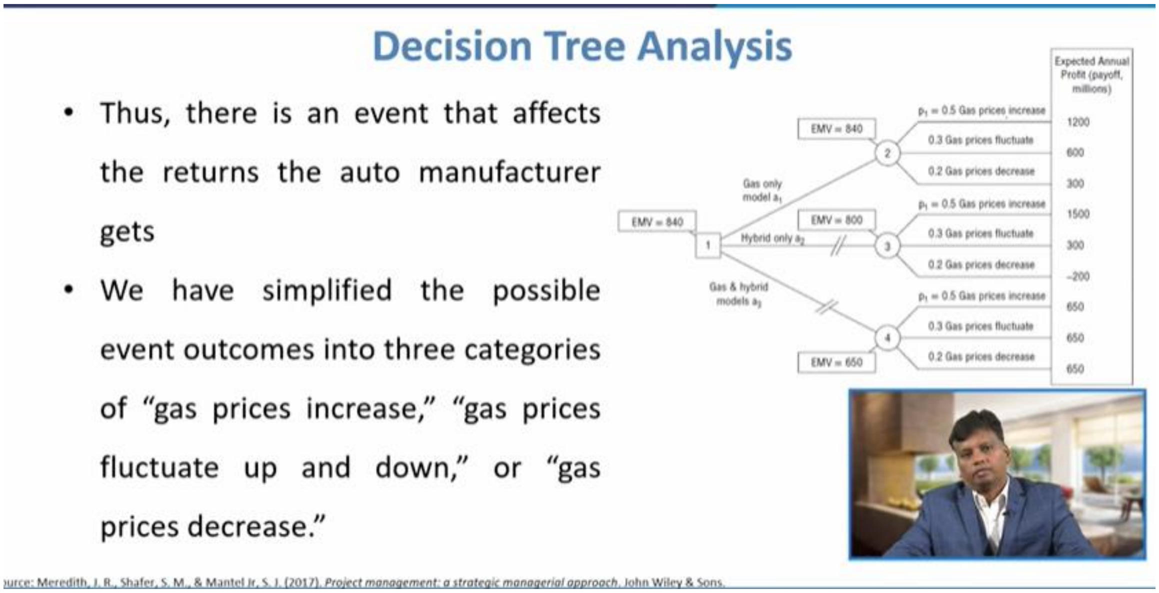
However, it could be extended to multiple actions or events if desired very easily. So, a decision tree is created from left, but solved from right at the end with either decision node as I told you the square represent the decision node and the circle represents probability node. In the example shown, an automobile manufacturer is considering whether a new car model development project should consider only a gas, hybrid or both gas and hybrid model. In this example, three options are being considered. We have to choose, we have to recommend which one is the best option.



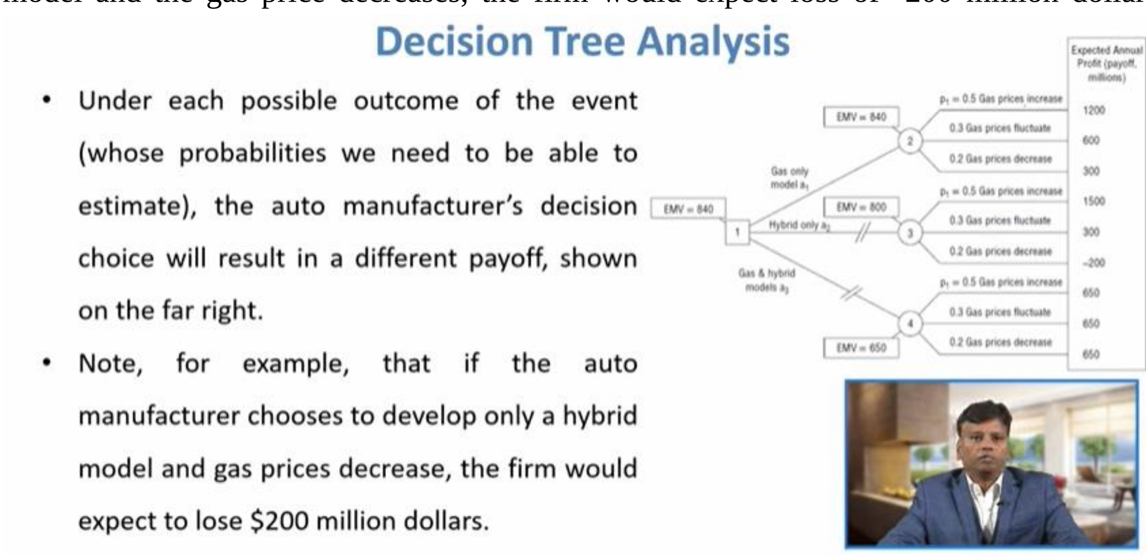


So, there are three alternatives emanating from the decision node, each one posing some risk and opportunity depending on what happens to the price of fuel over the coming years. Here the risk is the price of the fuel. Thus, there is an event that affect the result of auto manufacturer gets. So, we have simplified the possible event outcomes into three categories. The first one is gas price increases, then gas price fluctuate up and down.

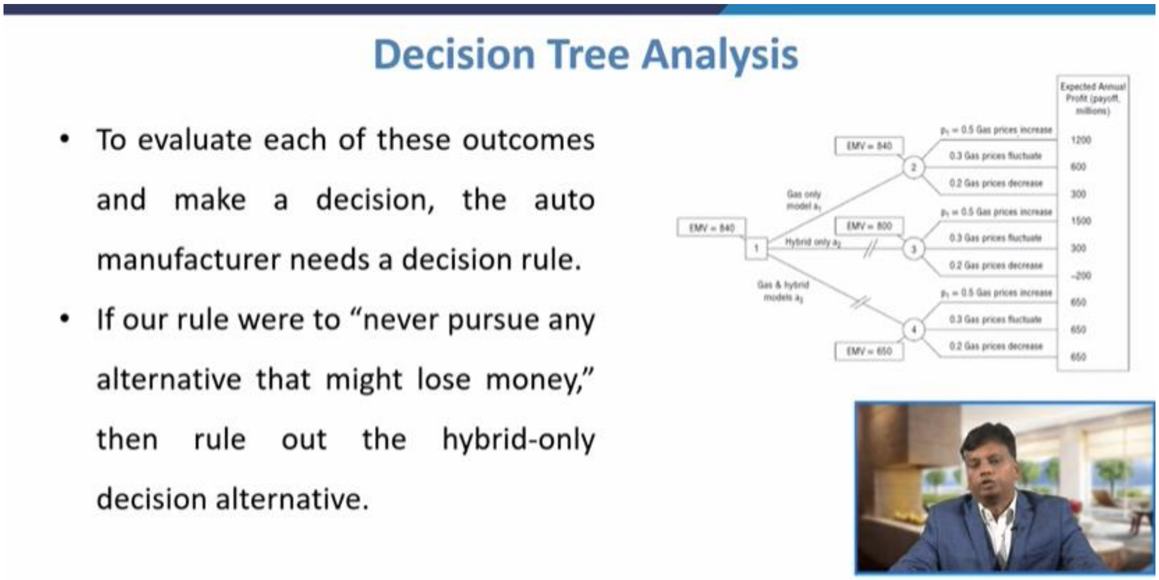


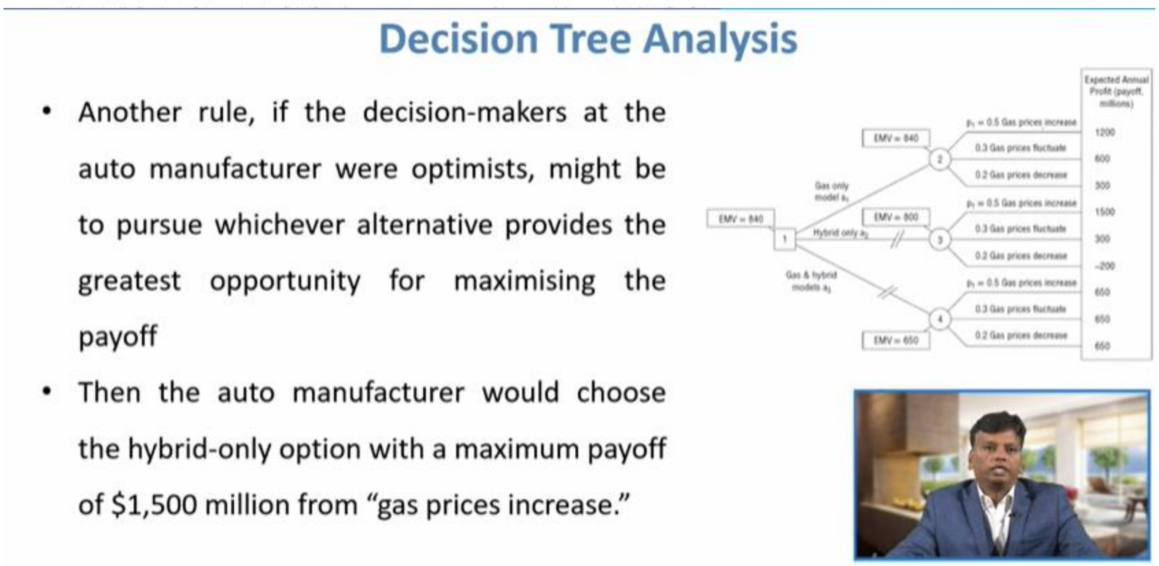


The third one is the gas price decreases. Note that the probabilities of each outcome are identical for each decision choice because the decision the auto manufacturer make does not affect the price of the gas. Under each possible outcome of the event, where whose probabilities we need to able to emanate, the auto manufacturer's decision choice will result to a different payoff shown on the extreme right. So, for example 1200, 800 and so on. Note for example, that if the auto manufacturer chooses to develop only a hybrid model and the gas price decreases, the firm would expect loss of 200 million dollar.



