Business Analytics for Management Decision
Prof. Rudra P Pradhan
Vinod Gupta School of Management
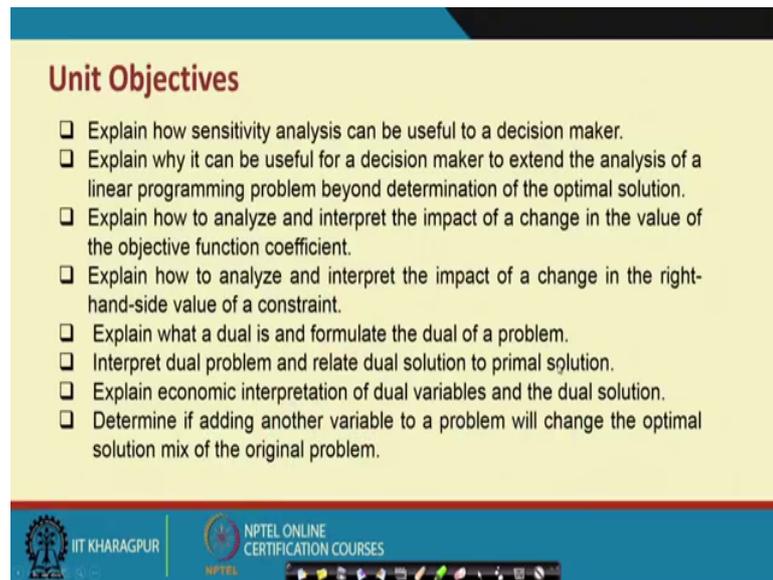**Indian Institute of Technology, Kharagpur**

Lecture – 47
Prescriptive Analytics (Contd.)

Hello everybody, this is Rudra Pradhan here welcome to BMD lecture series, and today we will continue with Prescriptive Analytics, and that to coverage on sensitivity analysis. In fact, in the last lectures we have highlighted some of the issues with respect to sensitive analysis. So, now we will continue with this similar kind of you know discussion, and then we will address you know more effectively this particular you know component that to the sensitivity analysis in the LPP you know structure that is the linear programming problem structure.

So, in the last lectures we have already highlighted the particular you know requirement, and the utility of this sensitive analysis, because the business is very dynamic any points there may be you know you know possibility possible change that which, because of the business requirement the kind of you know change of the business environment, and the volatility of you know business, and the with respect to competitions, and with respect to you know some kind of you know control mechanisms, or some kind of you know you know external, you know factors so; that means, there is a in reality there is a kind of you know possibility that the particular problem, I can change that to with respect to the coefficients of the objective, function the coefficients of the constants, and the kind of you know conditions.

So, now with given situations we look for the optimality agains, we look for the optimality with the changing situation, this is the this is the you know over all kind of you know structure of the sensitive analysis.
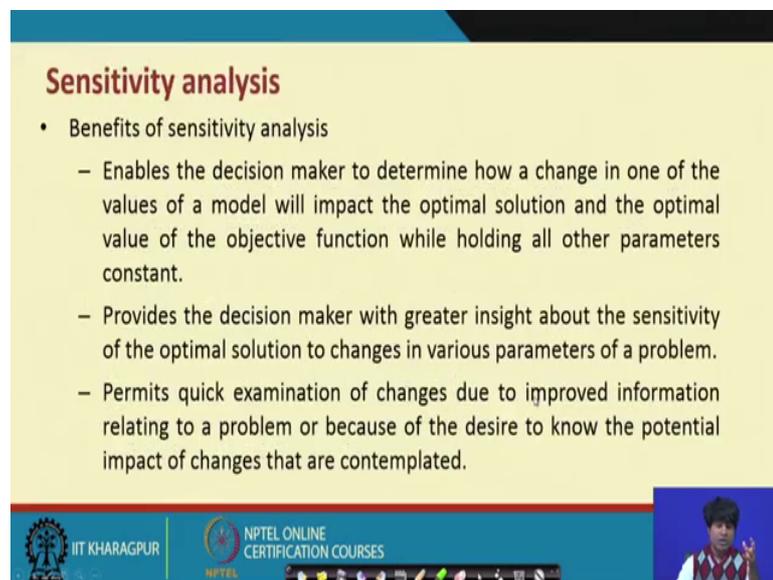
(Refer Slide Time: 02:07)

And in fact in the last lectures, we have already highlighted the particular you know you know objectives of the sensitive analysis or this particular you know unit objectives.

(Refer Slide Time: 02:14).

And to continue on that particular you know component. So, what I like to address. So, the sensitive analysis will give you the kind of you know clue, where the decision maker or it can determine how to change or how to bring a change in one of the values of the model, and that will impact on the optimum solution, and the optimum values of the objective function while holding all other parameters constant, and provides in that

decision maker with greater insight about the sensitivity of the optimal solution to changes in various parameters of a problem.

Then agains we quickly look for the kind of you know improvement with respect to the particular you know changed scenario so; that means, technically it is a kind of you know continuous process, or iterative process. So, every times we can jump to a particular you know step or the kind of you know positions where we may have a kind of you know improve situation that to with respect to values of the decision variable, and the values of the a kind of you know objective functions.

So, whether it is a kind of you know original structures where you will do the iterations and then look for the optimum solution, and agains after reaching the optimal solutions, again the iterative process will continue, if there is any change with respect to objective functions with respect to constants and the kind of you know conditions.

