Infrastructure Planning and Management
Module Flexibilities in Projects Part 2

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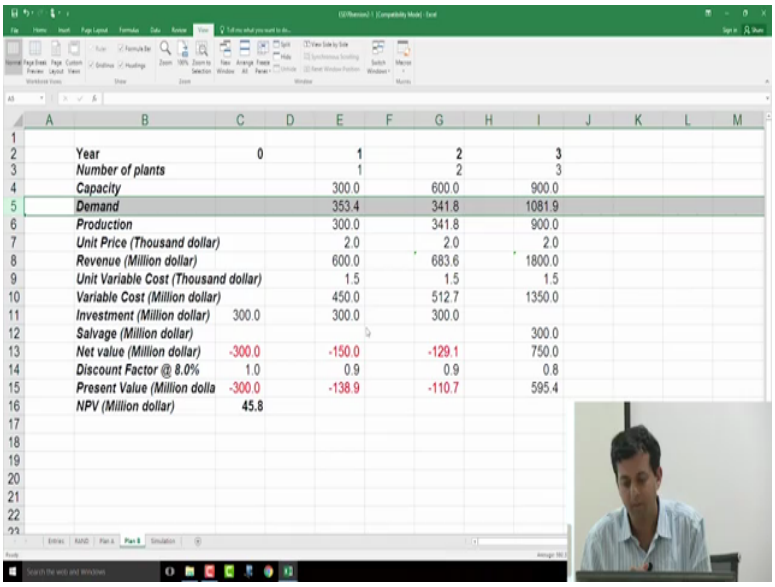

So now if I look at plan A the net present value of plan A is 740 point 3 right based on the current demand configurations the NPV of plan B is 45 point 8 right based on the current you know configuration all right, why is that and each of you will get something different right.

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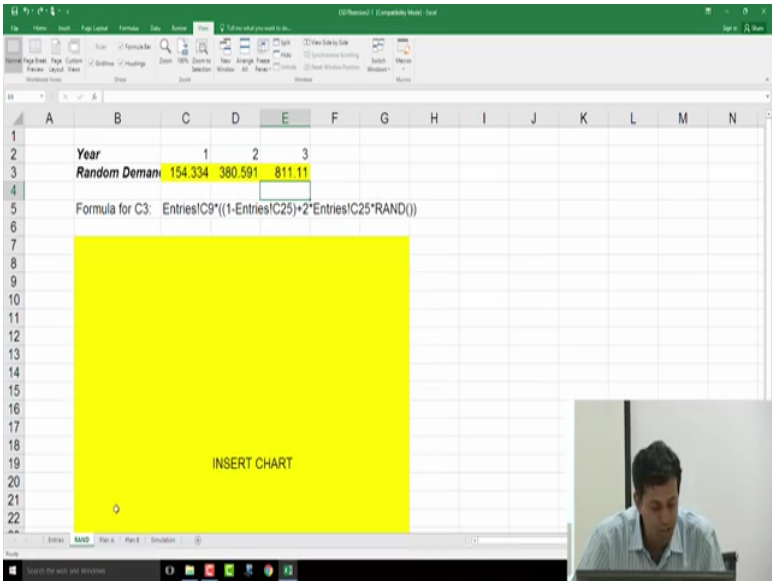

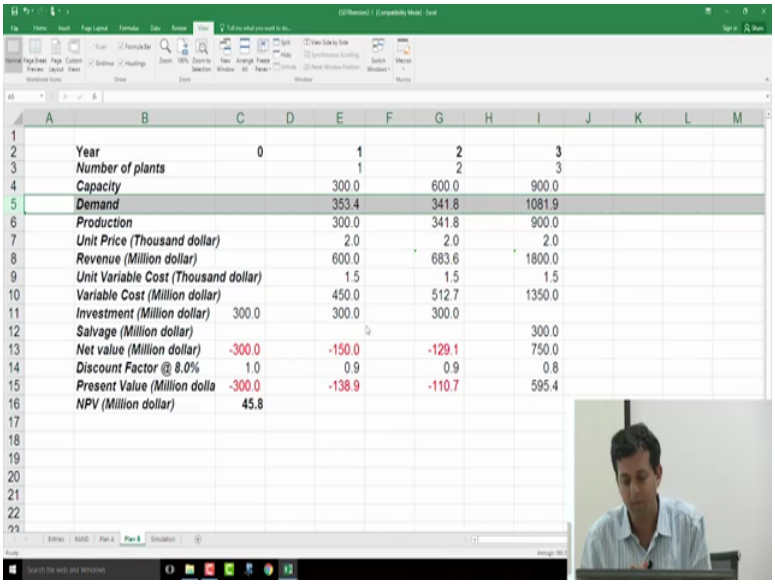

Each of you will get something different so for me what has ended up happening is that year 3 well for whatever we so year 1 I manufacture 350, year 2 I invested in the second plant right in the small plant but I still did not manufacture as much because the demand was not there and in year 3 I invested in the third plant but the variable operating costs etcetera seem to have been much higher.

So overall Plan B has performed very poorly for me oh but this is sorry these have sorry here we are the demand has been taken from that sheet right so the demand is taken from that sheet view ok but my overall NPV is only 45 point 8 oops what well I seem to have hit another random and I get all other kinds of NPVs right, so in some cases now I hit another RAND and the NPV of plan A and Plan B are again very different ok.

So I am now able to randomize but the problem is each of us now gets a different NPV A minus NPV B which one is correct? Right it is mine correct or yours correct right and among you which one of yours is correct? Right so how do I solve this problem? Right I have wanted to have some randomized demand because I cannot really predict it I put in the randomization but because I put in the randomization does that make it you know I get an answer you get an answer how do we actually resolve this.

Student is answering: Take the maximum and minimum (())(02:01).

Professor: Maximum minimum values of what? Yeah maximum minimum values of NPV is for.

Student is answering: (())(02:09) A and B.

Professor: Yeah but maximum minimum means I have only one value right I have A is 740 B is 40 point 3 I am getting a difference of 700 maybe you are getting a difference 120 or 640 or whatever it is right, so how do I deal with the that yes I have been able to put in randomization but the problem by putting in randomization is that we do not have a single source of truth right.

So here is where there is a technique that I do not know maybe you guys have come across called Monte Carlo simulation, so Monte Carlo simulation says you know do not do it once it makes no sense do it 2000 times or some large number do it 1000 times, 5000 times whatever and then average out those five thousands sorry that 5000 or those 2000 runs that you do and that will give you a little bit of a measure of what is the expected difference in net present value.

