

## DECISION ANALYSIS

# Booths Model

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Hi. Tony has given you a challenge of setting up a spreadsheet, so you can really understand whether it's wiser to play in the red booth or the blue booth. And so, we're going to spend some time right now, showing you one approach for doing this.

Let's start in cell A1 by entering the words 'Probably of Heads'. We said that the coin that we're playing with is a fair coin, so we'll enter .5 in cell B1. And this is a model input. We also said that we would be placing 100 bets, because we have been given 100 tickets. Lets enter the number 100 in cell E1, as a second model input.

You have been given 100 tickets. And your choice is to go into the red booth or the blue booth and play. so let's start by entering 'Red Booth' in cell A4 and 'Blue Booth' in cell A5. And no matter which booth you go into we're going to flip 100 coins. And each coin flip can result in a 'Heads' or a 'Tails'. And in these cells, B4 through C5 we're going to enter what the payout is for each of these outcomes. We said if you enter the red booth and the coin was flipped and it was a heads you win \$10. And if it was a tails you lose \$1. And if you enter the blue booth and the coin was flipped and it was a heads, you'd win a \$100. And if it was a tails you would lose \$20.

Now this is all the information that we really need to get a handle whether you should play in the blue booth or the red booth. And we're going to do that by setting up a Monte Carlo simulation. We'll this portion of the spreadsheet blank for the time being. And we'll start off by entering the word 'Bet' in cell A15. And we're going to use the computer to simulate the 100 coin flips. And then we're going to repeat this experiment many times, so you can really get a handle on what kind of outcomes are possible, given you have only 100 bets.

So let's set up our bets right now. We're going to place 100 bets. And so let's start a series and drag it down to the number 100. So those represent the bets. Now for each bet, a bet consists of a coin toss, we're going to simulate that by having the spreadsheet draw a random number. And you probably know by now, that the formula is just R-A-N-D, rand open parentheses close parentheses. And we can copy this formula down quickly by double-clicking on the bottom right

corner. We flipped a coin, now what we need to do is to record what the result was. And in this column we're interested in returning the word 'heads or 'tails'. How would you do that?

PAUSE the video: Set up your spreadsheet to record heads or tails.

We're going to use an IF function. So let's go up to the Insert Function button. Find IF. And our logical text is going to be, IF the random number is less than the probability of heads, given in cell B1 which should be anchored, we want the spreadsheet to return the word 'heads', if it's true. And if it's false, we want it to return the word 'tails'. Note that these are both character values and so they need to be entered with quotation marks.

Now we can copy this all the way down to the end, as well. Let's go ahead and bold and give an underline to the cells under row 15, just to keep those headings clear. So we have made a bet, we've flipped a coin, we record the result. And now what we would like to do is to record what you would have in your pocket had you entered the red booth versus the blue booth, same coin flip.

Let's start with the red booth. Let's enter the word 'Red'. And we're going to stretch that across both columns D and E. And we'll also use a font color of red, just to make more clear what we're dealing with here. In cell D15, let's enter the word 'Payoff'. In E15, let's write the word 'Cumulative' and use a '\$' dollar sign to indicate how much money is in our pocket as we go through these bets one at a time.

Let's start in column D by just recording our payoff. We flipped a coin, the result was tails. You're in the red tent. What should the payoff be?

PAUSE the video: What formula would you use?

Well, we're going to use another IF function. We'll go to the IF function, and here we want to evaluate whether our result was heads or tails - so choose one. If the cell to the left is equal to heads, then our payoff is whatever is in cell B4. Otherwise our payoffs was in cell C4. Those both need to be anchored. And we press OK. And this gives you the result of each and every bet that you place.

Now in this column [E] we're going to record, as I said 'what's in your pocket' when you start with bet 1, and you move down through bet 100. And we're going to just use a SUM function. And we're going to sum the values in cell D16 to begin with, and that looks a little funny, but

you'll see as we drag this formula down what happens. We need to anchor this very first reference. And then press the Enter button. And what this does, is it cumulates, as I said how money is in your pocket after you placed the first bet, the second bet, and so on.