So; that means, technically so it is the kind of you know you know continuous process, or iterative process till you get the optimum solution as per the particular you know requirement so; that means, this particular structure will give you enough flexibility. So, this is what the original kind of you know requirement, and now if the business a business you know business will be changed like this like this like this, then the particular solution will be like this like this.

So that means, we have a kind of you know flexible kind of you know structure through which we can actually come to a kind of you know solution for a business problems, and then the management decision will be very effective as per the particular you know business requirement. So, now so the first answer structure is a change in parameters value and that to so, the value of the objective functions, and the right hands, and the right hand side of the constants and left hand side of the constant, and the coefficient of a particular you know constant.

So, now the issue about the changes are you know which arrange, we can you know change the particularly you know structures of course, you know you know in a kind of you know predictive kind of you know environment for instance with a even more you know models with respect to of the different some constant, and you know conditions we look for the optimal solution. Now in the kind of you know future requirement, we may

not have any idea about to the kind of you know business environment, or the kind of you know business problem, but you know any change which you like to apply.

So, there should be some kind of you know plan or some kind of you know logic through which you can actually it is change kind of you know requirement, and then we look for the optimality, or optimal solution with respect to every change situation for instance let us say, but with a particular you know situations. So, our objective function with easy with respect to x 1 and x 2 that to or the coefficient of objective function for x 1 is a 60 or you know you know and 50 for x 2.

(Refer Slide Time: 05:54)
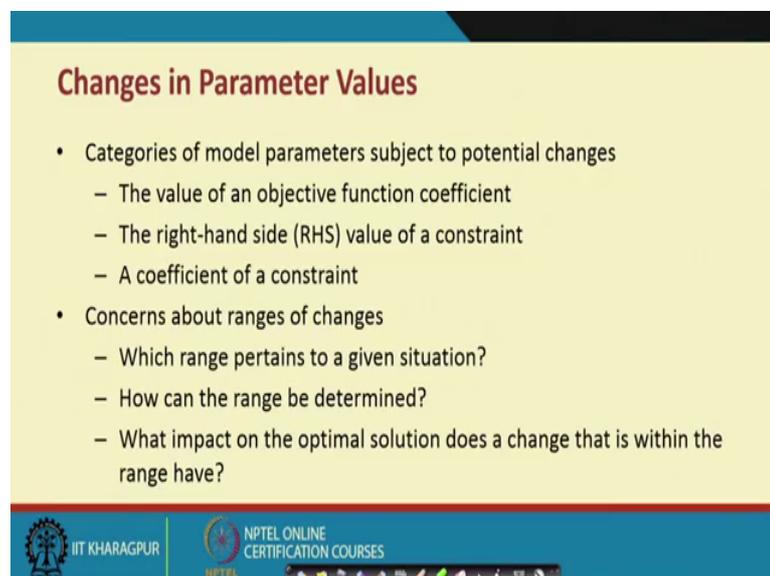
So, then you allow the particularly no coefficient to change you know with a 10 percent increase, 20 percent increase 30 percent increase the keeping other things remain constant, then you look for the optimum solution, again in the resource you know sites it may be change with respect to availability.

Let us say today the labor hour is it let us say availability is you know 100 hours. So, with respect to in a future requirement the 100 hours may increase you know with 10 percent, 20 percent, 30 percent; that means, we must have a planning proper planning through which actually you first fix the possible changes, and then for every change situation that is with respect to problem you know structuring, then we look for the you know optimum solution, or we search for the optimum solutions.

(Refer Slide Time: 06:38)
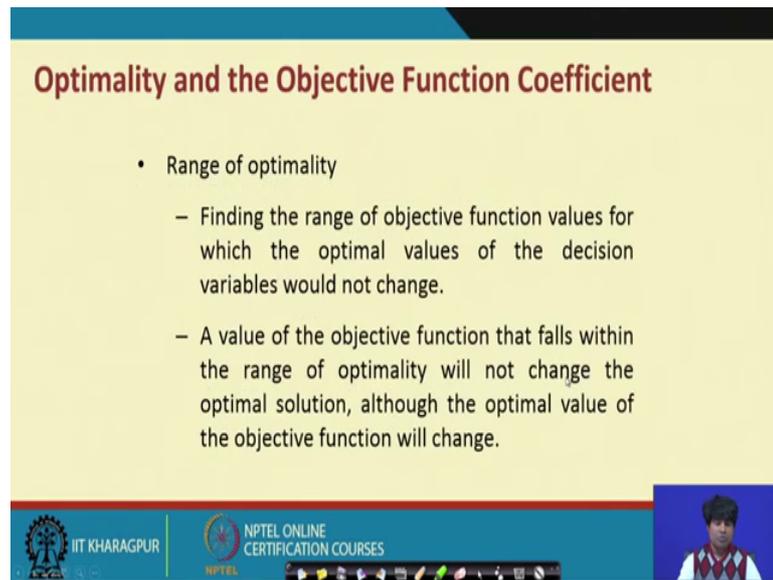
That is how the kind of you know beauty of this sensitivity analysis, and again suffer as a range of optimality is concerned finding the range of objective function values for which the optimal use of the decision variable will not change, and again a value of the objective function that falls within the range of optimality will not change the optimum solution though, the optimum value of the objective function will change.