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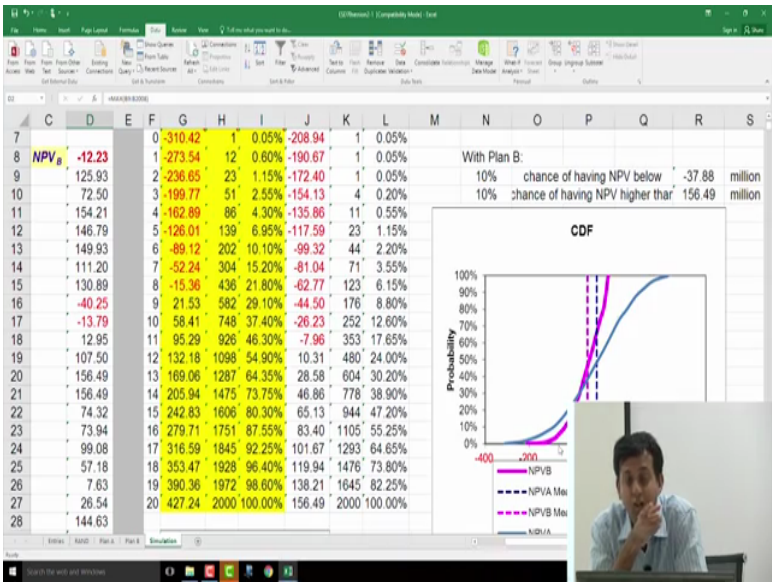

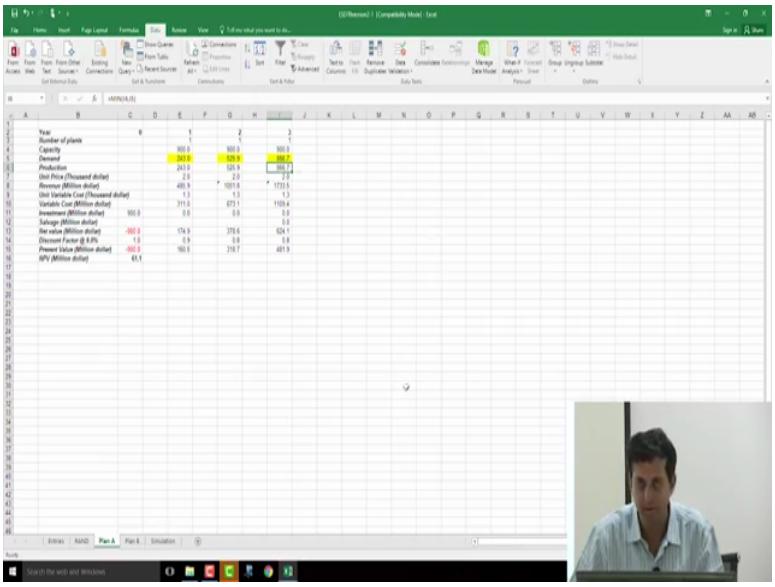

So if you go to the last sheet here right in some sense that is what has happened right, so for Plan B what we have done is we have said we have done the demand and whatever 2000 times right, so it will go all the way up to 2008 right you know row number 2008 right so I have got 2000 iterations of plan B and so you see I have got a large number of net present values but then what I have done is I have calculated the mean right of 2000 and I have also calculated a maximum and a minimum right and the idea is because I have done 2000 of these simulations and I assume that they are roughly normally distributed this is a probably a good expected value right.

So if demand does not vary right I had a particular NPV for B right which was I cannot remember what it 156 or whatever but if demand does vary then the expected NPV for B is about or the mean NPV is about 60 right is what this is coming out ok, so this is now a bit more sophistication in terms of analysis because I know have randomized demand, imagine we are trying to do this for a highway right imagine I just took one set of traffic projections right there is no and ok I might do a little bit of sensitivity but sensitivity is not randomness right sensitivity is sort of purposefully saying what if demand was 2 percent higher 3 percent higher but now I am randomizing demand, I am randomizing demand and I am looking at a number of scenarios of demand and then deciding you know what should what would the average demand be.

So we can do the same thing for A and we can use the data table for the right, so this you know here essentially I would say what I want to recalculate thousands of times is the NPV of planning, so the NPV of plan A is what I maybe I should make this bigger ok, so the NPV of planning is what I want to calculate a number of times, what do I want to vary?

Student is answering: (())(05:08).

Professor: Yeah I want a vary demand right but which cell do I want to vary?

Student is answering: Demands vary NPV of cell B plan B, so.

Professor: So earlier the point the question I am asking is earlier I wanted discount rate to vary right, so I went in and put discount rate varies ok so here which is what is actually very the random number is actually vary right, so in other words at I am not varying any particular parameter right I just want to do this 2000 times right so what I am going to do now is I am going to select this whole table ok that is probably a good way to do this but I do not know how so I am just scrolling until I get to 2008 got there, I have got 2000 cells selected and right on top here I have got this next to NPV A right I have got the value that I want to compute right which is the NPV of A so that I need to vary right 2000 times.

So I have selected 2000 cells ok but deliberately I am NOT selecting that I am not putting in any numbers earlier I was varying my discount rate I was varying I do not want to vary anything I wanted to do it randomly. So I go back to the same thing I do data what if analysis data table all right and in the column input cell I just click a blank cell right so I am saying you know take you know this variable which is nothing right and vary it 2000 times ok.

So essentially I am saying ok just sort of redo the whole thing 2000 times and knowing that every time it does it there will be a different random number that comes in there will be in demand distribution and NPV of A will change, so once I say ok here so for the benefit of people online what happened was we had not put in the demand, so we need to go back to the plan A web sheet, we need to click on demand and I have got to say demand is equal to what I got from the random function.

So this is the demand for year 1, this is the demand from year 2 and this is the demand from year 3, correct? Now I should actually if I go back to simulation very nice, so I have a bunch of values that have come out ok and I did not have to stop the recording ok wonderful ok great, so does everyone have a series of random values for NPV A ok so again so what we have done is slightly just more sophisticated we have said let us do some Monte Carlo modelling.

Let us take demand, let us see the demand varies at the moment it varies normally a (cro) around a mean and let us then try to simulate and see if there is some variation what

would it be and I have taken the demand is varying 50 percent around the mean, you can go and change that 50 percent value to 40 percent, 30 percent right, so we can have all kinds of variance right you can also have all kinds of distributions right you can have a normal distribution, you can have a triangular distribution you know whatever kind of distribution that you want.

Essentially as long as you can generate a random number right and you have some idea of the shape of the distribution you can start sampling it right which is what we are doing ok and we are finding and I am going to find out the mean of this so I am saying the mean of this is going to be the average of essentially B9 to B2008 ok, so the average is 98 point 9 the maximum is going to be the maximum of B9 to B2008 and the minimum is the minimum of B9 to B2008.

So I just use the max and the min functions just use the maximum and mean functions and you find right so roughly you find every time you click there is a slight variance but roughly the mean seems to be close to 90, 100 in the case of NPV or in case of plan A and it seems to be about 65 point 05 or whatever in the case of Plan B ok with varying minimum and maximum ok. So are we all here at the moment, so far are we all on the same page yeah, one by one, harsh.

