Optimization in Chemical Engineering
Prof. Debasis Sarkar
Department of Chemical Engineering
Indian Institute of Technology, Kharagpur

Lecture – 59
Software Tools for Optimization (Contd.)

Welcome to lecture 59. See, in our previous lecture, we discussed how to solve a linear programming problem using excel solver. We went through all the steps. In today's lecture, we will actually solve the problem using excel on this computer, so that you can have a better feel of how to use excel solver for solution of a linear programming problem.

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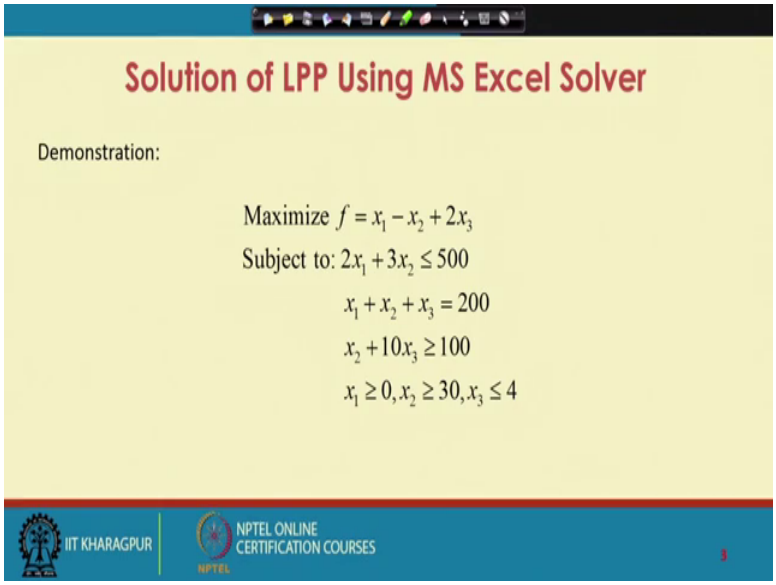

So, let us consider the same linear programming problem which we discussed in our previous lecture. So, maximize f equal to x 1 minus x 2 plus 2 x 3. Subject to 2 x 1 plus 3 x 2 less or equal to 500; x 1 plus x 2 plus x 3 equal to 200; x 2 plus 10 x 3 is greater equal to 100; x 1 greater equal to 0, x 2 greater equal to 30, and x 3 less or equal to 4. So, let us follow the steps that we have discussed in our previous lecture. So, let me start with an excel sheet.

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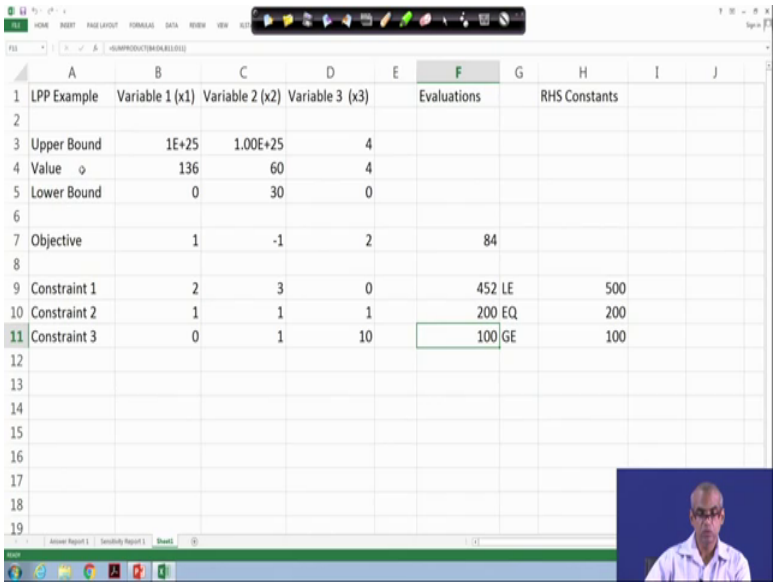

So, in the cell A 1, we said that let us write a label, so that we understand what kind of problem is this it is just a tag. So, we write say LPP Example. You can expand the width let us give a gap, and let us write here Upper Bound. Then we will write value we write Lower Bound. We give a gap and then we write objective or you can write Objective function if you want then let us skip one cell, then we write all the constraints Constraint 1, Constraint 2, and Constraint 3.