(Refer Slide Time: 07:03)
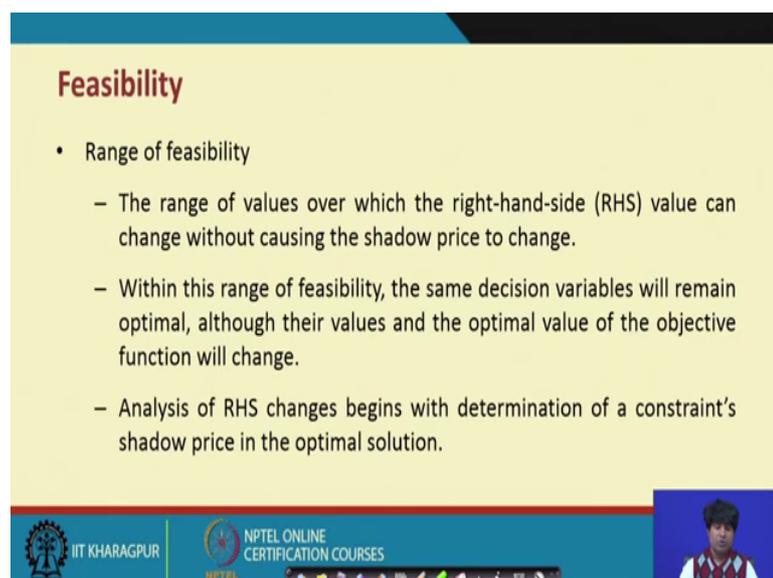
So; that means, we have a you know kind of you know flexibility all together. And so for as a feasibility is concerned the range of values over which the right hand side value can

change without causing the kind of you know shadow price to change, then within this range of you know feasibility the same decision variable will remain optimal although their values, and the optimum value of the objective function will be changed, and analysis of right hand side coefficient you know changing it changes with determinants of you know you know constant setup rise in the optimum solution.

(Refer Slide Time: 07:41)

So that means, when we change the particular you know structure of the problem. So, there is a high chance that you know the you know optimum solution will be changed, but there is in the same times there is a high chance that you know optimum solution will not change at all. For instance suppose we are using a particular constant with a you know it is a kind of you know production process, and we are allocating resources effectively.

But you know, but keeping other things remain constant if you know increase 1 after you know 1 after another you know unity of resources for a particular constant, then I you know I am very sure after a particular point of time, the value of the objective function or the optimum solution that is the values of the decision variable will not change, if you continuously increase the coefficient of that particular constant keeping other things remain constant.

So; that means, you know it is not that you know every times change of the constants, or the change of you know coefficients will change drastically the optimum solution, it

depends upon the type of you know problem, the kind of you know business, and the kind you know requirement, and obviously there is a possibility of you know change, but not necessarily that the change really happen with respect to change up all the you know structure of the problem, agains to address the sensitivity structure the same problems we can highlight which you have already solved.

(Refer Slide Time: 09:09).
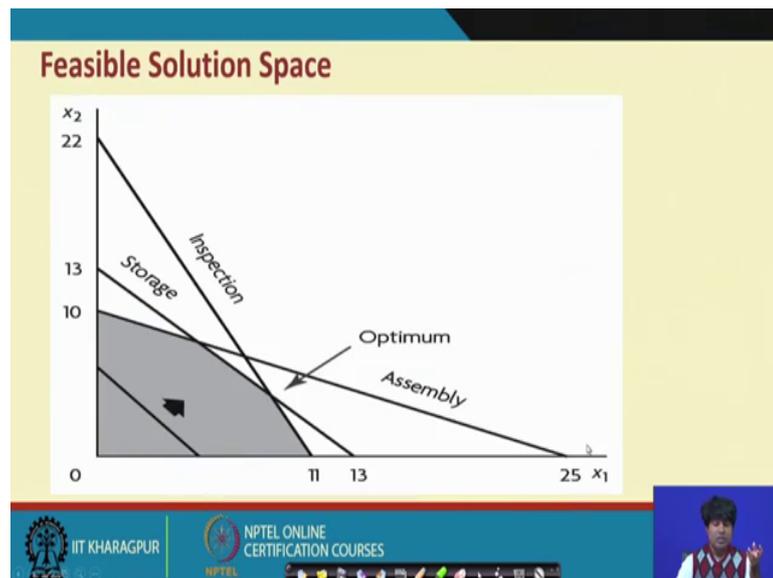
In the case of graphical method simplex method, and agains resolved through solver package, and then this is what the original solution corresponding to this problem that is you know with respect to 2 variables x 1 and x 2 with the 3 constraints, and the objective function is maximization type, and the constants are in a less than type and as a result.

So, we have the typical you know structure like this, and this is what the feasible regions, and then we are looking for the kind of you know solutions; Now coming to the sensitivity structures.