Harsh: Sir, how do you decide uncertainty?

So that is based on how do you decide uncertainty that you sort of have to do some kind of analysis to figure out what is the kind of distribution you are seeing in the sample, what kind of distribution does it fit, what is the mean of that distribution, what is the standard deviation the standard deviation or the variance is some measure of the uncertainty based on that what do I put into the model right. So that you have to do that data driven analysis to understand where that 50 percent comes from ok, yeah.

Student is questioning: (())(10:22) the demand values are changing here.

Professor: The demand values are changing here? No, every one of these simulations and demands are different.

Student is questioning: (())(10:33).

Professor: So what matters here is that is the 300, 600, 900 because I am varying around those numbers right so that matters but beyond that every one of these thousand that you are

seeing in the yellow here is a different run right and it is completely different demand, so essentially I am saying it is vary right do you know how much traffic they will be on the road tomorrow, I do, I cannot precisely tell you how much there will be I probably have a range I have some kind of a probabilistic view of what that traffic would be right but I cannot tell you exactly.

So the traffic could be on the lower end of that bound it could have be on the higher end of that bound so I am just sort of simulating it right the reason this is interesting is because of a of an inequality called the or an equality what yeah well some relationship which is called the flow of averages and the explanation for the flow of averages you know goes like this just if you get 50 percent less demand right in year 1 and 50 percent more demand in year 2 on average you meet your demand right that is the law of averages right.

So I am supposed to get 300 every year right I get 150 one year I get 450 the second year on average have still met my demand right I have still got 600 customers walking through my door. The problem is think about the fact that you own a hotel ok your hotel has a hundred rooms ok you expects 80 people to come in right because this is good season 80 people you always have some buffer rooms but there is a 50 percent probability of it going up or down right.

So on the one hand if you get 40 people coming in how much money will you make? Compared to what you expected right you expected 80 people to come in only half of them are able to come right how much money do you make? Half of what you expect right. Now the other scenario happens 120 people come in how much money do you make?

Student is answering: 100 percent (())(12:34).

Professor: Right how much money do you make? How much money as a percentage of what you had in mind.

Student is answering: (())(12:42).

Professor: Only 25 percent more right because your rooms are capped at 100 right 120 people came but you could not service them right because your rooms are capped at 100, so even though my demand was 80 and it vary in uniformly 50 percent this way, 50 percent that way when it varied 50 percent below I lost 50 percent when it varied 50 percent above I gained only 25 percent right and therefore the distribution although the distribution of demand is

symmetric, my ability to service it is not symmetric right and therefore I am losing more than I am gaining right and that is actually happening here as well right.

Remember in the first year I built you know I have a capacity of 300 in all those situations where I get between 150 and 300 plan B is fine, in all those situations where I get between 300 and 450 I am making money in plan A because I have 900 capacity I can build all of that I am not making money in Plan B because I only have one plant of 300 right you guys understand the logic right in year 2 I have 2 plants of plan B so 600 units right but the demand varies between 300 and 900 the demand varies between 300 and 600 no problem I service just as well as planning right but the demand variance between 600 those situations out of these 2000 simulations those cases where the demands were 600 to 900 in plan A I had one large 900 plant right and that was able to service the demand in this case I have just 600 unit cape capacity plant I am NOT able to serve the demand.

So in those cases plan plant A is able to sell 750 units, 800 units I am only able to sell 600 plan B that is why the differential between A and B is now getting bigger right earlier the differential was 5 point 66 but now that I have started varying write the number of cases where A is better off than B are starting to increase right because all those demand scenarios where there is over capacity with regards to B is profiting all right, so this is what is happening here.

Now if I look at this graph ok, it essentially tells me the same thing it tells me blue is A maroon is B alright and A is better than B the NPV of A is further on to the right it is more positive ok and this is sort of the cumulative you know density function for A the for B sorry which is pink or maroon whatever but I can plant the same thing for A to see what kind of an A curve a looks like right.

So what I am going to do first is I want to I want to take all of these values all of these 2000 values right and convert them into you know 20 chunks right I want 20 sort of steps or a or rather I want to take yes I want to create 20 intervals ok so I can plant a curve right so I want to plant I do not want to plant all of these 2000 points at one shot I want to plant this interval. So what I am going to do here is my bound ok is, so I am going to take 428 and 338 in this case right the minimum and maximum right and (subt) and divide them into divide that range into 20 equal parts right.

So how do I do that, I say this is equal to I take the minimum right and then I add and then I say take the difference this minus maximum minus minimum divided by 20 and I am going to multiply it by this number just so that it will keep increasing with equal steps I will also explained that again in one second oop see there we go you know what I should have done I should have because now it is varying it every time alright, so I do not so look at this cell here or look at these cells here, so in Excel the dollar sign sort of means you know do not vary that cell right.

So it is so normally when I take D3 and I drag it to the next row D3 becomes E3 but when I say dollar D dollar 3 it does not vary right, so let me do that again so there I do not want it to vary right because I do not want it to randomly simulate every time, so we will just sort of redo that let me get done with that I am going to say this is equal to you just put that in oops or let us just copy this for now and then I will explain again how it works right, ok.

So what is what I have done here I have taken my upper and lower bounds which in this case for me are 350 and 435 for you it will be a little bit different but not hugely different I would guess right roughly in the same ballpark and I am trying to divide that into 20 equal intervals right, so there is one interval from 350 to 311 or minus 352 minus 311, one interval from minus 311 to 271 roughly the intervals are about 40 units apart ok.

And the reason I want to do it is I have got 2000 points I want to see how they distribute it, I have got a minimum and I have got a maximum are they equally distributed in which case I should get a nice sort of diagonal 45 degree line right or are they bunched up towards the top and the bottom are they bunched up in the center where are these 2000 variables are these minimum and maximums out lines right.

So what am I doing I am taking that entire interval and I am breaking it into 20 different pieces how am I doing that? I am taking the gap, I am breaking it by into 20 parts, so and then I am starting from the lower bound so 350, 350 plus 20, 350 plus 2 into 20, 350 plus 3 into 20 or whatever it is which is where this number comes in right so in the reason I multiplied by F7 right is because it multiplies by 1 into 20 to or 1 into 40, 2 into 40, 3 into 40 and there are incremental steps.

Now oops every time I click it changes but it is ok, it is roughly in the same ballpark. Now what I want to do is I want to see how many values occur in between 296 and to minus 296 and minus 259 how many values occur in between minus 259 and minus 223 ok so for this

there is a function here called COUNTIF right what this formula means is it says if the what happened to my (())(19:24) if the number is between B9 and B2008 right if the numbers in those range or less than or equal to some parameter then count it right, so go through each of these go through 85 point 38, 360 point 12 minus 45 point 68 etcetera and if any of those numbers is less than whatever threshold then count it all right.

