The process by which Google determines which ads to display for which queries consists of three key steps.

First, Google runs an auction where advertisers place bids for different queries that they want to display their ads on.

Next, Google uses each bid in a metric known as the Quality Score, which basically measures how well a particular ad fits a particular query to decide a quantity known as the price-per-click.

Google does this for each advertiser and each query.

Finally, and this is where optimization plays a key role, Google decides how often to display each ad for each query.

This problem, as we'll see shortly, can be formulated as a linear optimization model.

Let's begin by thinking about the data that we need for this model.

In particular, let's think about the price-per-click.

So as we just discussed, Google decides each advertiser's price-per-click.

The price-per-click is how much each advertiser pays Google when a user clicks on the ad for that query.

Each advertiser also specifies a budget.

This is the total amount of money that the advertiser has available to pay for all the clicks on their ad.

Every time a user clicks on the advertiser's ad, the advertiser's budget is depleted by the price-per-click for that ad for that user's query.

Let's illustrate this with a small example.

So suppose that we are Google, and three of the major wireless service providers in the United States -- AT&T, T-Mobile, and Verizon -- come to us wanting to place ads on three different search queries: query 1, which is "4G LTE"; query 2, which is the "largest LTE"; and query 3, which is "best LTE network".

If you're not familiar with these terms, 4G and LTE basically refer to different standards of high speed wireless data communication.

The table here shows the price-per-click of each advertiser in each query.

So for example, this 10 here means that T-Mobile will pay Google $10 every time a user searches for query 1 and clicks on T-Mobile's advertisement.

In this example, T-Mobile's budget is $100.

If T-Mobile begins advertising and by some point five people have clicked on T-Mobile's ad when they search for "4G LTE", then T-Mobile will need to pay five times $10, or a total of $50.

If T-Mobile's budget is $100, this means that T-Mobile is left with $100 minus $50, for a remaining budget of $50.

Now, while the price-per-click is important to know, we must remember that the price-per-click is exactly that, the price that the advertiser pays to Google for a single click of a given ad, on a given query.

This price is paid only if the user clicks on the ad.

But typically, the people who use Google search engine, who are you and me, will not click on every ad that is shown to them.

Therefore, we need a way to capture how often users click on ads.

This is where the idea of click-through-rate becomes useful.

The click-through-rate is the probability that a user clicks on an advertiser's ad for a given query.

You can also think of this as the average number of clicks that we expect per user.

And this quantity is defined, as we said, per advertiser and per query.

So to illustrate this, for the example that we just introduced a few slides ago, suppose that we have the following click-through-rates.

The number 0.08 here means that there is an 8% chance that a user who searches for best LTE network will click on AT&T's ad if it is shown to them.

In terms of the number of users who click on an ad for a given query, this means that for 50 users, if the click-through-rate is 0.08, we expect to see 4 users clicking on the ad.

Similarly, if there are a hundred users who view the ad and 8% of them click on the ad, we expect to see eight users clicking on AT&T's ad for query 3.

In the next video, we'll define additional data that we'll need to formulate the problem.

In particular, we will see how the click-through-rate and the price-per-click can be combined together to obtain a new quantity called the average price per display.

This derived quantity will form a crucial part of our linear optimization model.