(Refer Slide Time: 09:37)
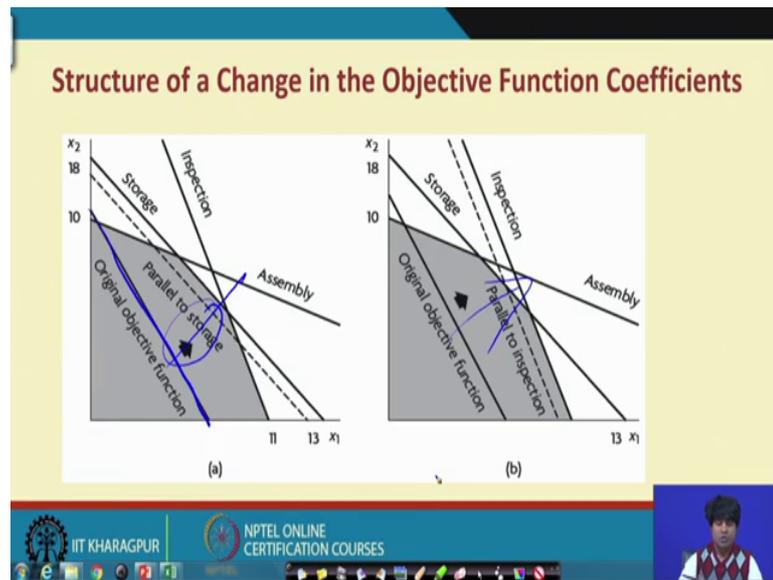
You see here, so the first structure of you know the kind of you know sensitivity. So, this is the original objective functions, and this is what the first objective function, now any change of the particular you know coefficient of the objective function, then the position of the you know objective function will not remain same. So, it will change it.

So, the movement will be go like this, and agains the any other change of the coefficients again it will move like this so; that means, you know keeping other things remain constant if you change the coefficient of the objective function. If the coefficients of objective function will be at the increasing rate, and then; obviously, the value of the objective function will be all set increasing rate, if it is actually less than to original situation, then the value of the objective function may be less as per the original situation.

(Refer Slide Time: 10:35)

You know so; obviously, we have not near idea what will be the final change with respect to change of these coefficients. So, now you know again you know we have to go you know in the kind of you know iterative process, and follow the kind of you know procedure, then ultimately we look for the kind of you know final solution, whether you know there is a change or you know it is still you know as per the particular you know requirement.

So, now the optimum values which have already solve is x 1 equal to 9 x 2 equal to 4, And Z equal to 740, and now with respect to you know kind of you know sensitive analysis. Let us say you know the coefficients of you know objective function will changed to instead of 50 totally change 200 or instead of you know 34 x 2 it will change to 60, then what should be the possible you know optimum solutions.

(Refer Slide Time: 11:28)
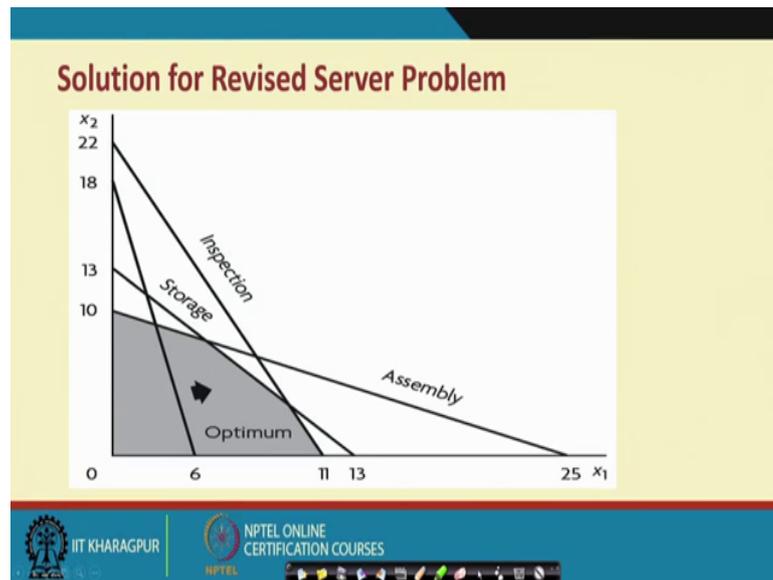
So, you know accordingly you have to actually again look for the final structure, and then we can actually; that means, you know if you are changing the coefficients of the objective function, then the constants position will be remains same, and as you know the same corner points. And the kind of you know values of the decision variable just what will it do.

So, put the value of the decision variable with respect to original means new objective functions, where the coefficients of that objective function you know it change now. And then we see whether you know there is a change of you know optimum solutions. So, this is again you know kind of you know dynamics of this particular you know requirement or the kind of you know business.

(Refer Slide Time: 12:10)

And agains this is a another kind of you know situation.

(Refer Slide Time: 12:18)
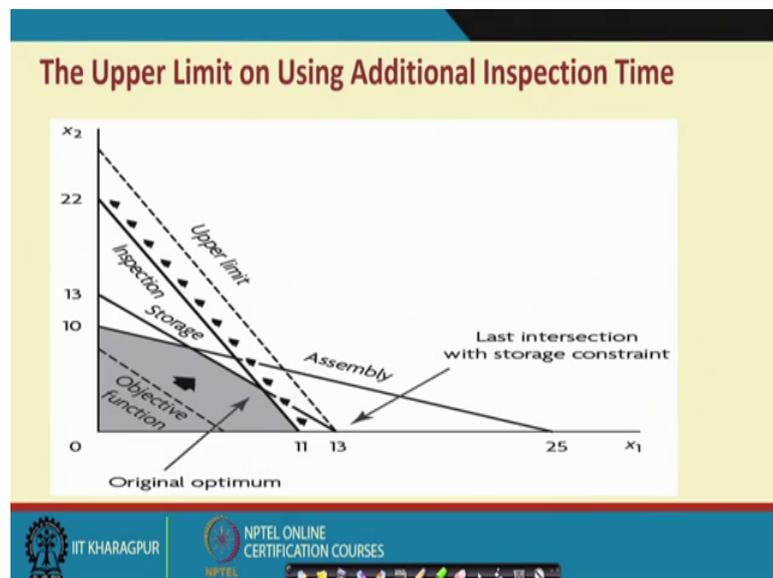
If we change then what should be the kind of you know possible solution. So, now here there is a kind of you know you know structuring like you know we have already discussed in the inferential analytics, and the kind of you know predictive analytics with a kind of you know problem, and the kind of inability of you know that time the kind of you know structuring. So, we may have some kind of you know you know solutions, the

values of the decision variables. Now here since it is a kind of you know optimization problem.