Here we are talking about here. They go for only hybrid model. If the market in the market the gas price decreases, there will be a loss of 200 million dollar. To evaluate each of these outcomes and make a decision, the auto manufacturer needs a decision rule. If our rule were to never pursue any alternative that might loss money, then rule out the hybrid only decision alternative. Because the company says that we should not take any we should not take we should not go for any loss.



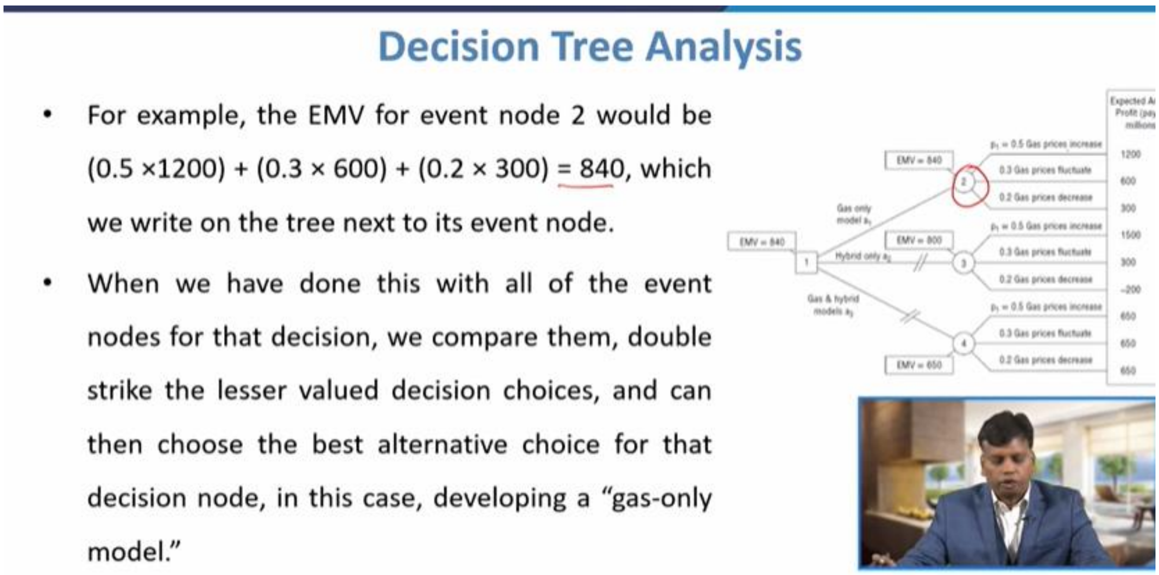


So, the company will not go for the second option of hybrid only vehicle. Another rule may be if the decision makers at the auto manufacturer were optimist about the gas price, they might pursue whichever alternative provide the greatest opportunity for maximizing the payoff. So, which one is giving the greatest payoff, then the auto manufacturer would choose a hybrid only option with a maximum payoff 1500 million from the when the gas price increases. However, we normally use a different rule called expected monetary value that we shortly call EMV because this maximizes our return over the indefinite future that is long run average. The process of solving the decision tree is to work from right with the outcomes that is the profit in each case and multiply each outcome times the probability of the event resulting in the outcome called expected value of the outcome.

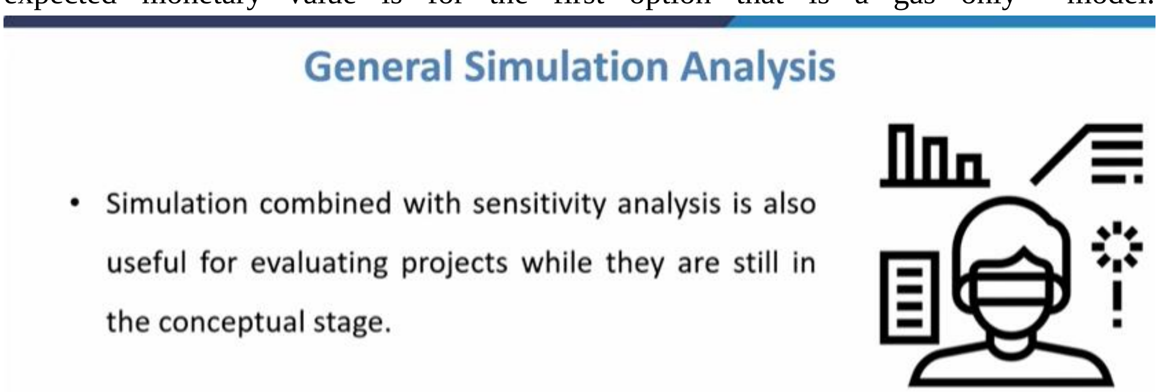
And then adding up all the expected values for the event node decision choice combinations. So, what we have to do, we have to multiply this expect the monetary value with corresponding probability, then we have to add it. So, that will be your expected monetary value for that decision alternative. For example, the expected monetary value for the event node 2 here would be 0.5 multiplied by 1200 plus 0.3 multiplied by 600 plus 0.2 multiplied by 300.

1200x0.5 +600x0.3 + 300x0.2 =840

So, we are getting 840 which we write on the tree next to 2 event. Similarly, we have done here 800. Similarly, here 650. When we have done this with all of the event nodes for the decision, we compare them and the double strike the lesser value decision choices.

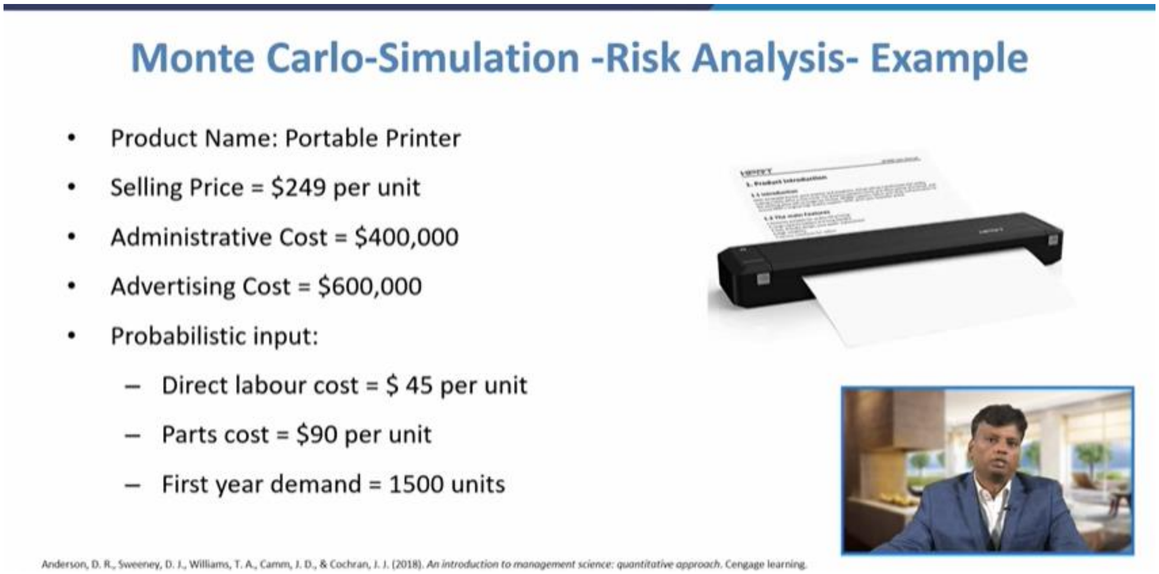


So, when we compare these three, so 840 is there, 800 is there, 650 is there. So, whichever is the smaller we are striking it off. So, that we are not going to that path. That means that is not the good choices and choose the best alternative choice for that decision rule in this case developing gas only model. So, the here highest EMV is expected monetary value is for the first option that is a gas only model.