So essentially what I am going to do is I am going to copy this again oops so going to copy this right so in other words I am asking in the first instance I was asking how many of the variables between B9 and B2008 were less than or equal to G7, G7 being 320 point 22, 320 point 22 is my minimum it is the lowest value, so clearly there is only one less than or equal to that ok but as I drag this down when I go down one more I am asking how many values are less than minus 288 point 41 right so there are more values and this is cumulative right so I am not looking at just that bound I am looking at cumulatively under that bound ok.

And then finally I say how many values are less than 433 which is the outer end, so how many values are less than 433 all of them right all values are less than the maximum or less than or equal to the maximum only the minimum value is less than or equal to the minimum so I have got 2000 on one side one on the other and then this tells me it gives me a little bit of a distribution ok.

So, so far so good, so I have got one value in the first bound, 5 of my 2000 values in the second bound or in the first two bounds 17 in the first three bounds 35 in the first four bounds 70 in the first five bounds and so on right. So when I start moving from my minimum possible NPV to my maximum possible NPV I am just counting I am splitting it into 20 equal intervals and I am counting how many are there cumulatively in the first interval, first two intervals, first three intervals, first four intervals and when I look at all my 20 intervals all my 2000 points are there right, any questions on this and everyone is got something like this ok.

Now I am just going to convert this into a percentage right because 1, 5, 17 what does that mean right, if I did 4000 simulations I would get more numbers, right if I did 500 simulations I would get fewer numbers right so these numbers pertain to the number of simulations that we have done and so what I am going to do is I am going to take this, this number and just going to divide it by 2000 which tells me the percentage of values right that are in that bag or less than that bag right.

So point 05 in the first bound and then when I go all the way down 100 percent will ok all I am taking is I am just dividing the counts by 2000 because I get them as a percentage I have got 2000 samples right so when I divide by 2000 I get a percentage right because the number by itself is meaningless because I did 2000 simulations I got 758 right within the first ten bounds right if I had done 5000 simulations I might have got 1680 within that bound whatever right, so I want to sort of look at it as a percentage right.

So now I have the percentage of points in each bound using this I can actually now click on this graph and plant a graph right, so I am going to click on the graph I am going to right click maybe say and go to select data already a bunch of data has been selected there is NPV B NPV A NPV B mean and I am going to add a series name which is NPV A ok the series values are oops where did that go let me add this again understand NPV A ok, so where did it go, there we are sorry yeah.

So what I am now going to plant is these boundaries so, I am going to plant this boundary which is the X series and then the Y Series is the percentage ok essentially all I am sort of again I am dividing it into these intervals and I am just plotting what percentage of my points are in each interval right, so I get a little bit of a shape of the curve, I am just plotting the cumulative distribution function I have got 2000 values, how do those 2000 values look right.

And what I am saying is those 2000 values are bunched between 329 and 434 and the blue, so 329 is somewhat here on the Left, 434 is plus 4 minus 329 is here plus 434 is there and this is how they sort of pan out it looks a little bit like an s curve right and you can click a few enters here there etcetera and you can see you can do your F9 is I cannot but right but you can see the curve move ok roughly it will be about it will be something like this.

So most of you get curves that look like this the blue curves a bit of an s curve and the maroon curve is a bit almost like a straight it is diagonal ok what does that tell you? So first of all whatever you do and I encourage you to F9 as many times as you want I doubt you will ever get NPV B to be greater than NPV A right the dotted vertical lines are NPV A and NPV B right and NPV A continues to be better than NPV B right, so that is one thing ok.

So even though we had this intuition at the start of the class that Plan B was somehow better right we were not able to get I mean we have tried everything right we have tried randomizing demand whatever right but B A always seems to be better than B right why A is

a better than B? Why A is a better than B and these curves give you a little bit of a hint as to why A is a better than B, what is the difference between the two curves.

Student is questioning: So A continuous to (())(27:32).

Professor: Right, so what can you say about the range of values that you find with A and B which one takes a larger range of values which one takes a smaller range of values, so A takes a larger range of values B caps it is upside and particularly so B caps it is downside but also particularly it is upside right B is not able to gain more profitability right because essentially unfortunately you know sometimes the demand is greater than what we can supply, A because it is a bit unrestricted right in some cases you get cases where demand is exactly 150, 300 and 450 right is one worst case scenario right, it is always at the lower end 150, 300 and 450 in which case you are probably using losing a lot of money out of way that is why A is negative is much higher right when you look at the minimum values right when you look at the minimum values on the top left of the screen.

Now A is minimum is always worse than B is minimum right but A is maximum is often higher than B is maximum right and what is unfortunately happening with B is although on the downside its losses are getting cut right because in the worst case scenarios you are investing slowly in the best case scenarios you are just not able to bring back those profits right this is exactly the hotel room analogy in the worst case scenario I am losing money right in the best case scenario I am not able to gain that money back right because my capacity is capped, A has larger capacity so while it is losing money it is also able to gain back money right.

So very counter intuitively right a seems to be the better bet ok but does that feel right the one monolithic plant seems to be better whether it is static or dynamic analysis than the modular plant does that instinctively feel right.

Student is questioning: Sir ji jo dimand tha (())(29:29) 50 percent (())(29:31).

Professor: I bet you would not see that much of a change because the same dynamic exists if you reduce demand variation to 0 ok A is still up by 5 point 66 and the more you increase the demand variation the gap between A and B is increasing, so it does not matter 40 percent yes you might not get this biggest spread but A is still going to be better than B.

Student is questioning: So the downside also (())(29:55) might be.

Professor: For who, so you are saying A people may not be they where is they but you know if I were to do and if I were to make a decision today based on this what would I take right if I showed you all this analysis right you are going to have to say a I mean it is more investment but it clearly shows you that it is going to be more profitable right then if you did B yeah.

Student is questioning: (())(30:18).

Professor: NPV A.

Student is questioning: So already of getting higher NPV (())(30:24).

Professor: In case A why do you say that the mean NPV A is 105.

Student is questioning: The highest value.

Professor: The highest value is 427 that is fine but when I look at the mean right A still better than B right and when I look at ok so up until this point here where the curves cross ok B is better than A right it is only after the curves cross that A starting to get better than B if you will right, so but the anyway this is a cumulative probability distribution so you cannot really read too much into it but there seemed to be so there is a 30 percent probability right see 30 percent of your cases A better the B is better than A right in 30 percent of your cases B seems to be better than A right in most other cases A seems to be better than B and overall A is better than B ok.

So the question is are you missing something or is it counterintuitive do you all agree always to invest in large plants, so build 500 mld desal plant do not build modularized desal plants, build large airports do not build modular stuff why do we agree? That should be the strategy, ok instinctively that does not feel right? Right ok yet the data is showing that this is true ok there are some assumptions maybe you know the costs are a bit different etcetera but roughly this is how things are larger plants tend to have you know lower variable costs ok remember plan B also a salvage value which plan A does not have, so there is some advantage already I have put it ok.