So, we are looking for the values of the decision variable, but in the case of you know inferential analytics or predictive analytics, the similar kind of you know structures we are you know we are looking for a kind of you know objective orientations for instance, in the case of inferential analytics, we have solved couple of problems to find out you know values of the you know population parameter. And then we are looking for the confidence interval for this for these population parameters. Now here also same thing. So, we are looking for the values of the decision variable, and that with the condition that you know the values of the decision variables are in a kind of you know positive serve only.

So, now here we can also create a confidence intervals, for instance we can put the restriction about the x 1 or x 2, and then you know let us say x 1 may be with respect to 20 and 30 range, or x 2 equal to 40 and 50 range, then again read on the models, and check whether the whether there is a kind of you know optimal solution or not.

So that means, you know it is a kind of you know again flexible kind of you know scenario, and of course when you add one after another constant then your feasible zone will be restricted, and then solution will be very pointed kind of you know things, and I mean see we are you know searching the you know or you know kind of you know or the kind of you know requirement only, so obviously if you know or you know focus the problem you know perfectly; obviously the solution is also, or you know for you know as per the particular you know requirement.

(Refer Slide Time: 14:34)
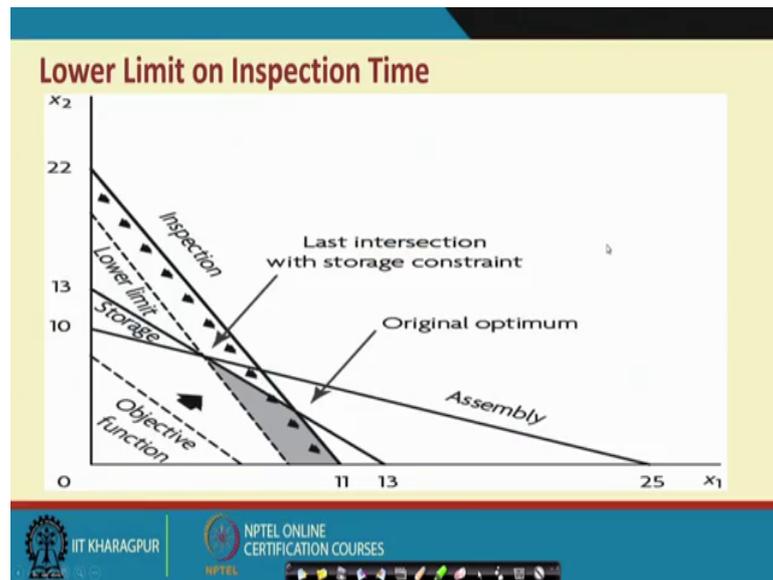
So that means, you know with respect to the kind of you know change. So, will have a kind of you know change scenario, and agains us look for the kind of you know optimality. So, here also like you know in the case of an inferential analytics, and predictive analytics we can have a we can have here also confidence interval, or the values of the decision variables, and then look for the optimality, where we can have the optimum knowledge of the decision variable, and then the value of the objective function.

(Refer Slide Time: 15:04)
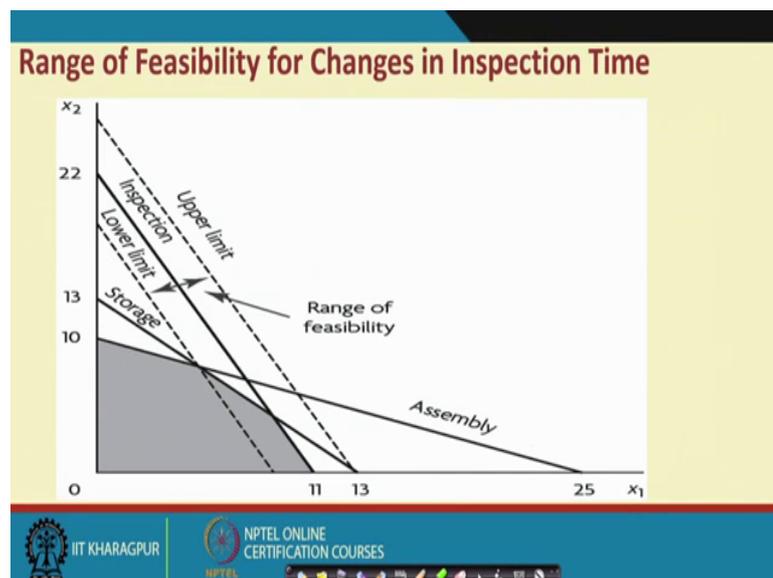
So, now these are all possible change agains, and this is what the structuring.