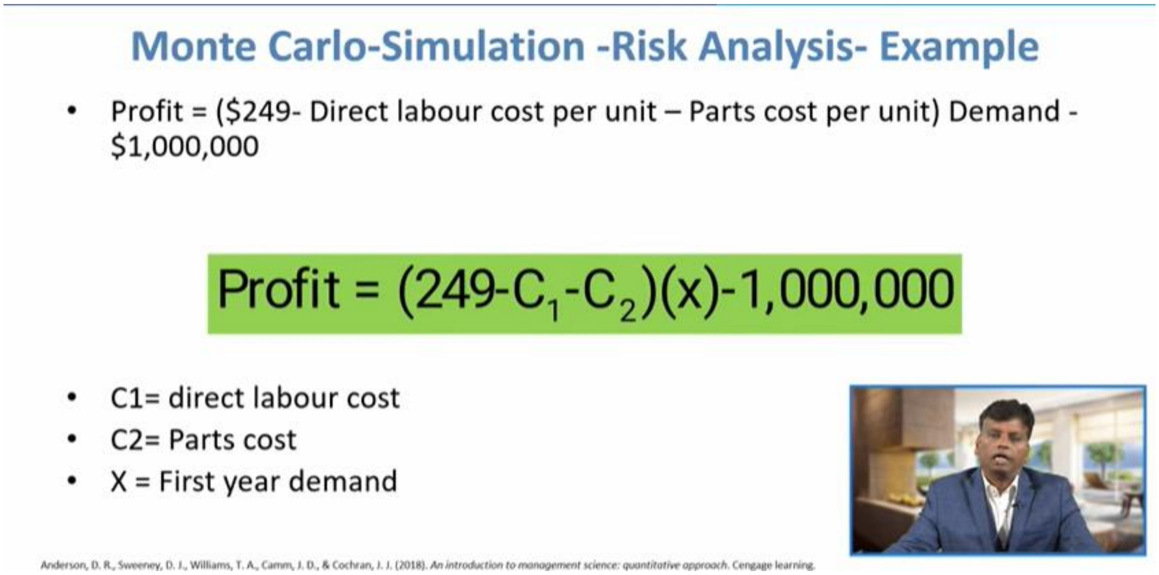


So, this is our the best alternative. Now, we will talk about very popular way of analyzing the risk that is called simulation. The simulation combined with the sensitivity analysis is also useful for evaluating project while they are still at the conceptual stage. So, before launching the product, it has happened for Chandrayaan 3 also. So, before the soft landing of Chandrayaan 3, they have done so many simulations in the earth by considering all the moon conditions. The same way for each project, when the project is at the conceptual stage, we can do the simulation, we can see the for different scenario, how the project outcome will be.

So, I have taken a sample a problem for the simulation, there is a Monte Carlo simulation. So, we are going to discuss about risk analysis for launching a new product. Assume that the company is launching a new product, we want to know the probability of the success or what is the risk, what is the probability of failure of that new product. So, the product name is a portable printer, assuming that the selling price of that portable printer is $249 per unit and there are cost administrative cost $400,000 and advertising cost $600,000. And most important thing is the simulation will have input that is probabilistic in nature.



So, for example, labour cost $45 per unit, but that is it is not the fixed amount, it may change. Similarly, the part cost is a material cost $90 per unit that also not fixed, it may change and the demand 1500 units, but it is not fixed, it may change. So, we have 3 probabilistic input and we have the selling price and administrative cost for the new portable printer. So, in this problem, first we have to find out the profit. So, what is the profit? The profit is selling price, that is a $249, then we have to subtract labour cost and part cost, then that whole value has to be multiplied by demand.



So, what will happen when you 249 minus labour cost minus part cost, so we will get a profit per unit, when you multiply by demand, so we will get overall profit. Then we have to subtract the fixed cost that is advertisement cost and the overhead cost, how much it was I will go back, you see here, administrative cost, advertising cost. So, administrative cost is $400, advertising cost is $600 that we have subtracted. So, this is the function of profit. So, what is the profit function? 249 minus C1 that is called labour cost minus C2 that is a part cost multiplied by X demand minus advertisement cost and the administrative cost.

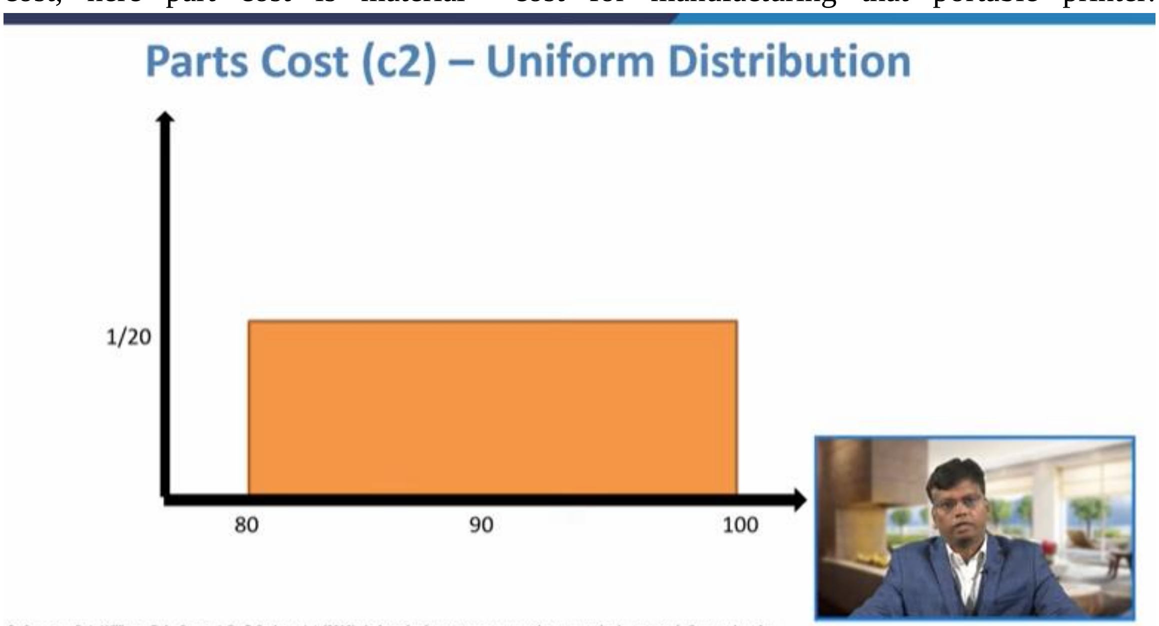
Profit = (249- C1 -C2)(x)- 1000000

Here there are 3 variables which are probabilistic in nature, one is C1, C2 and X. Here X we consider only the first year demand because we are going to launch the product. So, we may not know the historical demand, we are assuming that the demand will be this much X. Now, we will consider all probabilistic input, the first probabilistic input is direct labour cost, we may not know what exactly the labour cost is going to be. For example, during COVID time the labour cost was very high, now it become very normal.

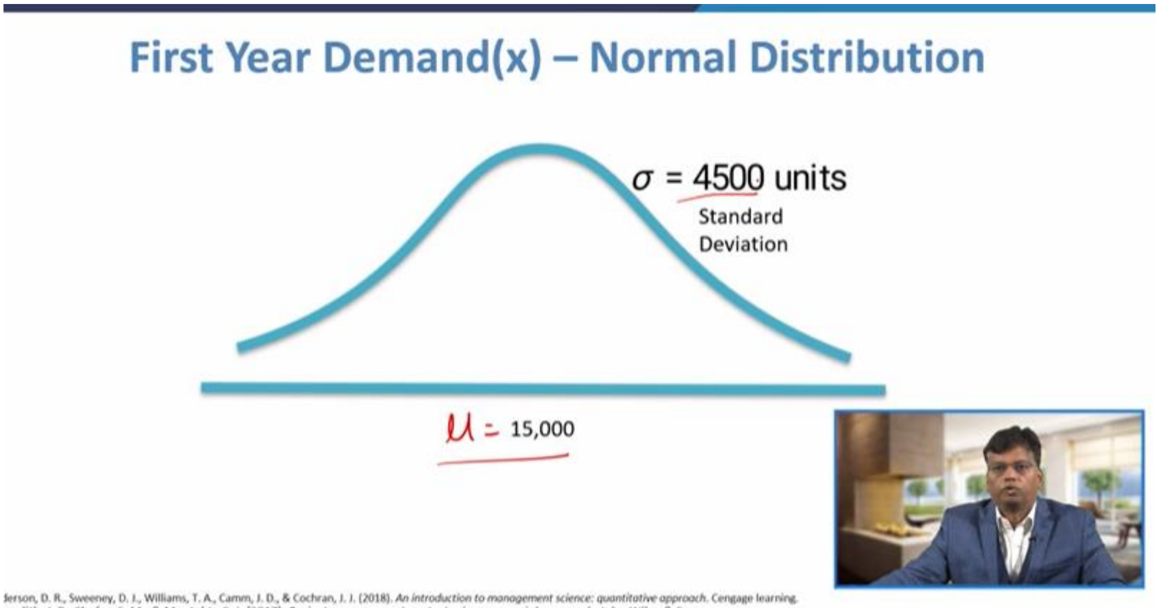
Direct Labour Cost (C1)

Direct Labour Cost per unit	Probability
$43	0.1
$44	0.2
$45	0.4
$46	0.2
$47	0.1

So, similarly, so there is a probability of the labour cost. For example, there is a 10 percentage chance that the direct labour cost per unit will be $43. There is a 20 percentage chance the direct labour cost per unit will be $44. There is a 40 percentage chance the direct cost per unit that is labour cost will be $45. Like this possible cost and corresponding probabilities is given, this is the first input. The second input is the part cost, here part cost is material cost for manufacturing that portable printer.