Now, we have put all the labels in column A. So, now, let us go to column B C D, and we set that it will be Variable 1 which is my x 1. Just expand it little bit Variable 2 x 2, you have to x 2 and then Variable 3 you have x 3 you need to expand little bit. So, we will give a let us skip one cell and then let us write evaluations. Again we will skip one cell, and write right hand side constants RHS Constants.

So, the Upper Bound values we have chosen for Variable 1, and Variable 2 which did not have any Upper Bound we had chosen 10 to the power 25 so let me write 10 to the power 25. Variable 3 was x 3 less or equal to 4, so it is 4. So, this row the value will contain initially the initial case for the problem and finally it will contain the converse solution. So, the Lower Bound in the problem the Lower Bound was x 2 greater equal to 30 others did not have. So, let us consider 0 0 and then for x 2 consider 30. So, we are done with Upper Bound and Lower Bound. And we have also supplied initial case for x 1, x 2 and x 3.

Now, we have to supply the objective function coefficients. The objective function was maximize. Let us say maximize f equal to x 1 minus x 2 plus 2 x 3. So, for x 1 the coefficient is 1, for x 2 the coefficient is minus 1, and for x 3 the coefficient is 2. So, x 1 minus x 2 plus 2 x 3 this was the objective function. Now, look at the constraint coefficients. The Constraint 1 was 2 x 1 plus 3 x 2 is less or equal to 500, 2 x 1 plus 3 x 2. So, 2 x 1 plus 3 x 2 for x 3 it will be then 0, it is greater or equal to so, let us go to column G skip this two cells, and go to column G it is greater or equal to.

So, let us write G E for greater or equal to sorry the first constraint was 2 x 1 plus 3 x 2 is less or equal to 500. So, less or equal to 500 under right hand side constants let us write 500. Similarly, the constant 2 was x 1 plus x 2 plus x 3 equal to 200. So, x 1 plus x 2 plus x 3 equal to 100. And then let us come to Constraint 3. The Constraint 3 was x 2 plus 10 x 3 is greater or equal to 100 sorry the Constraint 2 it was equal to 200 not 100. So, it was 200.

So, Constraint 3 was x 2 plus 10 x 3. So, x 1 coefficient is 0, x 2 x 1 is 1 and for x 3 it is 10. So, x 2 plus 10 x 3 is greater or equal to 100. So we have now entered the upper bounds, the lower bounds, initial guess, objective function coefficients, and the constraint coefficients, type of constants, and the right hand side constants. Now, we have to enter formula into the excel sheet that evaluates the objective function. And then we will do the same thing for the Upper Bound Lower Bound and the Constants. So, let us first start with objective function. So, we will now enter a formula that evaluates the objective function. So, let us go to row 7, and come to the cells under evaluations column.

So, you come to the cell that is in row 7 that is objective row, and also under column evaluations. So, there you type SUM PRODUCT; note that I am not pressing enter now. So now what you have to do is, you have to select the values see the cells B 4 C 4 D 4 is contained. So, it is selected B 4 up to D 4 put comma. And then come to row 7 which contains objective. So, start with the cell in the row 7 under column B containing variable 1 or x 1. So, from go right across x 1, then x 2, then x 3. Now, B 7, C 7, D 7 selected.

Now, you close the parenthesis, so first bracket is closed. Now, you press enter so 0is coming, because the objective the values that means the initial guess for the decision

variables are all 0. So, we are multiplying the cost coefficients with 0. Now, we have to do the same thing for the constants. So, come to row 9, which contains Constraint1 come under revaluations, put equal to then type sum product start bracket do not put or do not press enter, go to values take B 4 to D 4 put comma.

Now, come to row 9 that is Constraint 1 row, come under variable x 1 in the same cell go to right across x 1, x 2 and x 3 selected. Now, close the bracket press enter. Similarly, you do for Constraint 2 equal to sum product I select x 1 x 2 x 3 I put comma and then I select coefficients for Constraint 2 close the bracket press enter. Similarly, do for Constraint 3, I writes equal to SUMPRODUCT, now select x 1, x 2, x 3 under values put comma come to Constraint 3 row select x 1 x 2 x 3 close the bracket press enter. So, now you have completed data entry you have, now completed data entry.

Now, we ready to solve your problem. So, to solve the problem you go to data tab, and you see the solver is loaded already, so click on solver. So, set objective you have to set objective here. So, go to row 7 which contains objective in this row you go to the cell which is under evaluations click there F 7 cell references selected we are maximizing the problem. So, the max button is chosen by changing variables. Now, click on the by changing variables we are changing x 1 x 2 and x 3 so that is in row 4 with label value. So, to choose x 1 x 2 x 3 we click on this red button and then we select x 1 x 2 and x 3. So, B 4 to D 4 is selected here click on the red button again so B 4 to D 4 is selected.