(Refer Slide Time: 15:08)

And the same structure; So, when we change the particular you know structure, then the upper bound will be a in a having 43.5, and the lower bound is a 33 so; that means, if you change the kind of you know structuring, then the if you know since it is a linear combination of you know x 1 and x 2 they; obviously, we like to know we like to know what is the contribution of profit from the a product.

A product you know once, that the x 1s and what is the contribution of you know product to that is x 2, and then what should be the a final profit a in that is the combined profit for both x 1 and x 2. So, it depends upon the kind of you know the contribution of the objective function coefficient, and the kind of you know values of the distant variable.

(Refer Slide Time: 15:59)
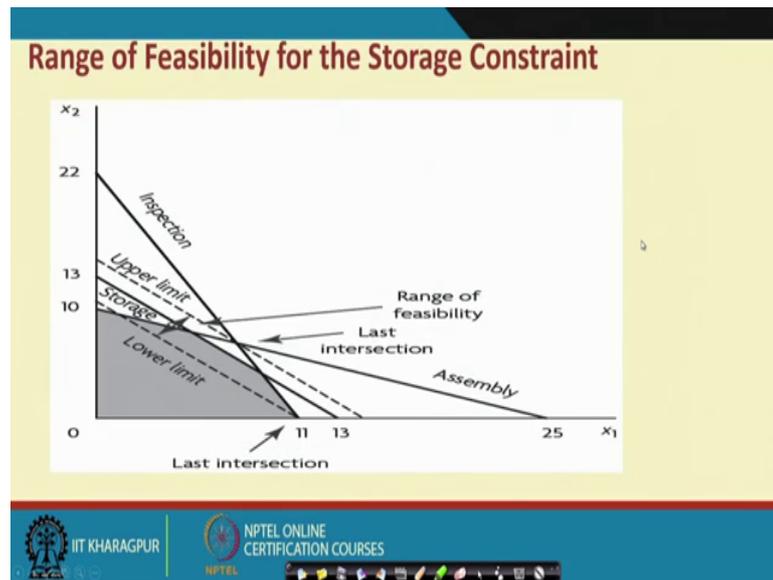
So, now this is agains the in the kind of you know flexibility.

(Refer Slide Time: 16:07)
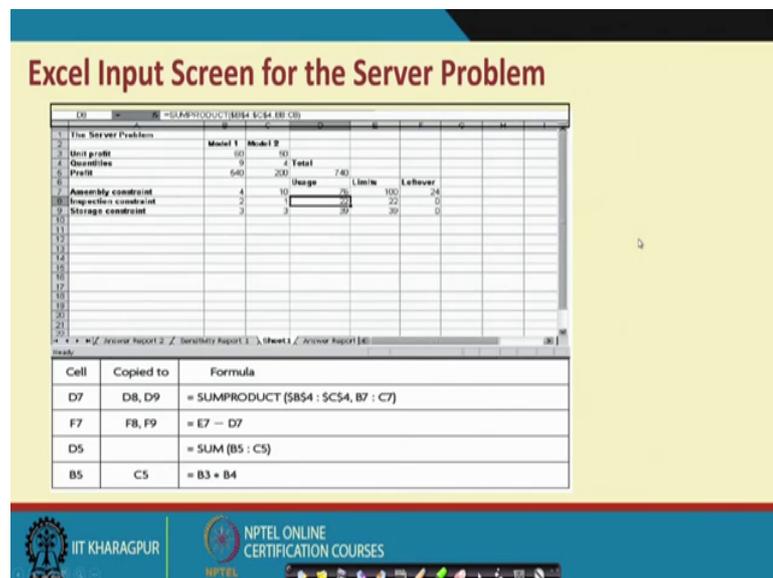
And with Respect to lower limit and upper limit again, if you know you know go to the kind of in a solver package, where we have already solved some of the problems for instance if you go to the kind of you know solver package you will find here.
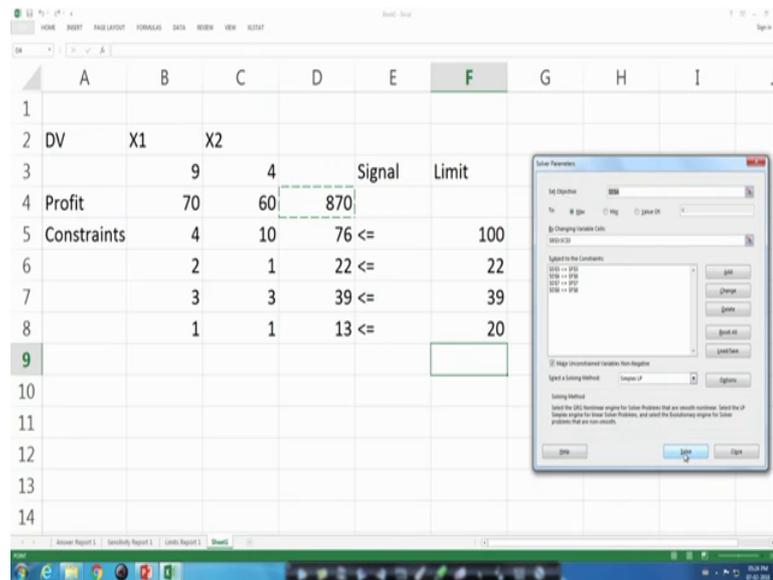
So, this is what the server package we have already you know discuss, now what will you do in that kind of you know sensitive analysis. Let us say the original problem is with respect to 60 and 50. So, now you change actually let us say we do we increase to 70 say. So, now, instead of 60 you put you know a 70 here, and in this case you put let us say 60, and then what should be the a kind of you know possible earth change.