A So, here the part cost follow uniform distribution, previously the labour cost followed empirical distribution, but the part cost follow uniform distribution. So, what is the characteristics of the uniform distribution? The minimum is 80, maximum is 100, this is the second input. The third input is the first year demand. So, what is the assumption here is the demand is going to follow normal distribution, the mean is going to be 15000 here and the standard deviation is going to be 4500.



These are my assumptions. Now, by considering these three probabilistic input, we are going to find out what is the risk of launching this product. Here risk in the sense, what are the chances for loss. In the Monte Carlo simulation, if there is an empirical distribution, the first step is we have to construct a table. So, that will cover say direct labour cost is given and the probability is given, then we found the cumulative probability. So, we are going to find out interval for random numbers, how we are done? So, 0 to 0.1, then 0.1 to 0.3, because this will be the your right side limit, then 0.3 to 0.7, then 0.7 to 0.9, then 0.9 to 1. So, what we have to do, we have to construct the interval for random numbers.

Value for the direct labor cost per unit

Direct Labour Cost per unit	Probability	Cumulative Probability	Interval of random numbers
$43	0.1	0.1	0.0 but less than 0.1
$44	0.2	0.3	0.1 but less than 0.3
$45	0.4	0.7	0.3 but less than 0.7
$46	0.2	0.9	0.7 but less than 0.9
$47	0.1	1	0.9 but less than 1

Anderson, D. R., Sweeney, D. J., Williams, T. A., Camm, J. D., & Cochran, J. J. (2018). *An introduction to management science: quantitative approach*. Cengage learning.

If you are using a random number table randomly or if you can use your calculator also, how to find out the direct labour cost randomly per unit. So, you have to choose the random number. For example, you are using a calculator, you say the random number is say 0.6, say random number is 0.6. So, we have to see where this 0.6 comes. So, here the 0.6 is comes in this interval. So, the corresponding direct labour cost per unit is 45 dollar has to be considered.

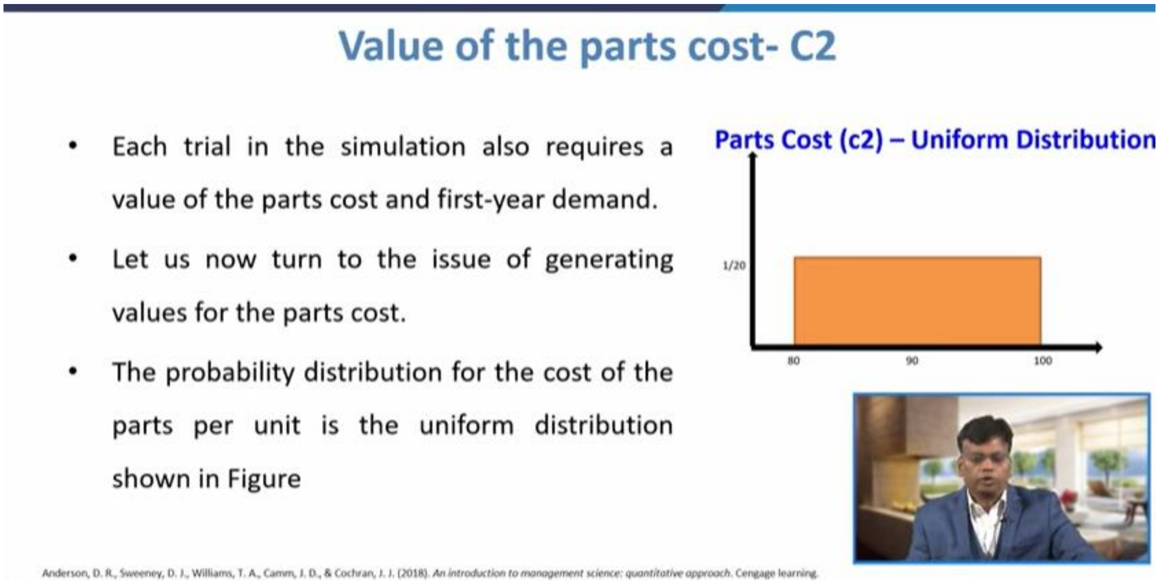
Random generation of 10 values for the direct labor cost per unit

Trial	Random number	Direct labor cost $
1	0.9109	47
2	0.2841	44
3	0.6531	45
4	0.0367	43
5	0.3451	45
6	0.2757	44
7	0.6859	45
8	0.6246	45
9	0.4936	45
10	0.8077	46

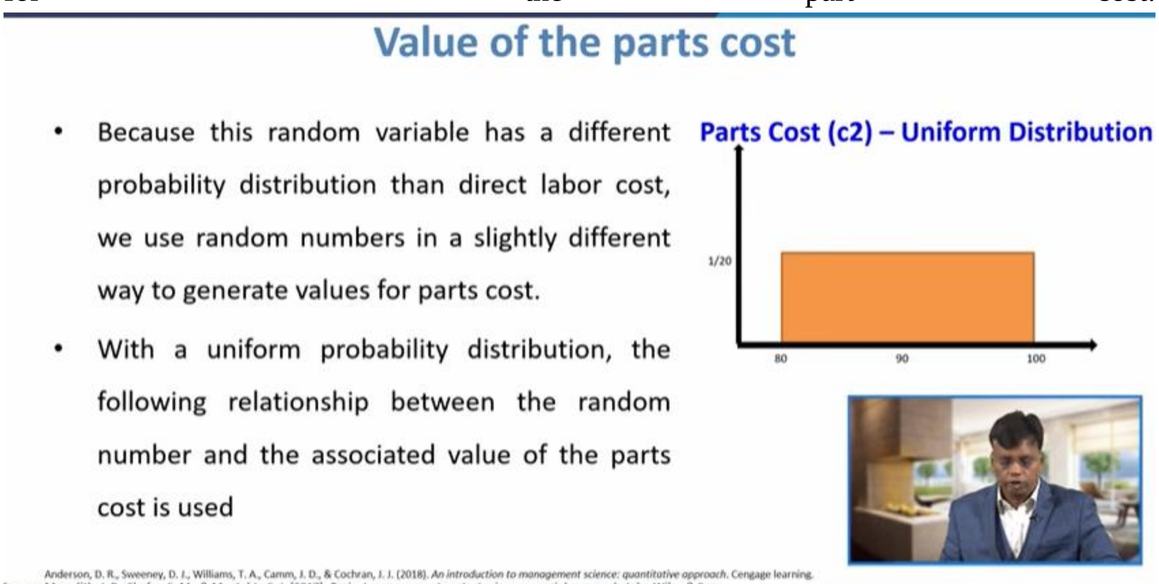
Direct Labour Cost per unit	Probability	Cumulative Probability	Interval of random numbers
$43	0.1	0.1	0.0 but less than 0.1
$44	0.2	0.3	0.1 but less than 0.3
$45	0.4	0.7	0.3 but less than 0.7
$46	0.2	0.9	0.7 but less than 0.9
$47	0.1	1	0.9 but less than 1

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

Here I have some random numbers. For example, the random number is a 0.91. So, we have to look at this table, we see where there is a 0.91. So, here there is a 0.91. So, the direct labour cost will be 47 dollar here. You generate another random number 0.28. So, we have to look at the table where there 0.28, 0.28 will be here. So, it will be corresponding direct labour cost will be 44. So, like that I have done 10 trial, then I have looked that where this random number appears in the table, then I have picked corresponding direct labour cost. So, this value can be used as a input for different iteration of the simulation.