What is the one thing that we have not changed? Why are we building modular? What is the point of building modular?

Student is answering: (())(32:15).

Professor: What can you do if you build modular?

Student is answering: You can change your plans investment.

Professor: You can change your plans to do what? What plans can you change? You can change your plans to invest right in the future ok.

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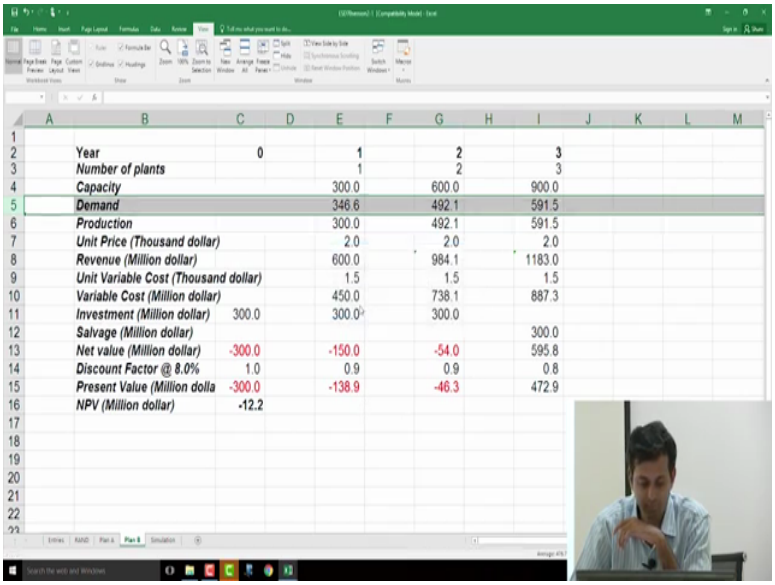

Year	0	1	2	3
Number of plants		1	2	3
Capacity		300.0	600.0	900.0
Demand		346.6	492.1	591.5
Production		300.0	492.1	591.5
Unit Price (Thousand dollar)		2.0	2.0	2.0
Revenue (Million dollar)		600.0	984.1	1183.0
Unit Variable Cost (Thousand dollar)		1.5	1.5	1.5
Variable Cost (Million dollar)		450.0	738.1	887.3
Investment (Million dollar)	300.0	300.0	300.0	
Salvage (Million dollar)				300.0
Net value (Million dollar)	-300.0	-150.0	-54.0	595.8
Discount Factor @ 8.0%	1.0	0.9	0.9	0.8
Present Value (Million dolla	-300.0	-138.9	-46.3	472.9
NPV (Million dollar)	-12.2			

Now let us go back to plan B to plan A what is my investment plan tell me from this spread sheet what is my investment plan? What is my investment plan here? What is the strategy? What am i doing? I am investing 900 that one plant in year zero and going through all right that is my investment plan. Let me go to plan B what is my investment plan here build 1 every year ok now based on what Jaikishan was saying what can I do? Can I change anything to plan to plan A right I need to build the plant if I do not build the plant I get nothing right. So I am going to build the plant can I change something to plan B what could I change?

Student is answering: (())(33:31).

Professor: So I could invest 600 right or what else could I do? So one option is at the end of the second year go to 600 what else could I do?

Student is answering: At end of second year (())(33:48).

Professor: So do not build at all in the second year right is another option right, so in other words the whole point of building the modular plant was it gives me an option to build or not to build is that option being modelled here right is there an option? No it is fixed whether you

like it or not built 300 first year, built 300 second year, built 300 third year right but now I actually have an option of building ok.

So now let us see what happens right if I start so when would I put in this option right what would my logic be I have an option of building or not building let us assume that I cannot go from 300 to 600 right let us just assume no I mean that is also an option ok how would I decide so in the first year I have to build one ok that is a given right I start off what should my decision be in the second year? How should I make a decision?

Student is answering: Risk demand (())(34:41).

Professor: So well the demand risk I know is 50 percent ok how would I make a decision give me a simple rule?

Student is answering: Like when you get some like other deal where you can (())(34:50).

Professor: No, so in this project ok I am ready to invest 1, 2 & 3 ok but I do not have to invest 1, 2, 3 all right in the beginning I invest 1 because I am getting into the project ok at the end of the first year how do I decide whether to do 2 or 3 or stay with one?

Student is answering: Rate of withdraw (())(35:13).

Professor: The well but if I do the mar or if I do the rate of return A is better than B, see as it is by investing by delaying my investment itself A is better than B all right if I is instead of building 2 I built 3 right away and put in more costs earlier A is going to continue to be better than B ok but how do i exercise what is the logic that we should have?

Student is answering: Demand (())(35:43).

Professor: Huh. What will I do it demand after first year?

Student is answering: (())(35:47).

Professor: So one way of looking at it is I sort of look at I do not look at mar whatever I say look I look at the demand after first year if the demand after first year was good I build a plant if the demand after first year was not good I do not build a plant all right. So now because this is the whole point of that flexibility the whole point of plan B is I now have that ability to build or not to build alright.

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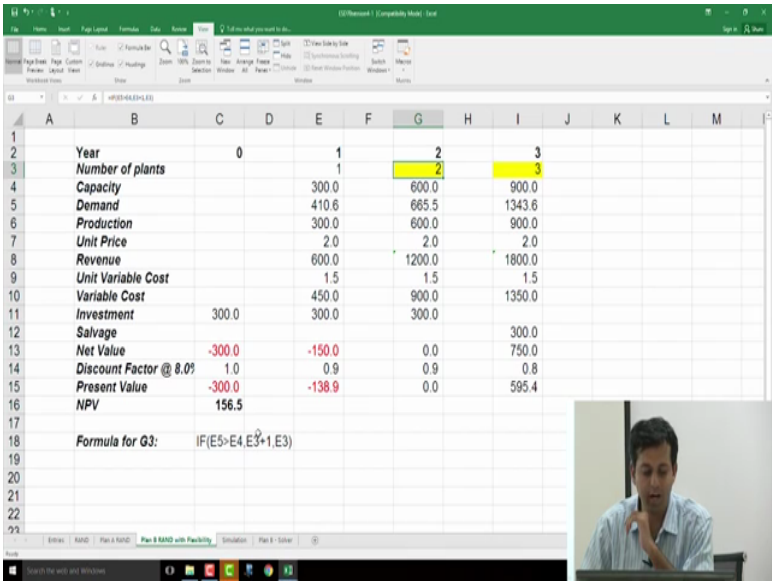