So, agains you go to the in resolver, and then the model is already actually you know finalized. So, either you can reset the process here, yeah there is option for easy at all, then you can do that and you know after that again you put the solve options, and then look for the solution, it will be automatically change the particulars. So, earlier it was a 740. So, now it is coming 870.

So, now agains similar kind of you know structure the first constant is non binding, and then the second constant third constant is a binding. Agains if you add you know one more constant you know, then 4 against you have to go to the solver and in this case you know in the in the previous you know change situation, we are just changing the object coefficient of the objective function as a result.

So, there is no structural change yes, but if you add 1 1 constant here then; obviously, in the input box here. So, you to put you know add on here. So, provided you must have information here, and then accordingly we look for the solutions for instance let us close

here. So, you can put here let us say 1 more constant here, 1 and 1 and then put the limit here let us say 20, and then check whether the solution is coming or not.

So, in this context again you go to the kind of you know again you allow that this will be also less than type, and what will you do. So, you go to the solvers again, and here there are only 3 constants, and then you have to put you know add on that is the third constants that will be here. And again so the signal is less than type, and the constant limit is actually here 20, and then again you put you know and so, as a result the third constraint is added into the process, and then again look for the optimum solutions and then ok. So, this is what the solution is all about. So, it is agains coming 870, and it is again actually satisfying the kind of you know criteria.

So, ultimately so this is a kind of you know situation through which actually we will look for the you know optimality, where the optimum solution structure is changing as per the particular unit change requirement. So, now corresponding to this problem so, heres so, the issue is you know how quickly can address these problems, and then you know look for the chain situations, and then look for the optimal solution with respect to the chain scenario.

(Refer Slide Time: 19:38)
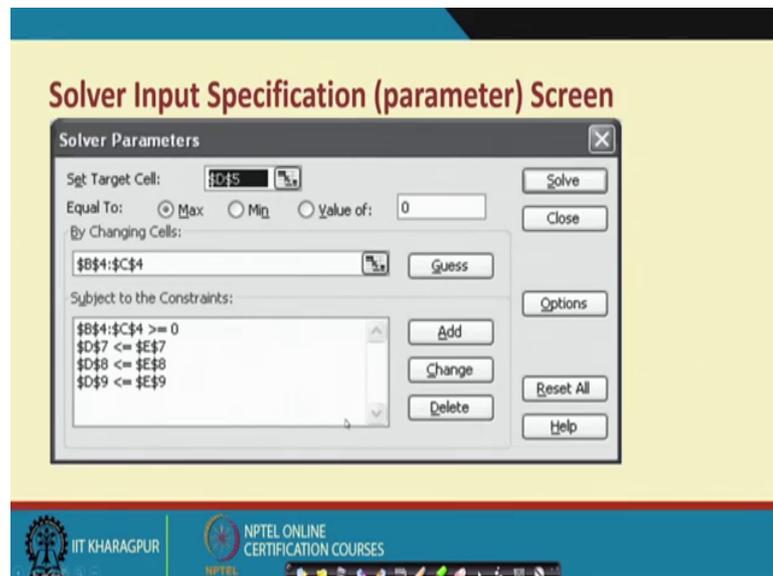
So, now you know I mean see in this problems, what we have already discussed here and in these are all optimum solutions, and that too with respect to changing situations all right. So, now, what is happening here, so if you go to the actually excel sheet here.

So, this is what actually the answer we put and you find here, this is what you know the original solution 740, and without any you know application of sensitive analysis, and in fact, what we have already discussed here the first constant is not binding, and the second constant is a showing binding, and third constraint is binding.

And so, for is sensitivity report is concerned we have here sensitivity report, and the objective coefficients are you know 60 and 450, and if you allow you know increase you know 40, and 10 and allow decrease 10 and 20, then what should be the possible you know optimum solutions. So, these are all you know various possible solutions, and with respect to this particular you know problems right.

(Refer Slide Time: 20:42)

Another example

Let us consider how the solution to the server problem would be affected by multiple changes to *either* its objective function coefficients *or* the RHS values of its constraints. Let's consider these changes:

a. A change in the objective function from maximize $60x_1 + 50x_2$ to maximize $70x_1 + 56x_2$.
b. A change in the RHS of the inspection constraint from 22 to 23 hours and a change in the storage constraint from 39 to 36 cubic feet.

Solution
(Values for allowable increases and decreases are taken from Exhibit 5.)

a. The change in the x_1 coefficient is +10 (i.e., 60 to 70), and the change in the x_2 coefficient is +6 (i.e., 50 to 56). From Exhibit 5, the allowable increase for the x_1 coefficient is 40, and the allowable increase for the x_2 coefficient is 10. Thus, we have

Variable	x_1	x_2
Change	+10	+6
Allow. inc. or dec.	+40	+10
percent change	25% + 60%	= 85%

So, that means technically what I like to say that you know sensitive analysis is actually beautiful kind of you know structure through which, it will give you know or it will be bring some kind of you know multiple options, through which you can address the business problem more effectively, and then we come with a kind of you know management decision as per the particular you know requirement.