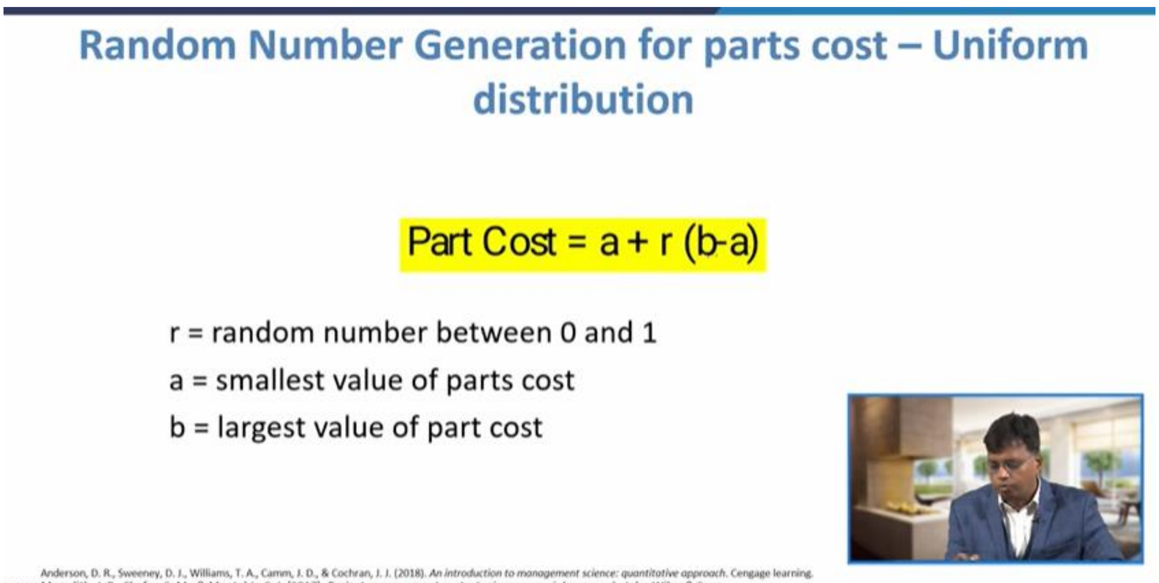
The second one is part cost. As I told you, the part cost follow uniform distribution. So, each trial in the simulation also requires value of the part cost and the first year demand. Let us now turn the issue of generating value for the part cost. The probability distribution for the cost of the part per unit is the uniform distribution as shown in this figure. Now, we have to generate different part cost that should follow uniform distribution. Because this random variable has different probability distribution, then the direct labour cost, we use random numbers in a slightly different way to generate values for the part cost.



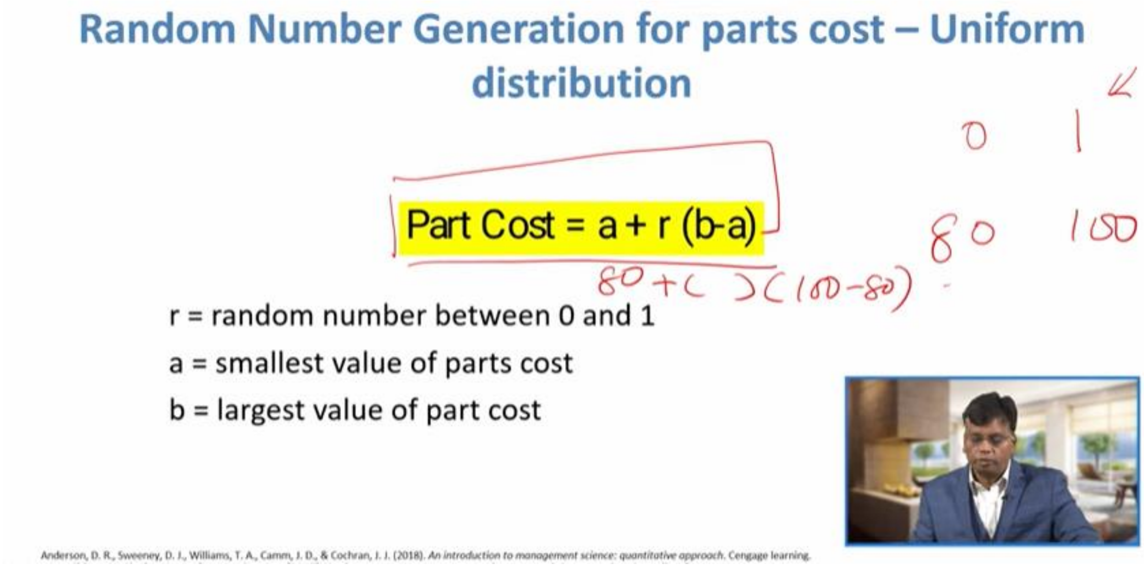
With a uniform probability distribution, the following relationship between the random number and the associated value of the part cost is used. What is that relationship? The part cost is a plus r multiplied by b minus a.

Part cost = a+ r(b-a)

What is the a here? a is the smallest value of the part cost, b is the largest value of the part cost and r is the random number between 0 and 1. What we do? So, suppose if you generate a random number from the table, that will be many times it will be 0 to 1. But we want random number when you look at the table, we want a random number between 80 and 100.

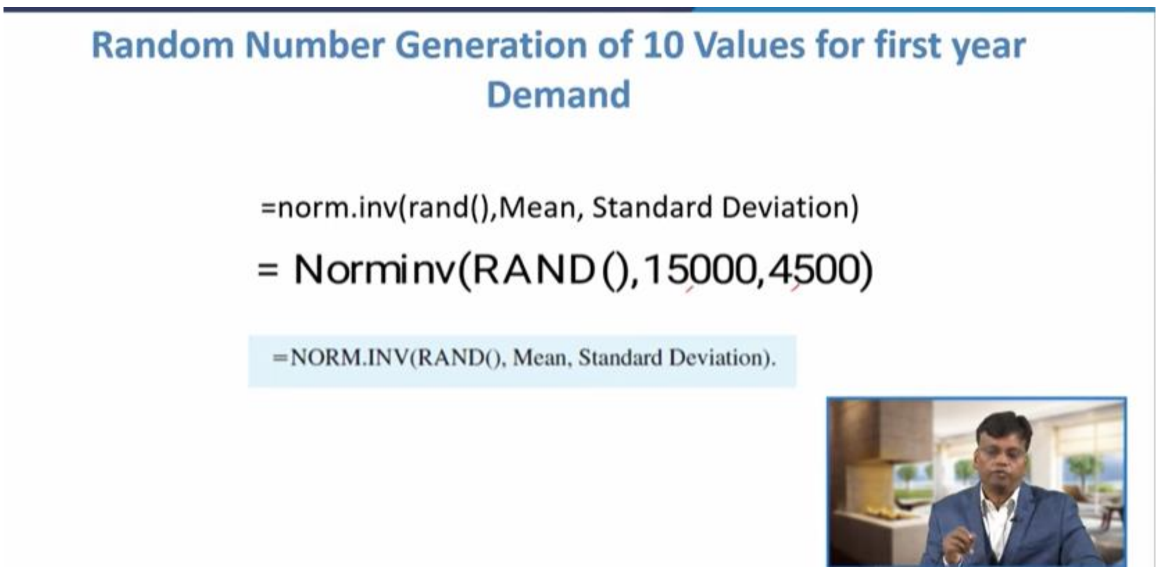


Because it has come from this table. So, the lower limit of this uniform distribution is 80, upper limit is 100. But if you use calculator you are getting the random number between 0 and 1. But we want random number between 80 and 100. For this to convert a random number between 0 and 1 to 80 and 100, we have to use this formula a plus r (b minus a.)



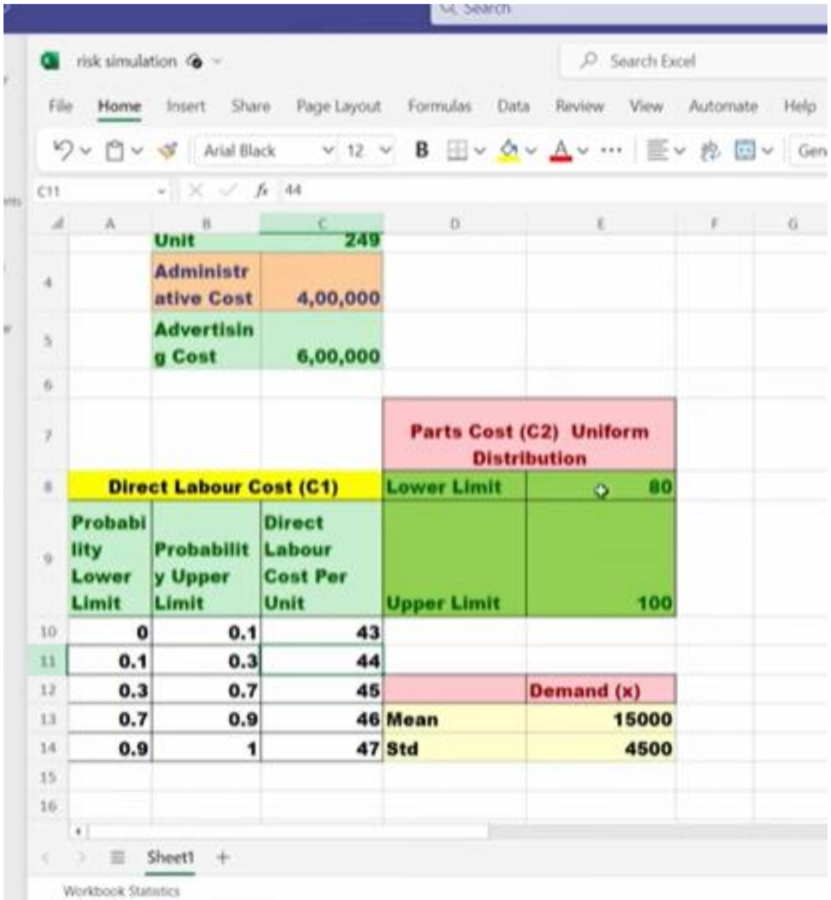
It is called pseudo random numbers. What we are doing? Why we are using this formula? We are converting random number which are generated from the calculator and later we convert into the uniform distribution. That conversion is done by using this formula. Here a is your 80, lower limit of that random number plus r is what value you will get from the calculator, then multiply it by b minus a, 100 minus 80. So, this formula should be used for converting pseudo random number which follow uniform distribution.