So here we have placed 10 bets and we have \$45 in our pocket. So when we started we played our first bet, and we were in the hole by a \$1. We played the second bet, we lost that, and we were in the hole \$2. We played the third bet, and we won \$10, so now we have \$8 dollars in our pocket. And so that is how that function works. Copy that down all the way to the bottom, too.

Now let's do the same for the blue [booth]. We need to record the payoff and cumulative earnings had you played in the blue tent. Let's go ahead and merge and center those and then also choose a font color of blue. And we're going to use the same headings here, that we used for the red tent. Let's go ahead and see if you can enter some formula here, and then we'll walk through it together.

PAUSE the video: Enter the formula into your spreadsheet.

In the blue tent, the payoff is going to be another IF function. And since we're familiar with that function now, let's go ahead and just start typing 'IF' and then follow through, piece by piece these different arguments. The first argument is highlighted in bold, so we're entering the first argument. Is the result, equal to heads, yes or no. Press a comma, and now we're on the second argument entry. If it's heads and we're in the blue booth, we win the value in cell B5. Press a comma and now we're entering the third argument of the IF function. If it's not a heads, and it's a tails, and so our earnings are given in cell C5. We can copy that all the way through. We can use that same SUM function to cumulate what's in our pocket, as we go through each and every one of these bets.

What we would like to do is record, given these values here in the payoffs for each one bet. We'd like to record what our result is, what's in our pocket after we placed 100 bets. So let's record those in column D. Let's write the word 'Earnings' in cell D3. What we're looking for is a formula that will record the number of earnings that we have, given the number of bets, that's up here in cell E1.

It would be easy for us to simply reference the very last bet and enter that value. But what we're striving for here is some kind of function in the spreadsheet that will let us quickly see how the results differ had we changed this number of bets. And there is a very handy formula called

VLOOKUP, which we'll use to get this number.

Go to the Insert Function key and find the VLOOKUP function. We're going to look up the number 100, whatever is in cell E1. And we're going to look for that value in the first column of this big table.

So here is the first column, it's going to find the number 100. So let's go ahead and identify the values that we're interested in potentially returning. So that is cells A16 to E115. And we're going to return the result, once we find that number 100. We want to return the result that is in the first, second, third, fourth, fifth columns. Enter the number 5, as the column index number, and because we want the exact match we'll enter the word false, under the Range\_lookup section. And then press OK. This is a model output, so let's go ahead and shade this as a blue color.

So that means I have played in the red booth, and I have flipped my coin 100 times. For this set of random numbers, I came home with \$450 in my pocket. If I play this game again in the red booth, the next time I come home with \$417 in my pocket. \$494, and so on.

Let's use that VLOOKUP function and enter a formula in cell D5 to record the earnings from the blue booth. We've just used it, so just press OK. We still want to look up the number of bets that we have placed in this table. And now our table needs to stretch out to include the results from the blue trials. Once we find the number 100, we want to return the result in the first, second, third, fourth, fifth, sixth, and seventh column. So we enter the number 7 under the Col\_index\_num. And again, we want the Range\_lookup to be false, because we want an exact match. [OK].

So there are the earnings from playing in the blue tent. If there was one coin and that same coin was used to decide what your earning were, whether you played the red tent or the blue tent, this tells you what your earning would have been in both cases. This is given 100 bets. And the reason you want this flexibility from this VLOOKUP formula is that if I change my bets and placed only 5 bets, then the VLOOKUP function is going to find the number 5. And it's going to return \$28 for the red booth and \$260 for the blue booth. So that's the value of using a function that allows, more or less, an easy sensitivity analysis.

We've played this game a few times. And what we want to do, and each time we press F9, we can see that our results are changing. What we're going to do is set up a Monte Carlo simulation, so that we can get a better handle on how these results change. And what would be

the absolute worst we could do, and what is the best we can do, in these two situations.

