Here, we have a spreadsheet in LibreOffice that contains all of our data.

Up here, we have the basic data, which are the price-per-click and click-through-rate.

Below, we have the average price per display, which we will actually be using.

Below it, we have the budgets, and below that we have the query estimates.

After the data, we then have the variables.

So these are the x_A1s through x_A3s, the x_T1s through x_T3s and the x_V1s through x_V3s that we saw in the previous video.

And below those, we have the objective, the constraints, so that the budgets are not exceeded and that the query estimates are not exceeded.

So we'll have to fill in all of these expressions, which reflect, for example, how many times query one is used in our advertising strategy, how much of, for instance, T-Mobile's budget we use in your advertising strategy, as well as the objective, which is the total average revenue from our advertising strategy.

Let's start by defining the objective of our problem.

To form the objective, we go to the cell next to revenue, and we start by writing, =SUMPRODUCT.

The SUMPRODUCT function takes two collections of cells, multiplies corresponding cells together, and adds them up.

Here we want to use SUMPRODUCT to multiply the average prices per display with the number of times we display each ad with each query.

Our variables are all the cells between B35 and D37.

And the average price per display is contained in all the cells between B17 and D19.

So we need to input these into the function.

So we write B35:D37 comma, so the comma indicates that we're moving on to a new collection of cells.

Then we include B17:D19.

We press Enter, and so now we have our expression, which reflects the objective value for our advertising strategy.

Now to compute how much of each advertiser's budget we're using, we're going to use the average price per display and the decision variables of each individual advertiser.

So to get, for example, AT&T's budget usage, we would use SUMPRODUCT again in the same way that we used it for the objective, but this time we would use it just for AT&T's decision variables and AT&T's average prices per display.

So we use SUMPRODUCT again, as I mentioned.

So we write =SUMPRODUCT, but this time we select the cells between B35 and D35.

So we write B35:D35.

These are the cells that correspond to AT&T's decision variables.

For the second collection of cells, we select the cells between B17 and D17.

These are the cells that correspond to AT&T's average prices per display.

We can do the same thing for T-Mobile and Verizon.

In this case, we don't need to enter the expressions again.

We can just simply drag these expressions, and LibreOffice will conveniently fill the expressions in for us.

And now we need to do a similar thing for the number of times that we use each query.

So, for example, to get the number of times query one is used, we need to add the cells corresponding to query one.

In the spreadsheet, these are the cells corresponding to B35 and B37.

And in this case, we simply need to add the decision variable cells -- we don't need to multiply them with any other cells.

So we just need to use the sum function.

So we write =SUM, and again, we're using the cell's B35:B37.

For query two, we have to use SUM again.

And we need to SUM the cells corresponding to query two, so we write =SUM(C35:C37).

And for query three, we need to use SUM again, but this time we need to use cells D35 through D37.

So we write D35:D37.

So we've now defined all of the expressions that we'll need for our model.

Now we need to input the decision variables, the objective, and the constraints into the LibreOffice Solver.

So we need to first open up the LibreOffice Solver.

So we go to Tools.

We open up Tools, and we click on Solver.

So, to do this now, we need to specify, again as I mentioned, all the pieces of the problem.

So for "Target cell" -- so the target cell here is the objective cell.

So we need to specify our objective.

So this cell was just B40.

And we want to maximize this as we're maximizing revenue.

The "changing cells" here are the decision variables.

So this is just a collection of cells, B35 through D37.

So we write, B35:D37.

Now, underneath, these rows corresponding to the "Limiting conditions", these are just the constraints of the problem.

In the first row here, we'll handle the budget constraints.

So under "Cell reference" we'll input the budget expression, and these are contained in cells B45 through B47.

So we can enter these or we can just click on the input button and just select them in this way.

And then we click on the shrink button here.

Under "Operator", we want to select less than or equal to because we want to ensure that the amount that we use of each budget is less than the total budget of the advertiser.

And here under "Value", we're going to select the actual budget amounts, which are on the right hand side of these less than or equal to signs.

So we select them, and we put them in.

So that handles the budget constraints.

And in the second row here, we're going to handle the query estimate constraints.

So here again, under cell reference, we're going to specify the expressions that correspond to how much we use each query in our advertising strategy.

And so these are just the cells, B50 through B52, which we select, and we input them into the solver.

Under operator, we want to keep it as less than or equal to, because we want to ensure that the amount that we use each query is less than or equal to the expected number of times that we estimate for that query.

And under value, we want to input the query estimates, which are just the cells, D50 through D52.

So, we can just select them in this way, and input them.

So, at this point, it might be tempting to think that we are done, but we have two more things we need to do.

First, we need to tell the solver to explicitly treat this as a linear optimization problem.

Second, we need to include another set of constraints.

This set of constraints requires each decision variable to be greater than or equal to zero, since it does not make sense to display an advertiser with a certain query some negative number of times.

Now, while we could include these constraints here, these types of constraints are very common and very typical in linear optimization models.

They come up all the time.

And, in fact, they come up so often, that solvers often have an option that you can toggle, that incorporates these constraints automatically.

So to handle both of these considerations.

Let's just click on Options.

And under options, where we have the drop down menu for "Solver engine", we'll click on there, and then we'll select LibreOffice Linear Solver.

This indicates to LibreOffice to use the linear optimization solver for this problem.

And under the settings here, one of the settings, is to assume that the variables are non-negative.

We'll just activate that option and hit OK.

And now we're ready to solve the problem.

So if we hit solve, we get this dialogue that says that solving successfully finished, and that our result, in this case, this is the objective function, was 428.

So we have an advertising strategy that achieves an average revenue of $428.

Let's just hit here, Keep Result, and just take a look.

The cells that we specified as the decision variables have been populated with their optimal values.

So our optimal strategy, based on this linear optimization solution is the following: so we're going to show AT&T with query one 40 times; we're going to show AT&T with query two also 40 times; we're going to show AT&T with query three 80 times; for T-Mobile, we'll show T-Mobile's ad with query one 100 times; and we're only going to show Verizon's ad with query two, and we're going to show it 40 times.

So this specifies, completely, the advertising strategy that Google should use.

And this strategy, as we just saw, achieves an average revenue of $428.

Let's double check that the solution is feasible by looking at the budgets and the query estimates.

So if we scroll down here, we see that AT&T's budget that we use here is $168.

AT&T's actual budget is $170.

We can see that for the other two advertisers, that we are in the clear for both of them.

Similarly, with the query estimates we can see that for all the queries that we are considering here, we do not use any query more than the estimate for the number of times that we expect to see that query.

And finally, as one last check, all the decision variable values that we see here are all greater than or equal to zero.

So we're not using any advertiser with any query a negative number times, which obviously would not make sense.

So, the solution as a whole is a feasible solution.

In the next video, we'll show how to solve the problem using a greedy common sense approach, where we will allocate ads to queries by prioritizing them by their average price per display.