If it is some other distribution there will be a different formula. Here since the part cost follow uniform distribution you have to follow this formula. The third input variable is demand. But now we have to generate the demand that should follow normal distribution. That mean should be 15,000 and standard deviation should be 4,500. So, for this purpose I am going to use the excel function to generate this random numbers which follow normal distribution whose mean is 1,500 and standard deviation is 4,500.

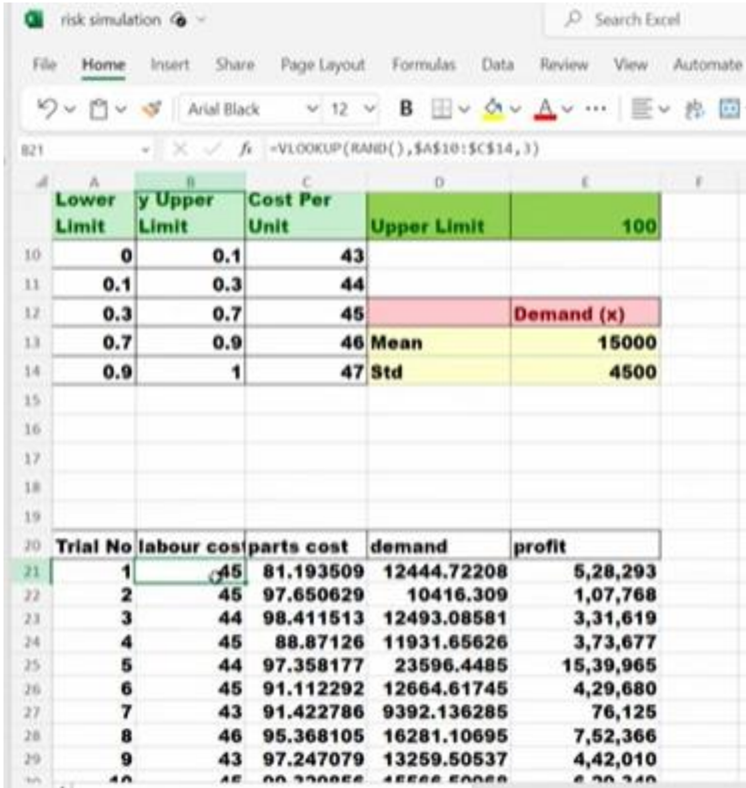


So, for that purpose excel has the standard formula. So, if we use “norminv” normal distribution inverse random this number what you are generating then the mean and the standard deviation. So, when you supply this you will get this type of formula. If you in the excel if you use this one you will get a random number which follow normal distribution by considering these two parameter. When you drag it you will get as many number of random numbers which follow normal distribution.

Now I will go back to the excel. I will explain I have done this Monte Carlo simulation using excel then I will come back to the result. Dear students in the Monte Carlo simulation selling price is given $249, administrative cost is given $400,000, advertising cost is given $600,000 and there are three input direct labor cost which follow empirical distribution. We wrote that the probability interval the probability lower limit and upper limit and direct labor cost when it is a 43. If it is 44 we have given probability lower limit and upper limit and we have done it for all other value of different labor cost. And here I have taken part cost that follow uniform distribution lower limit is 80 upper limit is 100 and the first year demand the mean is 15,000 standard deviation is 4,500.



By using this input I am going to do a Monte Carlo simulation. So, the first one is labor cost. So, here the labor cost I am going to use a VLOOKUP function. So, equal to VLOOKUP function then RAND then we have to select that table that is from A10 to C14 then comma you see 3 that is the value in the third column will be chosen. So, what is how this VLOOKUP function is working? Randomly we generate the number, the number is traced in the table in the probability table.



Lower Limit	y Upper Limit	Cost Per Unit	Upper Limit	100
0	0.1	43		
0.1	0.3	44		
0.3	0.7	45		Demand (x)
0.7	0.9	46	Mean	15000
0.9	1	47	Std	4500

Trial No	labour cost	parts cost	demand	profit
1	45	81.193509	12444.72208	5,28,293
2	45	97.650629	10416.309	1,07,768
3	44	98.411513	12493.08581	3,31,619
4	45	88.87126	11931.65626	3,73,677
5	44	97.358177	23596.4485	15,39,965
6	45	91.112292	12664.61745	4,29,680
7	43	91.422786	9392.136285	76,125
8	46	95.368105	16281.10695	7,52,366
9	43	97.247079	13259.50537	4,42,010

Suppose the number is say 0.35. So, 0.35 is comes under interval 0.3 and 0.7 and the corresponding value is 45 that 45 is in the third column that is why number 3 is written. So, that value is picked here. So, see this 45. So, what you can do if you press F9 this value will change you see that sometime 46 sometime 43.

So, this is the way to generate the labor cost. The next one is the part cost. The formula for the part cost is the lower limit of that uniform distribution that is given in E8, E8 is 80 plus random number then multiplied by upper limit minus lower limit that is E9 minus E8. Remember here I have given the dollar sign because I have freeze did because I am going to drag it. So, this is the way to generate the part cost. Here also for if you keep on press F9 please note this column C where the 81 will change when I keep on press F9.

See sometime 83, sometime 96, sometime 93 and so on. The third column, the third input is demand. So, here I am going to use norm dot inv function rand then I have to specify what is the mean and what is the standard deviation. So, here I got 9495. So, when you keep on press F9 see that I am getting see that now I got 15667, now I got 21243.

Direct Labour Cost (C1)			Lower Limit	80
Probability Lower Limit	Probability Upper Limit	Direct Labour Cost Per Unit	Upper Limit	100
0	0.1	43		
0.1	0.3	44		
0.3	0.7	45		Demand (x)
0.7	0.9	46	Mean	15000
0.9	1	47	Std	4500

Trial No	labour cost	parts cost	demand	profit
1	45	81.550799	15667.14186	9,18,429
2	45	97.866951	9867.110793	47,227
3	47	81.42936	13469.99302	6,24,086
4	43	94.955908	12442.94268	3,81,715
5	46	88.61688	25260.69896	18,89,398

Now I have randomly generated 3 input. Now I am going to use the profit function to find the probability. You remember in my presentation I am showing the profit function that is a selling price that I have given in C3, selling price is in C3 that is a 249 dollar minus labour cost that is there in B21 minus part cost that is in C21. Then I have to multiply by demand multiplied by D21. So, I will get overall revenue minus there are two cost is there. One cost is there at C4 another cost in C5 400,000 and 600,000 that also I am subtracting.

E21 =(C3-B21-C21)*D21-C4-C5

Lower Limit	Probability Upper Limit	Cost Per Unit	Upper Limit	100
0	0.1	43		
0.1	0.3	44		
0.3	0.7	45		Demand (x)
0.7	0.9	46	Mean	15000
0.9	1	47	Std	4500

Trial No	labour cost	parts cost	demand	profit
1	45	92.691266	21237.93477	13,63,968
2	44	83.608314	11562.41074	4,03,581
3	46	86.845863	15990.24062	8,57,333
4	45	96.868865	14895.36018	5,95,757
5	45	91.408585	15579.11151	7,54,074
6	45	92.53343	15451.5675	7,22,333
7	44	92.004212	20786.11722	13,48,744
8	46	92.692271	20940.49321	13,09,898
9	46	88.8009	14085.63057	6,08,566

So, in the last column I am getting the profit. So, for the trial 1 my profit is 13,63,968. So, I can drag it up to as many number of iteration. So, I have done how many trial I have done it I have done it 500 trial I think. I have done 500 trial. So, what I have done here randomly generated the labour cost, part cost and demand then I have used profit function.