The word Monte Carlo simulation comes from the casinos in Monte Carlo, where people play games of chance. In this simulation our game of chance includes this random component, because we don't know what the outcome will be. We're just going to use the computer to run a whole bunch of those simulations for us, so we can get a better handle what the variations and results could be. Let's do that.

How many trials would you guess that we would have to play, in order to get a good idea of the variation in these earnings from trial to trial? Remember each trial consists of 100 bets. Traditionally, we run many many trials, thousands of trials. But for the purpose of this spreadsheet, we're going to run 500.

So let's enter the word 'Trial' in cell H15. And let's set up a series that goes from the number 1 all the way down to the number 500. Now let's assume you hopped into the red tent. And you want to record the red earnings. What we want to do is use a macro to record how this number changes as we do 500 different simulations for 500 different trials. And we actually saw negative earnings at one point, just by chance. There is a streak of bad luck for you, it happens.

We need to record these trial to trial variations, in this column, Column I. So is going to be simply, pressing F9 to generate a new trial which consists of 100 bets. Grabbing the information is cell D4, dropping down to the word Earnings and finding the next blank cell. And then pasting those earnings into the next blank cell. And then repeating that 500 times. That's probably enough times for us to get a good handle on how these results can change, given that there is a chance element involved. Let's go ahead and do that.

Go to the View tab on the Ribbon. And go over to the Macros button. Let's choose Record (new) Macro. And let's call this macro 'PlayRed'. You can enter a shortcut key if you like, and store the macro in This Workbook and enter a description for your macro. [OK]

The first thing we're going to do is press F9 to get a new set of random numbers. Come up to the Earnings in the red booth and we're going to copy that. We drop down to the word Earnings in cell I15. We come up to Find and Select button and choose Find [and Replace]. And we're going to find a blank cell, but we want to be careful. We want to search by columns, we want to search down the columns, find the next blank cell and then press Close. Then we want to come over to the Paste button and we want to choose Paste Values. And now we are done with our macro, so we want to come down to the bottom of the page and press the box, or the square,

and that will stop our macro from running.

Now to look at that macro, go back to the View tab, and now choose Macros. And this time, let's View the Macros. And we'll choose PlayRed and Edit that macro. So this is the sub routine called PlayRed. And if you want to change that name, you could do so by just replacing the words here. Remember that the coding with the apostrophe are comments. Those are comments for you the modeler, they are not read by the computer. We started out our program by pressing F9, the Calculate key. We went to the Earnings recorded in cell D4. We copied that value. We went to the results section for trials and we found the next blank cell. And then once we were there we pasted in the earnings into that blank cell. And then stopped the sub routine.

What we would like to do is add a few pieces of code, so that is routine loops 500 times. And we're going to do that, by entering the words 'For counter = 1 to 500. And then before the words 'End Sub', we'll write the word 'Next'. And what that does is when your macro begins to run, the first thing it does is hit this counter [For counter = 1 to 500] and it sets the counter to 1. Then it computes all of the code until it hits Next. In which case the counter moves to number 2. And repeats and loops through it until it hits 500. And then it hits the word Next, the counter has been passed, so we're kicked out of the sub routine with the End Sub note. And that is basically all there is too that. We can choose the red X to close out of the Visual Basic editor. And now we have a macro that is set up to run 500 simulations for us.

Let's go ahead and insert a button onto our page. And you can use any kind of shape that you would like. I'm going to choose a smiley face and color that red, just to keep that clear. And then I'm right-clicking on the smiley face. And then I'm going to choose the Assign Macro link, and then choose PlayRed. So that when I press this button now, it will run through that macro. So here we go! OK, when you are finished, scroll back up to the top of the spreadsheet.

Now, we would like to do basically the same thing had we been in the blue tent. Let's go ahead and type in Blue Earnings. And this time since we need to do the same kind of macro that we had just done with the red. We can use a little shortcut by just copying the code that we just generated for the red side and paste it into the blue side. The difference is we want to reference the earnings in cell D5. And when we search we want to search down column J.