	A	B	C	D	E	F	G	H	I	J	K	L	M
1													
2		Year	0		1		2		3				
3		Number of plants			1		2		3				
4		Capacity			300.0		600.0		900.0				
5		Demand			410.6		665.5		1343.6				
6		Production			300.0		600.0		900.0				
7		Unit Price			2.0		2.0		2.0				
8		Revenue			600.0		1200.0		1800.0				
9		Unit Variable Cost			1.5		1.5		1.5				
10		Variable Cost			450.0		900.0		1350.0				
11		Investment	300.0		300.0		300.0						
12		Salvage							300.0				
13		Net Value	-300.0		-150.0		0.0		750.0				
14		Discount Factor @ 8.0%	1.0		0.9		0.9		0.8				
15		Present Value	-300.0		-138.9		0.0		595.4				
16		NPV	156.5										
17													
18		Formula for G3:	IF(E5>E4,E3+1,E3)										
19													
20													
21													
22													
23													

So now let us just close this spread sheet and open 4 do not open 3, 3 is not required open 4 dash 1 ok, let me know if you guys have all opened 4 dash 1 you guys all open 4 dash 1 alright. Now 4 dash 1 is exactly the same except that in all my earlier spread sheets right the number of plants was 1, 2 & 3 ok, here I have said 1 because obviously I am assuming I am getting into the project and building 1 but in year 2 and year 3 I have not put anything else right.

So I am going to put a very simple decision making room right I am going to say right if (ik) you put the equal to because is logic if the demand in the last year if the demand in year 1 right is greater than the capacity nearly one right if the demand in year 1 is greater than the capacity in year 1 right then I take the number of plants I had in year 1 and I add 1 ok if E5 is greater than E4, E5 is demand E4 is production.

So if E5 is greater than E 4 right then I will increase by 1 ok otherwise I will not increase it will just be the same value as the previous right that is what is there the bottom that formula there again I have to sorry increase the font right ok so I have taken this formula here what does it say if the demand exceeded capacity last year then invest right if the demand did not exceed capacity last year then do not invest ok same thing here except I am now looking at year 2 so I am going to say if the demand exceeded capacity then take whatever I had last year and increase it by 1 else just keep what I had last year.

Student is questioning: Capacity will be the addition?

Professor: Will be the addition of what? Will be I am adding 1 right so here I am saying take previous last year is demand versus supply right if the demand was greater than supply right then add one more if the demand was not greater than supply then do not add right. So I am looking at scenarios where the demand is not picking up and I am saying do not add all right, so very simple formula all right it is the same thing here if E5 greater than you can cut and paste this except when you do your 3 E is will be replaced by G is right, W is become replaced by G is ok.

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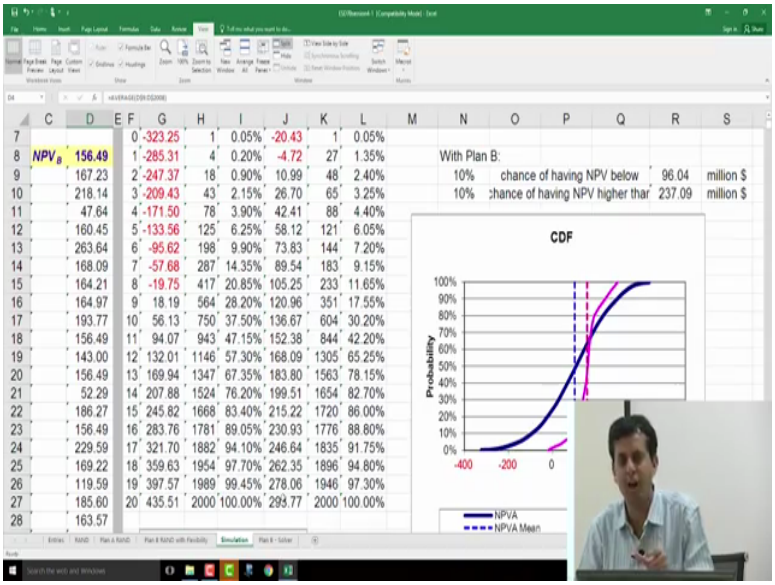

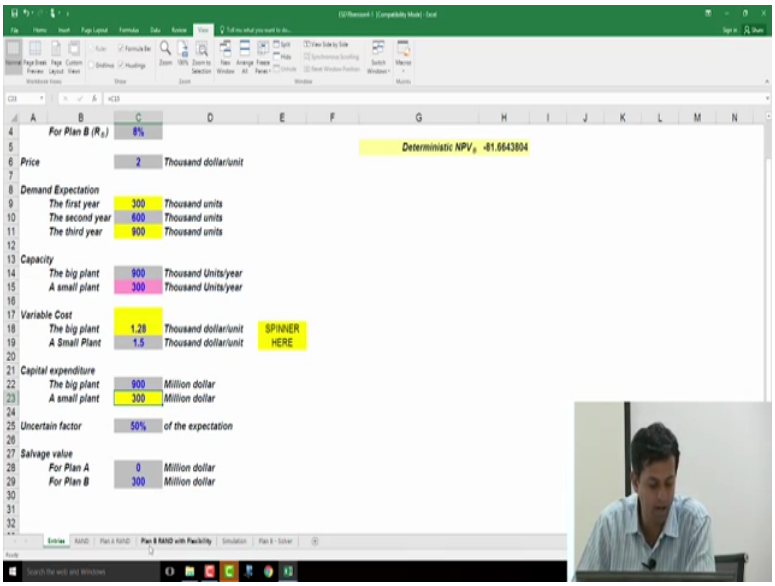

If you have done this then click on simulation, click on simulation and tell me what you see? What do you see?

Student is answering: (())(39:57).

Professor: Now all of a sudden B is better than A right because now you have exercised that fundamental flexibility which we all intuitively thought may be superior to A which is look if demand is not picking up do not throw your money into that project right, so there is for instance a scenario where you know you might so you can easily in many scenarios you can go 1, 1, 2 there is actually scenario where you can go 1, 1, 1 ok so in the first scenario right it was less than 300 ok then you would not invest, in the second scenario when the demand was exactly 300 you might still not invest right and therefore you are minimizing your outlay right instead of committing yourself to 1, 2, 3 right.

The whole point of flexibilities you can make a decision to invest or not invest plant A is not flexible you are putting in the 900 demand is varying and you get an NPV of whatever it is right you get a mean NPV of about 100 ok, if you use the same logic with plan B because the operating cost of plan A are lower you know A is better right if you use the same fixed logic right I there is no flexibility I am going to do 1, 2, 3 ok A is obviously going to be better because its operating costs, variable costs are lower but when you bring in the flexibility of B which says I do not need to invest when I do not need to right.