So, you have now selected the target cell which contains objective function we have set the objective. We have indicated there is a maximization problem and we have also chosen x 1 x 2 x 3 as decision variables this has been done by changing variable cells and choosing B 4 to D 4. So, now we have to add the constraints. So, you will add the Upper Bound, Lower Bound then Constraint 1 Constraint 2 and Constraint 3. So, now click on add button. So, we are now putting first upper bound. So, click on this cell reference on this red button and then value that means x 1 to x 3 use select click on the red button. So, B 4 to D 4 is chosen under cell reference. Now, this is upper bound, so less or equal to sign is selected from the dropdown menu.

The constraint click on the red button and then go to the row 3 which contains Upper Bound as label select Upper Bound for x 1 Upper Bound for x 2 and Upper Bound for x 3. So, B 3 to D 3 is chosen and then you click on add Upper Bound is chosen. Now,

similarly let us choose the lower bound. So, under cell difference click on the red button, let us choose x 1, x 2, x 3 this is Lower Bound, so greater or equal to we have to choose from the drop down menu. And then under Constraints again click on the red button and we now go to row 5 which contains Lower Bound as label, and select x 1, x 2, x 3 Lower Bounds, so click on add.

Now, similarly let us do for the constraint 1, 2, and 3 so for click on for Constraint 1 click on cell reference then come to the cell which is in the Constraint 1 row, and under evaluations column click there. This is less or equal to type, so less or equal to type, and the constraint, and the constraint click on the constraint. Then go to the right hand side Constraint corresponding to Constraint 1 click that cell you add. Similarly, for Constraint 2 go to the Constraint 2 row come under evaluation cell this is equal to type select equal to from the dropdown, and then click the cell under right hand side constants corresponding to row Constraint 2 add.

Now, again for Constraint 3 go to Constraint 3 row come under evaluations click on that cell. This is greater or equal to type constraint, so choose greater or equal to sign from drop down menu, and under constraint you click on the cell under right hand side constraints corresponding to constrain 3 row add it. So, all Upper Bound Lower Bound and 3 constraints have now been added. So, you can now put can you can now it cancel to go back to the dialogue box.

So, the problem is now completely define parameters have been set. The only now I have to do now is have to select a solving method. From the dropdown menu which I choose simplex LP you can look at under options let all be set as default value. So, to solve the problem you just have now to click on the solve button. So, I click on solve button. So, solver found a solution all constraints and optimality are optimality conditions are satisfied. So, keep solver solution button I choose and I also choose answer as well as sensitivity then I click on ok. So, this is the solution I get x 1 equal to 136 x 2 equal to 60, and x 3 equal to 4.

The same solution that we discussed in our previous lecture, Optimal solution is optimal value of the objective function is 84. Note that the constraints all the constraints are satisfied. For constraint 1, 452 is less than 500, 200 is equal to 200, 100 greater or equal 100. All the constraints are satisfied and the optimal solutions is contained in the row 4

which has label value. So, x 1 equal to 136, x 2 equal to 60, and x 3 equal to 4 at the optimal solutions, and the corresponding values of optimal values of the objective function is 84.

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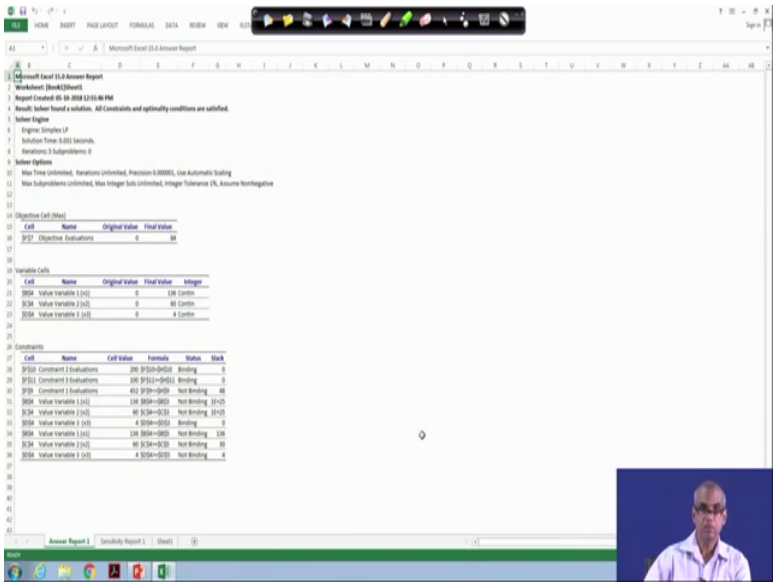

So, now answer report is self explanatory, it tells you that it took 5 iterations it started with 0 values for the decision variables and converse to x 1 equal to 136, x 2 equal to 60, and x 3 equal to 4.