Let's go back up to our Macro. And again we'll View the Macro. We'll Edit the PlayRed macro. And then just take your mouse and highlight the entire macro code, and then copy it. Scroll down a couple more lines and paste that in. So we have pasted in the red macro.

Now all I want to do is call this 'PlayBlue'. And remember that we said that we're going to first press the F9 button. And then we want to take the earnings from the blue tent, which are in cell D5, and then we want to copy those results, or those earnings. And then we want to record the blue results in column J. So we want to select cell J15. And other than that our macro is basically done. So we press the Close button. Now let's add another little smiley face to our spreadsheet. And this time we're going to tag this smiley face to the macro called 'PlayBlue'. We'll do that by right-clicking, and then assign PlayBlue. And then press OK.

So that is a very fast way of generating a new macro. And let's go ahead and push that smiley face, and off she goes. One thing I had just noticed while my macro was running was that the number of bets is still set as 5. And so let's go ahead and do one more macro that will quickly erase these results. And this time we're going to use a different kind of button just to show where those buttons might be.

All of the buttons in the spreadsheet can be found through what is called the Quick Access Toolbar. If you choose that little arrow at the top of your spreadsheet, we can customize the Quick Access Toolbar by choosing the More Commands option. And then we want to show all of the commands that are available within the spreadsheet. And so let's choose 'All Commands'. And you'll see that there is an enormous number of options within this particular spreadsheet program. And we're just looking for a button. And so it's listed as a button. And once we find it we can click on it 'Button Form Control' and then choose the Add button. And that will now become a part of our Quick Access Toolbars. And then we can say OK. And now what you will see is the button is added to this Quick Access Toolbar. And now if I want to do another macro, this time I'm going to launch that macro by pressing a button.

So let's do one more macro. This macro is simply going to be to clear out our old results. Let's do that.

Choose the View tab. Go to Macros. Record new Macro. We'll call this macro 'EraseResults'. And we'll simply select all of the results and then press the delete key. When we're finished we can go back up and Stop Recording. And now we can add a button to our page by clicking on that button you just added. And placing one on the spreadsheet and then assign the macro EraseResults to it. And then press OK. You can change, and select the words inside the button. And this looks a little bit more formal, than a smiley face.

At this point I'm going to set my bets back to 100. And then I'm going to play red and play blue,

500 trials each. So I'm going to run both of those macros. And I'll see you back here in a minute or two.

PAUSE the video: Run your macros

The goal of this whole analysis was to play this game 500 times to get a really good handle on the variation in earnings, given that one trial consists of 100 bets. And we're really trying - we know that there is a chance element involved. So we have played this thing 500 times.

And so what we would like to do now is to go ahead and simply record our outputs. And we want to use some very simple summary statistics that will tell us, well what was the best you did in the red tent and what was the worst you did in the red tent. And what is the best and worst you did in the blue tent. On average how did you do in each of these tents. And we're going to record those in this section of the spreadsheet here [G2].

So let's enter the words 'Monte Carlo Simulations'. And we're going to record the results of Monte Carlo. And we're going to use three very simple summary statistics. We're going to calculate the minimum earnings, the maximum earnings, and the average earnings. So let's write 'Min', 'Max' and 'Average' in cells G3, H3 and I3. And then let's go ahead and record those for the Red Booth and the Blue Booth. These are such common formulas - Min, Max, Average - that they're not only accessible through the Insert Function key, but they are also available through this AutoSum. If you drop-down, you can find there's Min, Max and Average. A quick way for you to get to those functions.

Let's start by calculating minimum, since we know minimum is just M-I-N. We can just type that in. And then take the red column, start your series, and then use the Ctrl-Shift and down-key to get to the end of the series. And then press the Enter key. Let's calculate the maximum. And M-A-X, and open parentheses, and choose the red series again. And last, but not least, let's go ahead and calculate the average for the red series. Ctrl-Shift down.