And in fact, in the predictive analytic structures we call this particular component, or we call this particular structure called as you know robustness, we have a different kind of you know flexible structures, which you can pick up the best as per the problem requirement and the management requirement.

Here the similar kind of you know structure, but here the particular structure is called as you know sensitive structure that to over should be the optimal solution corresponding to change up the a scenario, that to with respect to the coefficients of the objective function, the coefficients of the constants, and the kind of you know conditions.

(Refer Slide Time: 21:39)

So, these are all various you know optional change in that to we look for the optimum solutions, and so you know we like to address here some of the cases like this.

(Refer Slide Time: 21:50)

So that means, technically what we have already you know discussed in the kind of intensity analysis, so that means, we have highlighted the a problems, and that to look for the optimum solution with respect to objective functions, and the kind of you know constants. So, then you know we allow the kind of you know problem with respect to you know change scenario, and that should be actually in a kind of you know logical

setup, or the kind of you know the future requirement, or the kind of you know management requirement, with respect to management objectives.

So; that means, we like to you know first predict the possible changes that to you know apply in that case of in objective functions with respect to constants, and the conditions, then for every change we look for the optimum solutions so; that means, whatever changes you live you know being. So, for every change will find you know another kind of you know optimum solutions.

Now we must have a kind of you know comparative analysis that too we have our original optimum solutions, now with respect to any change of the particular problem structure what should be the new optimal solutions, then we can compare with the original optimal solution with the new optimal solutions, then we freeze accordingly as per the particular requirement. So that means, with a given situation we have optimal solution corresponding to objective function and constant, and then and then we will have a here kind of you know prospective solution for the future requirement provided.

We must have a kind of you know predict kind of you know structure that to with respect to you know objective function constant and the conditions. So, so that requires you know enough exposure to understand the problem, understand the business environment, and then look for the solutions you know as per the a particular you know management requirement. And what I have already mentions.

So, when we apply sensitive analysis. So, there are you know number of possible changes can happen, and that too with respect to coefficients of the objective functions coefficient of the constant that left hand side right hand side, and you may have the option to a you know add one after another variables, we can have a options to add one after you know another constants, and any change you will apply then agains it will run the model and look for the optimal solution, and the beauty of the system is here. So, once you get the optimal solutions. So, now, any change you will apply that to so the that to the change will be effective at the you know final optimal solution only.

So that means, in the simplex procedure. So, your final optimal tables will be the input for you know any change scenario. So, any specific change with respect to a particular you know options that to with respect to of the depends on or with respect to constants or you know condition, then you look for the optimum solutions, and then we like to

address the problems how is the kind of you know chain scenario with respect to original you know structures.

So, you know so or so if you sum up then you know there is the a there is a 2 possibility. So, the first possibility is a there is no change of optimum solution corresponding to the chain situation, and in the second options there is a change of optimum solution corresponding to a change situation that with respect to objective functions, and with respect upon you know constants.

So, this is this is actually a you know very you know useful as per the you know business environment is concerned, because most of the business are very dynamic you know highly volatile, and highly uncertain, and there is huge leaks and; obviously, there is a you know lots of you know external factors, and there is lots of you know competitions, and sometimes you know this in this particular structure will change, here you know and there is a increase of you know competition levels, and there is a high chance there is a decrease of you know computational level so; that means, anything can happen in future.

So, if you are in a position to predict the future kind of you know structure, the business structure, then you allow that change to the optimal solution and look for the again the change optimal solution so; that means, the typical structure is that you know if you are in a position to predict the future kind of you know problem structure, or the promised you know the kind of you know business structure, then agains you may be in a you must be in a position to look for the optimum solution with the changing situations.

So, ultimately the challenge is how best you can bring the possible changes you know as per the future requirement that to with respect to objective function with respect to constraints, and the kind of you know condition. And so, you know that is how you know it is more interesting, and you know we must you know before you start this problem, and you know bringing the kind of you know change, you must have you know enough exposures enough understanding about the business problem, and enough you know knowledge about or the idea about the business environment altogether.

Then you can actually you know you know bring the possible change, and then look for the a possible you know optimum solution corresponding the corresponding to particular you know change, and finally so, what I have already mentions.

So, either you know the you know optimal solution will change, or you know optimal solution will not change. In fact, sometimes you know if optimal solution will changed. So, the value of the objective function will change, and the a number of you know decision variables will remain constant, only the values of the decision variable will change as a result the generally will change that the objective function value will change.

And sometimes the change there will be structural change of the optimal solutions, initially there may be you know typically you know clusters. Let us say with respect to 4 variables in the optimal solution original ability well solutions it is only 2 variables are there. Now with respect to change then you will find all the values of the decision variables are in the track to address the problems, and to come with a call independent solution which is not economically feasible, and in fact you know socially you know sustainable, or environmentally sustainable.

So; that means so what we have address till now, is the kind of you know linear programming structure through which actually we are you know addressing the problem corresponding to the business objective, business constraints, and the business conditions, and looking for the optimum solution.

And agains looking for further optima you know optimal solutions, corresponding to the changing environment that to business dynamics, with respect to objective function constraints and conditions, and then we can actually; that means, technically we have actually enough understanding or you know annex flexibility to on address the problem more effectively, and then come with a kind of you know management decisions as per the particularly know business requirement with this will stop here.

Thank you very much have a nice day.