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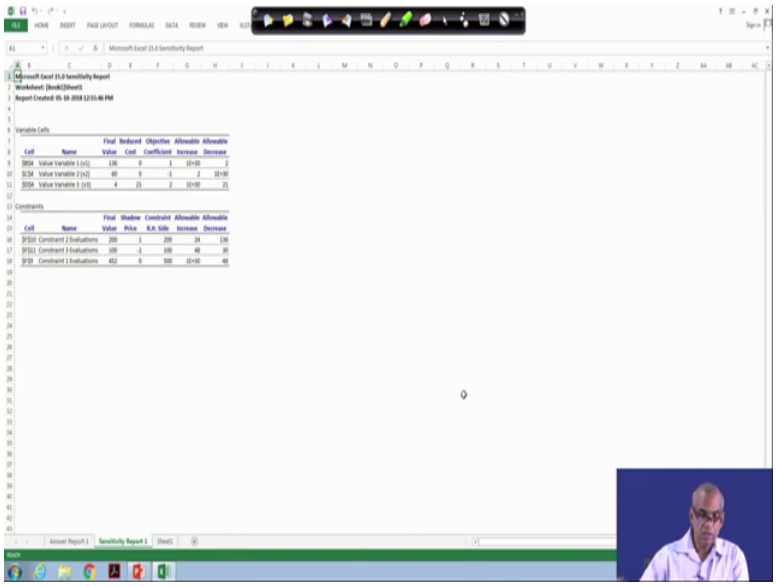

And it also contains sensitivity report. So, this is how you can solve a linear programming problem using Microsoft Excel solver.

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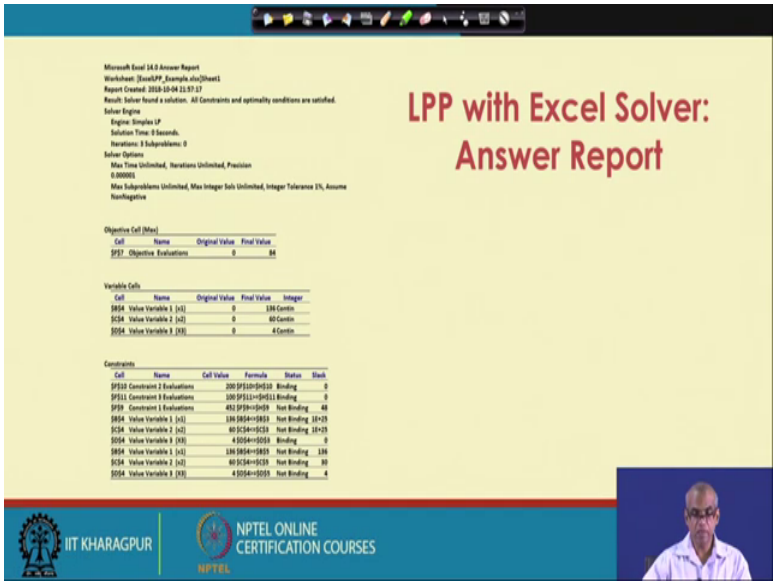

Now, so this was the answer report and this is the sensitivity report.

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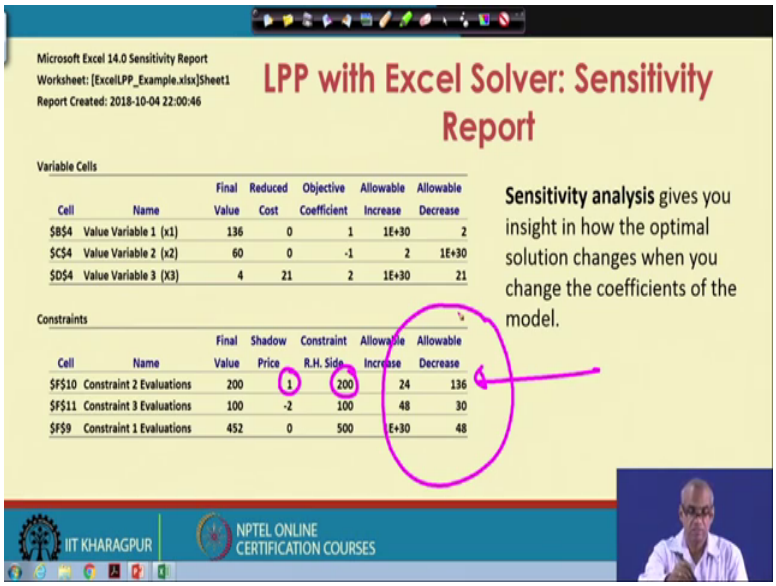

So, sensitivity analysis gives us the insight in how the optimal solution changes, when we change the coefficients of the model.