A	B	C	D	E
490	45	89.535982	16734.39604	9,15,486
491	44	80.162958	5328.800028	-3,34,768
492	43	85.713649	12060.28207	4,50,687
493	45	88.814238	13936.33294	6,05,267
494	45	88.31528	11791.51899	3,64,099
495	44	89.477526	12602.31202	4,55,850
496	43	97.50764	15990.66795	7,34,865
497	44	84.357009	19050.10604	12,98,262
498	46	90.702196	15806.88296	7,75,078
499	44	99.238453	20346.08506	11,51,833
500	45	93.340862	22531.15234	14,93,278
			Mean profit	7,12,259
			Std deviation	508262.8267
			Minimum Profit	-7,4[illegible]673
			Max. profit	22,89,702
			No. of Loss	39
			Probability of L	0.078

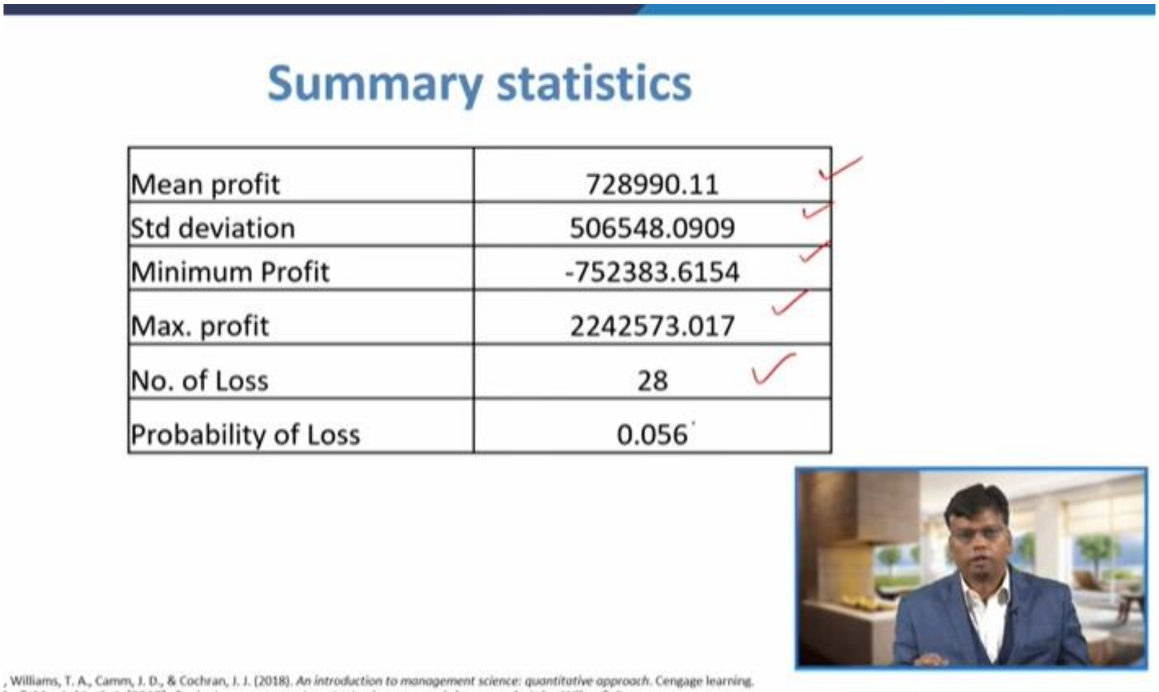
So, the last column E is the profit function. Here I am getting. So, I got some statistics mean profit is 712259 standard deviation is given, minimum profit because there is a mean function then maximum profit I given the there is a max function. Here the number of loss it is more important. So, here to find the number of loss I have used the countif function. So, equal to countif in that profit column E 21 to E 520 wherever there is a negative profit that I have considered as the loss.

For example, here the number of loss is 39. So, if I press if I press F9 you see the 39 will change. See 33 it is 43 it is 41 it is 46. So, that is the number of loss from this what I am going to do the probability of loss. So, probability loss is number of losses upon total number of iteration.

A	B	C	D	E
490	45	89.838611	15229.83057	7,38,659
491	45	96.867029	11076.85526	1,86,696
492	46	99.010911	7629.769416	-2,06,587
493	44	84.246851	11774.42392	4,21,799
494	44	92.546806	7988.969896	-1,01,615
495	44	96.9606	13706.21669	4,80,811
496	45	82.804565	21510.14087	16,06,931
497	44	93.963636	13947.96257	5,48,731
498	44	80.714079	17681.24085	11,97,529
499	47	87.786179	13192.50576	5,06,766
500	44	80.635629	16306.79012	10,27,984
			Mean profit	7,05,765
			Std deviation	518189.2964
			Minimum Profit	-7,76,363
			Max. profit	20,67,089
			No. of Loss	46
			Probability of Loss	0.092

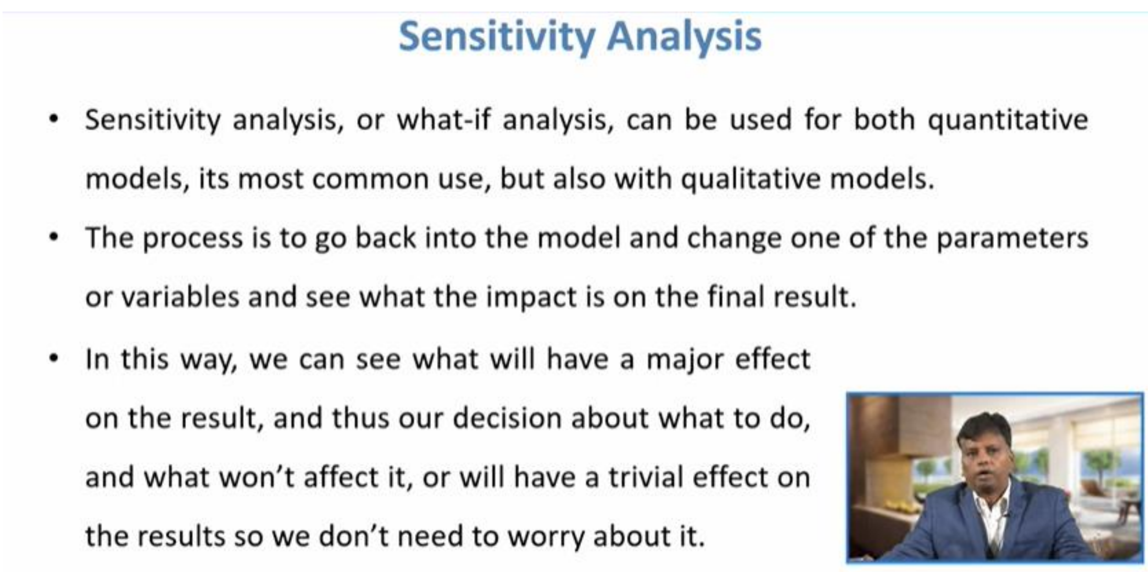
So, here total number of iteration is trial is 500. So, number of losses upon 500. So, this for example, here at present there is a 9 percentage chance that the new product will enter into the loss in situation. So, when we keep on press F9, please observe only the profit loss column. So, you see that sometimes 7 percentage loss, sometime 8 percentage loss, sometime 6 percentage loss, you can observe that the loss always below 10 percentage. So, what we conclude from here is if you launch this new portable printer, there is a 10 percentage chance that this may fail in the market.

So, this is the conclusion of this Monte Carlo simulation. Now, I brought the summary statistics. So, I got the mean profit, standard deviation, minimum profit, maximum profit, number of losses. So, the probability loss is 5.6 percentage. So, this is the way to do a Monte Carlo simulation to assess the risk of launching a new product.