So here what is happening is if demand goes through the roof if the demand at the end of year 3 is 1300 there is nothing I can do about it whether it is A or B I will only sell 900 right it is like the hotel room thing ok but if demand is low do not go ahead and build the next 50 rooms in your hotel right away right, why are you building hundred rooms and then saying I have only 40 percent occupancy right build as demand develops right,

So this is one kind of text ability this is also we talked about the parking garage example in class right, so you build 3 storage then when demand picks up built 4, build 5, build 6 right you know or whatever you want but do not necessarily build 6 and then just hope that demand will pick up. So there are three option one is you build 6 and you are taking a gamble the other is you say you know I will build 3 today but I am committed to building 4 next year 5 the year after, 6^{th} a year after right where again you are incurring extra costs for the reconstruction and you may not get the benefits, the third is the option is the flexibility right where you are saying I am actually going to build only when demand exists.

So that extra capital investment will get an immediate return right and if the demand is low I will not waste extra money on capital investment right, so that essentially is flexibility the ability to choose in this case when to invest is one kind of flexibility right in this case it is the flexibility to expand your production many other kinds of flexibilities but if you model the

flexibility then you see that the flexible option is often better than the inflexible option and in this case the differential is about 50 thousand dollars or whatever the units were right.

So this essentially in a nutshell is how flexibility is modelled ok and how you can actually see if flexibility gives you benefits right and it is very clear that because of this sort of flow of averages kind of reasoning inflexible projects if you assume in flexibility and this is what most consultants do by the way you assume in flexibility when you do your modelling right you get a certain response if you start assuming randomness you start doing Monte Carlo simulations right and you start putting in flexibility to combat that randomness then you find you get much higher NPVs recall the NPV of A has not changed it is been hovering around 100 right, the NPV of B has gone from 60 to 165 right two and a half times whatever right.

So this is how this is model and so therefore when we do these analysis for infrastructure projects right we should try to see if we can do this kind of Monte Carlo simulation plus flexibility modelling right to really see look I can put in a number of options you can use the same concept I can put in a number of different options right and then I can evaluate which option is actually giving me a large amount of value therefore what option should I design into the project right.

So you can do a lot of analysis to understand how the project should be designed ok because this is just one option yeah.

Student is questioning: The suppose in some cases we need to do not we do not need to make any more cart sorry (())(44:30) salvage value is constant so maybe that is contributing to the (())(44:35).

Professor: So that might be yeah there is a little bit of the salvage value you know discussion because yeah that I think is.

Student is questioning: I mean technically just.

Professor: Yeah, so you should be salvage value per plan and then we should have that accordingly but again my guess is you are getting salvage value in the third year it is being discounted you know three years so I think your effects of that are I mean it is true it will have some effects or is there and there will be certain cases whether effects are magnified but yeah I agree with you there is some there is a little bit of a flaw in this but I doubt it will

change the results completely I think you will find that maybe the gap narrows a little bit, ok that is a very good observation ok.

So do you guys get how you model flexibility and why flexibility is valuable right, if you went and took up a job with someone next year and they asked you to do a demand analysis on a road would you feel comfortable being able to do this kind of analysis if some consultant gave you traffic data right and he says I did traffic service for whatever a number of days and this is what I found ok could you then do you feel you will be able to do this kind of analysis?

I mean obviously you may not be able to do it right away because you are not familiar with some of these but conceptually right you guys clear how this kind of analysis could be done because this is exactly I mean road projects this could for instance be how you decide how to go from a four lane to a six lane road right, so somebody says build a six lane road and you say why am i building a six lane road, let me build a four lane road and then decide later on when I should expand to six lane right, so based on my traffic studies and my uncertainty around traffic I can do some simulations and figure out what is the value of being given the option to expand later and also roughly from these simulations roughly at what point does that kick in? Right when do these demand values roughly you know get to point.

So I can also plan my investment right I can sort of say ok I am investing now and then six or seven years later I am going to invest in the expansion and you will have a far better competitive advantage over your competitors who budget for that expansion right away all right and of course there are other kinds of trends and I will show you were there is a PowerPoint that I have I want to run through it but I will show you.

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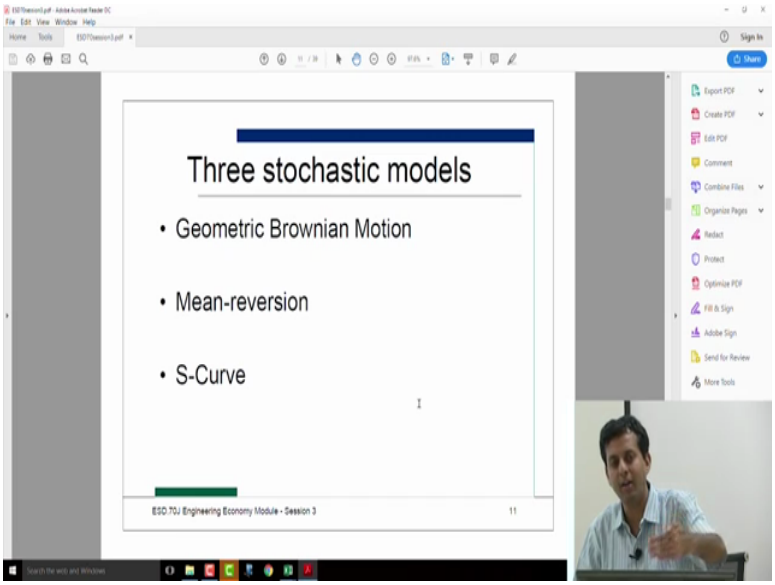

There are all kinds of ways in which yeah so you can look at demand progression. So we looked at a very simple distribution like 50 percent whatever but you can also have distributions that say the next year is demand is last year is demand plus some variation.

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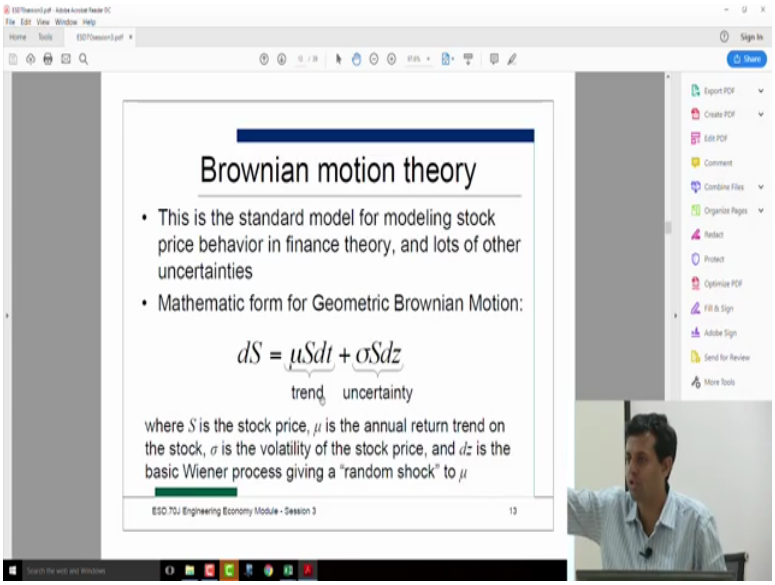

So you have formulae that come out of geometric Brownian motion that look at this thing there is a little bit of a trend, so I can see a 2 percent increase every year but it is not constant 2 percent there is some uncertainty around that trend right.