And here we see, that the worst we did in the red booth was come away with \$252 in our pocket. The best we did was to come home with \$604 in our pocket. And on average we would bring home \$449.89. Not bad.

Now let's do those same calculations for the blue booth. Let's start with a minimum. The maximum. And the average. These are all currencies, so we should format those as a currency type of formatting.

And just to keep things clear instead of shading these blue not to confuse the outcomes of the red booth with the blue booth. Let's just go ahead and color our outcomes in red, with the color red. And color the outcomes in blue, with the color blue.

Let's just take a second and see what this says. In the blue booth the worst you did was \$2,500. The best you did was \$5,500. This is way better than the best you did with the red booth. The best you did with the red booth was \$604. That's way lower than the worst you did in the blue booth.

Now what we really wanted to have you think about, here, is this computation called 'Average'. Do these two numbers look familiar to you, closely approximating some numbers that Tony talked about in the lecture? They should. These are very close to the expected values. And those would be expected values you would calculate, given this value probability of a heads, but no element of random chance. Lets reminder ourselves how to calculate those in this portion of the spreadsheet.

The goal, here, was to play in two booths. So let's go ahead and enter tails if you played in the red booth. And we'll color those red. Alternatively you could have played in the blue booth. So we have heads and tails in the blue booth as well. And we're going to have a question of which one we should 'Play?'. We're going to choose 'Red' or 'Blue'.

So let's go ahead and make that more crystal clear, by entering in an arrow. That's an arrow. And we can make that color different by choosing Shape Outline / Color, and making that red. And then lets insert another arrow. And here this represents our decision that needs to be made.

So this is the 'Outcome' of a flip. Now we're going to record the 'Probability'. The probability of getting a heads in the red tent is given in B1. And the probability of getting a tails is  $=1$  minus B1. We want to reference those values up on top here, because our spreadsheet is automatically updated as we change these inputs.

The blue tent had the same probabilities, so we can enter those same formulas once again. Now if we actually flip a coin, lets record the 'Payoffs'. And these are just referenced to these cells here [B4, B5 C4, C5]. If you are in the red tent and you get a heads, your payoff is given in cell B4. If you are in the red tent and you get a tails, the payoff is in cell C4. If you are in the blue tent, and you get a heads, the payoff is in B5. And if you get a tails in the blue tent, your

payoff is in cell C5.

Now from these numbers we can compute the 'Expected Value'. These expected value calculations don't include an element of trial to trial variation. We're just simply going to enter that equation. Do you remember how to do it?

The expected value for the red tent is a heads, one outcome, multiplied by its payoff, plus the second outcome tails, multiplied by its payoff. And we see that the expected value is \$4.50. But since we played 100 times, we should take that result – that whole result – and put it in parentheses, and then multiply it by the value in cell E1. This is a currency, so let's choose a currency format. And we'll go ahead and shade the background red to make it clear.

Now let's compute the expected value for the blue tent. In the blue tent, you have two outcomes - head or tails. And each one is uncertain as to what the result would be. So to compute the expected value, we take the probability of the first outcome, and multiply it by its payoff. And to that, add the probability of a second outcome, and multiply it by its payoff. Once again let's put that whole term in parentheses. And we'll multiply that by the value in cell E1, which is our number of bets, and press enter. This is the expected value for the blue tent. And again let's format with the currency formatting.

What we wanted to have you notice is when you play a Monte Carlo simulation, even though it involves an element of chance. When you play it over and over and over again, and you compute your averages, the averages come very close to these expected values. Here we're off by 11 cents. Here we're off by a little bit more, but not too bad. And you can prove this to yourself by erasing your current earnings and just playing those trials again.

This is why those dealers in Monte Carlo and Las Vegas, they actually play by the rules of expected values. Because they're playing these games of chance as the dealer over and over and over again. But you as a gambler may not place 100 bets over and over and over again. And so there are times when you don't want to play by the expected values, and instead you'll want to also call in your own value judgments. And this is a topic that we'll visit here shortly. Let's head back to Tony.

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