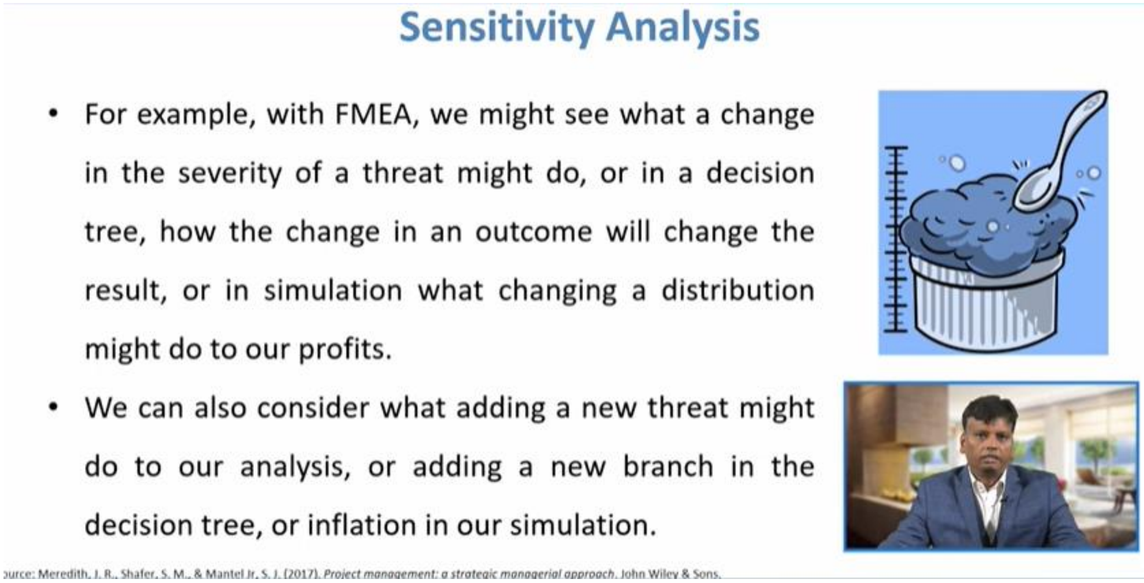
Mean profit	728990.11
Std deviation	506548.0909
Minimum Profit	-752383.6154
Max. profit	2242573.017
No. of Loss	28
Probability of Loss	0.056

Next, we will discuss about sensitivity analysis. Here the sensitivity analysis is for example, we consider three input, labour cost, part cost and the demand. We assumed that labour cost followed empirical distribution, part cost followed uniform distribution and the demand followed normal distribution. Suppose if the distribution changes, what will be the impact on the risk? So, that can be done with the help of sensitivity analysis. So, sensitivity analysis or what if analysis can be used for both quantitative models, it most common use, but also in qualitative models. The process is to go back into the model and change one of the parameter or variables and see what the impact is in the final result.



For example, we consider the mean of the demand distribution is 15,000. Suppose if it is

20,000, what will happen? So, that change in parameter and corresponding effect impact on the risk can be done with the help of the sensitivity analysis. So, in this way, we can see that what will have a major effect on the result and thus our decision about what to do and what would not affect or will have a trivial effect on the result. So, we do not need to worry about that. So, these kind of conditions can be assessed when we do sensitivity analysis, whether impact is going to be severe, whether there is no trivial impact.



So, these kind of inferences can be obtained with the help of this sensitivity analysis. But in the Monte Carlo simulation, I did not do the sensitivity analysis, you can do by changing different parameters and we can see what is the impact of that. For example, in the failure mode effect analysis, we might see what a change in the severity of threat might do or in the decision tree, how the change in the outcome will change the result or in the simulation, what changing a distribution might do our profit that can be done with the help of sensitivity analysis. We can also consider what adding a new threat might do to our analysis or adding a new branch in the decision tree or inflation in our simulation. One weakness of sensitivity analysis is that a single change in the environment does not usually happen. Instead, many variables or parameters commonly change the same time, which is harder to check and determine how it might affect our decision.

Sensitivity Analysis

- One weakness of sensitivity analysis is that a single change in the environment doesn't usually happen, and instead, many variables or parameters commonly change at the same time, which is harder to check and determine how it might affect our decision.

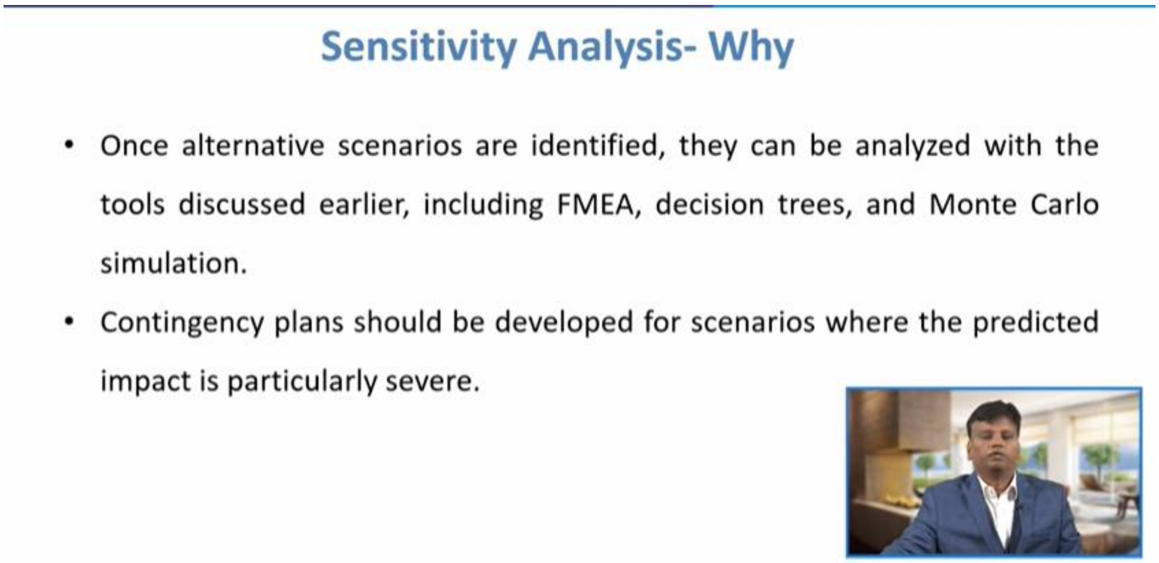
Sensitivity Analysis- Why

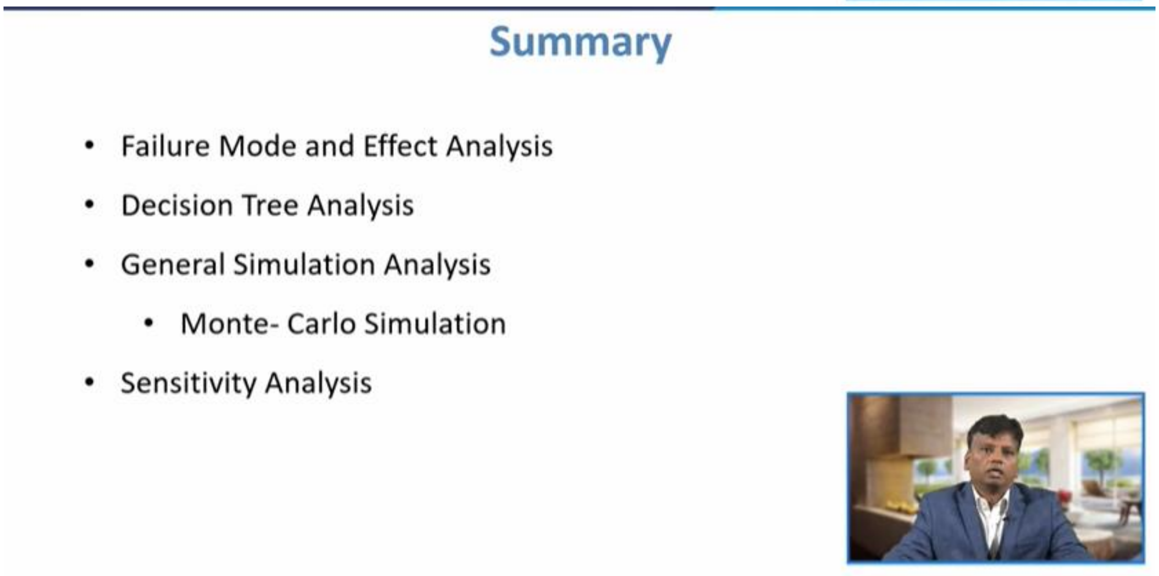
- There is also a form of scenario sensitivity analysis, where the impact of alternative developments or scenarios in the completion of the project are predicted.

For example,

- what would be the impact on the success of the project if the PM left the organization?
- If a major contractor suffered a strike by a labor union?
- If an important new technology did not perform as expected?
- If a competitor beat us to market?

As I told you, sensitivity analysis done by changing one parameter at a time, but many times that may not help. So, what we can do simultaneously, we have to change different parameters, then we can see overall impact that is very difficult to do with the sensitivity analysis. There is also a form of sensitivity analysis, where the impact of alternative development or scenarios in the completion of the project are predicted. For example, what would be the impact on the success of the project, if the project manager left the organization, if a major contractor suffered a strike by a labor union, if an important new technology did not perform as expected, if a competitor beat us to market. So, these kind of scenario analysis also can be done by doing an advanced simulation analysis for assessing the project risk. Once alternative scenarios are identified, they can be analyzed with the tools discussed earlier, including failure mode effect analysis, decision tree, Monte Carlo simulation and contingency plan should be developed for scenarios where the predicted impact is particularly severe.





So, in this lecture, dear students, I have discussed about various quantitative techniques for analyzing the project risk. I have discussed three quantitative techniques, one is failure mode and effect analysis, second decision tree analysis, third one with the help of Excel, I have explained how to use Excel for doing Monte Carlo simulation. Then finally, I have explained the importance of sensitivity analysis. Thank you. Thank you.