So you can start putting in formulae they start modelling demanded a little bit more sophisticated manner right it does not have to be 300, 600, 900 from that you do some

variation you can take last year is demand you can say this is a bit of a trend this is some uncertainty surrounding that trend it might go down it might go up etcetera and these people use by the way to simulate stock prices and so on.

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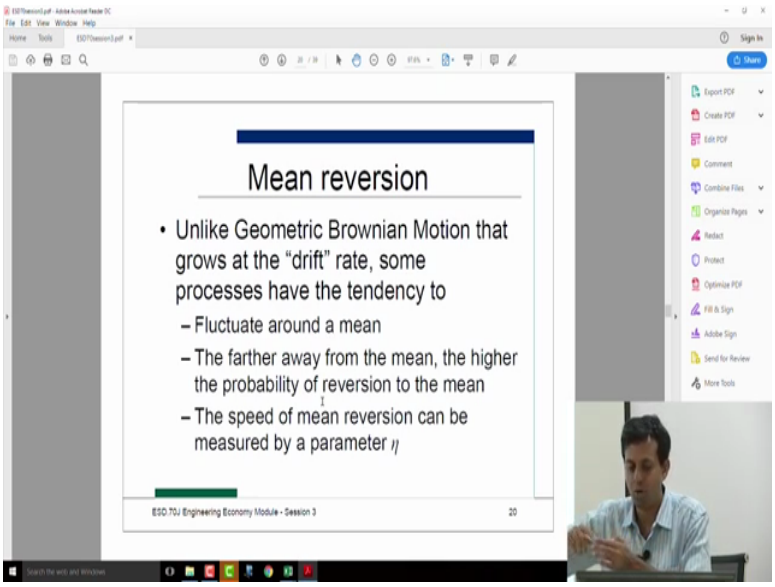

There is also reversion to the mean which means you know you have this sort of iterative motion where there is constant fluctuation around a mean that might be another sort of formula.

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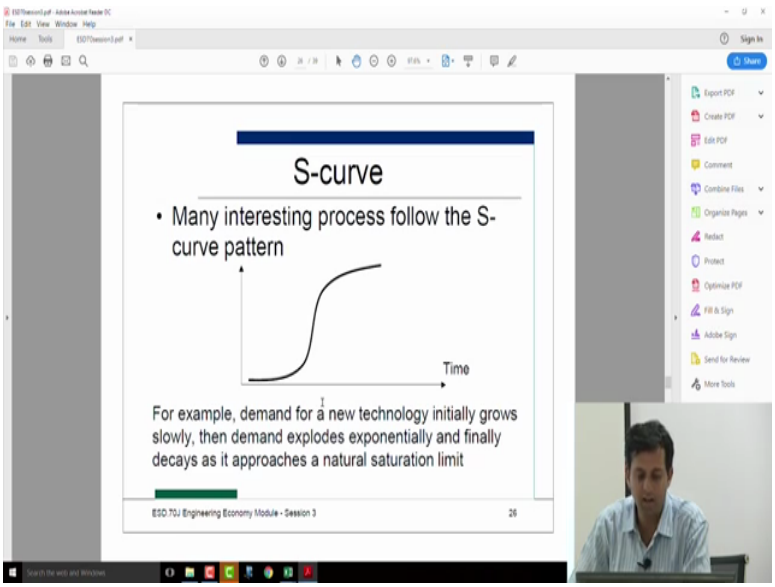

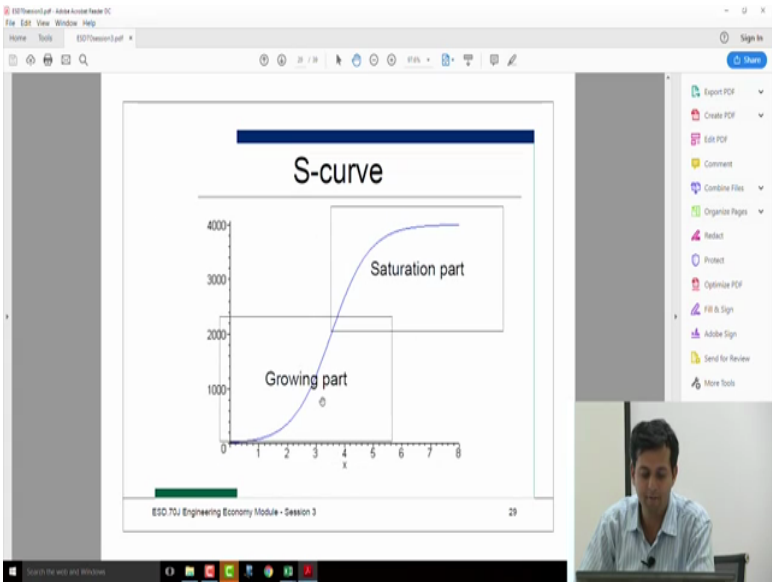

Then there is sort of the s curve you might have demand that goes on some kind of an s curve where there is a little bit of saturation right which means you actually have two parts there is a growing part with a certain equation and a saturation part so if you are selling a product it is stupid to sort of expect that people will continue to keep buying that product right because over a period of time people might already have it and some of these products do not get replaced that quickly right which means you have a growth curve and a saturation curve.

So the way you model demand we modelled it very simply we took 300, 600, 900 and varied a little bit around it there are many ways in which you can model demand for roads or for televisions or whatever in a much more sophisticated manner but the principle is the same demand is vary so I need to do a Monte Carlo kind of simulation because I have to average out a number of data point because there is variability and if I can put in flexibility where some input parameters some investment parameters can be staggered based on my discretion right and that is the key part it staggered based on my discretion when I did 1, 2, 3 I had no discretion it was being done irrespective whether I liked it or not but when I can actually stagger at my discretion that means I have an option right to do something then what would the returns increase in NPV B right certain options returns in NPV might be negligible right may there may be no return on NPV.

Other options they might be much larger in NPVs and then you can take that back to the person is avoiding the project and see this flexibility should be put in because it increases project value, so allow the developer to go from 2 lanes to 4 lanes or 4 lanes to 6 lanes at their discretion right or you might put in the higher cost of acquiring land later on and you might say boss my just better off to do 2 lanes to 6 lanes today right because if we want to do a little

bit of land acquisition and then 5 years from now to do more land acquisition it will never get done.

So you can wait these flexibility some might work some might not but this is really the way in which you analyze projects to determine A is the project feasible and what kinds of flexibilities do I put in to make the project feasible yeah cool so comfortable conceptually comfortable at least ok, good.