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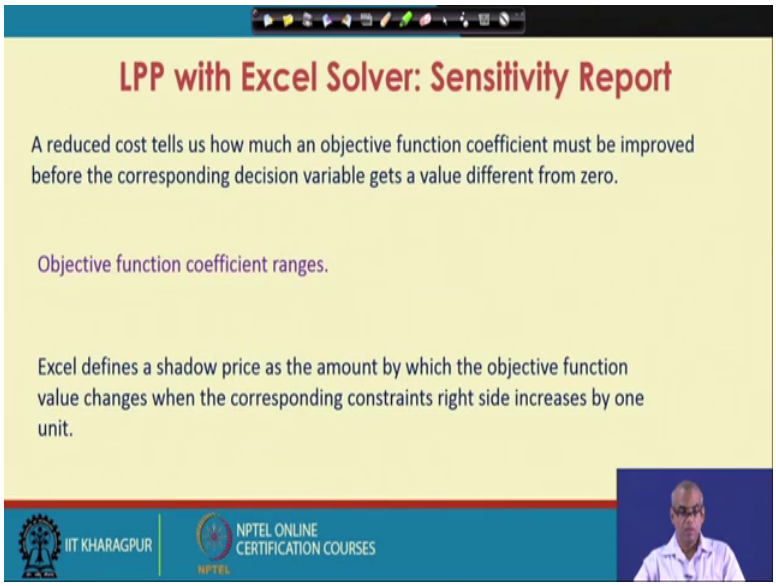

So, if you look at it, there is reduced cost shadow price, and this allowable increase decrease columns. And there are 2 tables one is for variable cell that is for x 1, x 2, and x 3. And this is for constraints those 3 constraints. Now, what do this mean a reduced cost tells us how much an objective function coefficient must be improved before the corresponding decision variables gets a value different from 0. So, reduced costs tells us how much an objective function coefficient must be improved, before the corresponding decision variable gets a value different from 0. So, my decision of the decision variable is 0.

So, if a decision variable is 0, then the entry under reduced cost column will tell you how much an objective function coefficient must be improved so that that decision variable gets a value different from 0 say 0 to 1. Now, the objective function ranges, now these are the objective function coefficient. If you remember, the objective function was x 1 minus x 2 plus 2 x 3, so these are those coefficients.

Now, allowable increase is 10 to the power 30 that means you can consider to be very large or infinity, let us say allowable decrease is 2. What it means is that you can the amount of increase or decrease that you can make to these objective function coefficients and still the optimal solution will not change. So, allowable increase tells you by how much you can increase the object that objective function coefficients without changing the objective function value.

The same interpretation holds true for allowable decrease. How much you can decrease that particular objective function coefficients without changing the optimal solution for the problem. So, in this particular case you can decrease by 2 only, but increase you can increase by any amount. Now, excel defines a shadow price as the amount by which the objective function value changes when the corresponding constraint right hand side increases by one unit.

So, the shadow price is the amount by which the objective function value changes when the corresponding constants right hand side increases by one unit. So, what it means is that the shadow price for this particular Constraint, Constraint 1 is 1 that means if I increase the right hand side Constraint that means 200 for this constant to 200 and 1 my objective function value will be increased by 1. And this interpretation is valid within these Allowable Increase or Allowable Decrease.

So, within this range, if I change the right hand side constant by unit amount, the shadow price will tell you the amount by which the objective function will change. So, this is how you can interpret the sensitivity report of the Excel Solver. So, this is how you can solve a linear programming problem using Excel Solver.

So, what you do it? You did is we took an example where there are 3 constraints. All the constraints are of three different times greater or equal to lesser or equal and equal to. So, we have learned how to setup the problem in the excel sheet, and how to use the solver, how to set the parameters and solve the linear programming problem. We also tried to learn briefly although how to interpret the sensitivity report that the solver also gives you with this would like to conclude lecture 59.