In this video, we're going to explore our linear optimization model further.

We're going to use it to answer some "what if" questions and to conduct some sensitivity analysis.

So here, we have a spreadsheet that is formatted very similarly to the spreadsheets that we've used in Video 5 and Video 6.

So we have the data up here, we have the price-per-click, the click-through-rate, the average price per display, the budgets, the query estimates.

Below those, we have the variables.

So we have the cells corresponding to the decision variables.

We have the cell corresponding to the objective.

And to the right of these, we have cells that contain the values of the decision variables and a cell that contains the value of the revenue from our original solution from Video 5.

So what we're going to do is, we're going to change our data, and we're going to see how the solution changes and how the objective value changes and compare it to our original solution.

So as one of the questions that we might consider, let's consider the following question.

What would happen if the click-through-rate of AT&T with query one increased from 0.10 to 0.5?

So to answer this question, let's crawl up in the spreadsheet until we hit the click-through-rate.

And let's change the click-through-rate from 0.1 to 0.5.

Now, if we do this, you may have noticed that the average price per display for AT&T in query one also changed.

So of course, this makes sense, because the average price per display is just the click-through-rate multiplied by the price-per-click.

And here, the way we've set up the spreadsheet is so that these cells are exactly the product of the corresponding cells.

So the cells that correspond to the click-through-rate and the price-per-click for that respective query and advertiser combination.

So our average price per display has changed appropriately.

And so now, we just scroll down until we see our variables and we see our objective.

And let's click on Tools.

Let's open up the Solver.

And we have the Solver configured the exact same way from last time.

So we don't need to do anything here.

And so now, all we have to do is just hit Solve and click on Keep Result, and voila.

We have a new solution.

So now, several things have changed with the solution, if you can see.

So the first thing is that the allocations have changed.

So for instance, we allocate query one and AT&T 68 times.

So we decide to show AT&T's ad with query one 68 times, as opposed to the original solution, where we did it 40 times.

And we can also see that AT&T is never shown in query two or query three in our new solution, whereas before, it was shown 40 times for query two and 80 times for query three.

Similarly, we show T-Mobile 72 times with query one, whereas before, we only showed it 100 times.

And we also showed T-Mobile with query three 14 times, whereas before, we didn't show it at all with query three.

And Verizon's allocations say the same as before.

In terms of the revenue, our revenue has gone up slightly from $428 in the original solution to $430 in the new solution.

Now, this may seem like a small amount.

But actually, this is the most that we can hope to achieve.

And the reason for this is, if we scroll down, if we look at our budgets, so the budget for AT&T is 170, for T-Mobile, 100, and for Verizon, it's 160.

If we add up these values, you can see that actually the sum of these values is 430.

Now, this isn't a coincidence.

In fact, if you think about it, this makes sense, because what Google earns from each advertiser is exactly how much that advertiser spends.

And if the most that each advertiser spends is that advertiser's budget, then the most that Google could hope to earn is in fact the sum of these budgets.

So in fact, we are attaining the highest possible revenue that we can hope to attain in this case.

So that was rather interesting.

And now, let's change back the click-through-rate from 0.5 back to the original value of 0.1.

And let's answer another question.

So the question that we'd now like to answer is, what would happen if AT&T's budget increased from 170 to 200?

So for example, AT&T calls us and tells us that actually they can afford more advertisements.

So how would that change our solution?

Well, in this case, let's just find AT&T's budget data.

So in this case, it is the cell here.

And let's change it from 170 to 200.

Now, let's scroll down to our variables and our objective.

And let's just set them back to zero.

And now, let's go to Tools again, let's open up the Solver, and let's hit Solve.

We get 428, which is actually the same objective that we got from before.

And let's just click on Keep Result and take a look at the solution.

Now, interestingly, this new solution is actually exactly the same as the old solution.

So what happened here?

Why didn't this change anything?

Well, actually, if you recall from the previous solution, in the previous solution, we actually only used $168 of AT&T's budget.

And in the previous solution, AT&T's budget was $170.

So in the previous solution, we didn't actually use up all of AT&T's budget.

And since this constraint was not binding, then increasing this constraint beyond 170-- so increasing the budget from 170 to 200-- won't actually have an effect on the solution.

So this is why the solution didn't change.

And in fact, in this case, we didn't really need to change the data and to solve the problem again, we could've deduced this from actually looking at the budget values.

So these are examples of two questions that we might consider in this setting.

And so this concludes our exploration of this problem in LibreOffice.

In the next video, we'll return to the slides, and we'll discuss some ways that we can extend the problem beyond the formulation that we've been thinking about here.

And we'll also summarize what we've discussed so far.

So see you in PowerPoint.