DECISION ANALYSIS

Buy A Car Model

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Today we're going to set up a spreadsheet model that outlines the process called SMART, which stands for Simple Multi-Attribute Ranking Technique. And you've been given the problem of working in a group with some parents, and grandparents and a teenager, and the goal is to buy a new car for the teenager.

And after going through some discussion, there were four objectives that were decided upon that would be relevant in making a decision about which kind of car is appropriate. The first one was price. The second one was safety. The third one was fuel efficiency, and the fourth one was the cool factor. And as Tony said, there were four options that the family arrived upon, which they agreed upon would be suitable for this particular purchase. And one was a Honda. The second was a Mustang. The third was a pickup, and the fourth was a Focus.

And the spreadsheet, we can just set this up simply as a grid. And let's start by setting up a column heading from cells B2 to cell E2 and merge those cells. And we're just going to name this particular cell 'Objective'. And this is a heading, so let's go ahead and shade that a color that signifies it's some sort of a heading.

Let's go ahead and write in the different objectives that we had. So the first one was price and that's measured in dollars. The second was in safety and that's scored on a scale between 0 and 10. The third is fuel, which is miles per gallon. And the fourth is the cool factor, and that's scored on a scale of 0 to 100.

Let's go ahead and stretch the columns out. And you can auto-fit those, by simply choosing the right side of the column and double-clicking, so that we can see all of those column headings clearly. And let's go ahead and bold those.

And what we're going to do is now list our alternatives in column A. So these are our options. And we'll go ahead and list those. 'Honda' in cell A4, 'Mustang' in cell A5, the 'Pickup' in cell A6, and the 'Ford Focus' in cell A7. And in these cells here, we're going to input what the values are - what is the price, what is the safety, fuel and cool factor. These are going to be our model

inputs. So let's go ahead and border those and shade those green, because these are our model inputs. So we have four objectives, and these are our alternatives. So I'm going to go ahead and write 'Alternatives' in cell A3.

Now these objectives, price, safety, fuel, so on, they require some kind of a measurable--something we can measure about them. And how we measure and score each of these things is called an attribute. So price, for example, is easy. We can just enter in what the price of the model is. So let's enter $10,000 for the Honda and $15,000 for the Mustang, $5,000 for the pickup, and $7,000 for the Focus. This price attribute is dollars.

Safety uses a scaling between 0 and 10. And let's go ahead and make up some numbers for these. Let's say that the Honda has a safety rating of 8, the Mustang 3.2, the pickup 5.1 and the Focus 7.6. This attribute has a totally different scale than the price scale.

Miles per gallon is pretty straightforward, so we'll just enter in what the miles per gallon are for each of those different models. Let's enter a 30 for the Honda, a 17 for the Mustang, a 15 for the pickup and a 28 for the Focus.

Now let's look at coolness. Coolness is going to be scored on a scale from 0 to 100. Let's go ahead and enter a 50 for Honda, 100 for the Mustang, a 75 for the pickup and a 30 for the Focus. Just to clean these up a bit, I'm going to select all of our input cells and center them.

So this is how you would set up your smart analysis. The objectives are written out across the columns, and the alternatives are written across the rows. Each of these alternatives is scored for each of the four objectives, and how they're scored depends on how you choose to represent that particular attribute; what's the scaling that you would use.

So for example, for the cool factor, we could have used very cool, uncool and medium cool, high, medium and low, but the problem with that is it's hard to give those scores that are used in a quantitative analysis. We could have ranked them differently, used a different scaling. And there's lots of different ways to think about these, but the goal here is to enter numbers into these squares. And these, as Tony said, are things that you would all agree upon. These won't be the source of any contention in the decision problem.

Well the next step then is to do some simple summary statistics. Let's calculate the minimum and the maximum for each of these different attributes. In cell B9, we're going to enter the

minimum. We can go up to the insert function key and find the function called MIN. If we can't find it directly, simply choose the 'All' option and then type the letter 'M' to bring you down to those functions that begin with an 'M'. And scroll down until you find MIN and then press OK.

This brings up a dialogue box, and in the dialogue box, we want to enter the range of cells that we'll be evaluating. And you can see here that on my computer, B4 through B8 are selected. What I need to do is to change that and have it give me the minimum for cells B4 to B7, and press OK. Now I can take the bottom corner of that cell and drag it across to cell E9, and the minimum calculation will be carried through and calculated for each of those different objectives.

Let's do the same thing for the maximum. The formula for max is just simply MAX, open parentheses, and again, we can now enter our argument after the first parentheses. And we want to take the maximum of the cells in B4 to B7. And once you have that, you can push the 'Enter' button. If you don't know that this is the name of this particular formula, just use the Insert Function key and find it that way. Once you've entered that, take the bottom right hand corner of the Fill Handle and pull that over so we calculate the maximum for each of those different objectives. And let's go ahead and center these cells here. These are calculated model outputs, so let's shade those blue and give them a border.

Now let's think about what our goal is with each of these objectives. Do we want to choose a car that has the lowest price or the highest price? Let's go ahead and write this in here. Cell A11, enter the word 'Goal'. And in the case of price, our goal is simply to 'Minimize' that price. Choose the model where we have the minimum or lowest cost.

What about safety, fuel and cool? Well for each of those we want to maximize. So I can type in the word 'Maximize' and then just copy that over. And we have now - what is the minimum value for each of these objectives, and what is our goal for each of those.

Once we have a clear understanding of what the goal is, now we can look back at our raw data here, and look and see if we have any irrelevant objectives or any dominated alternatives. What an **irrelevant objective** is - is an objective where there's not enough variation between your alternatives. So for example, if we chose four models and they all ranked 50 on the cool factor, then that objective really won't play into our decision, and we can eliminate that.

So let's look through these and see if any of these objectives, given our alternatives, can be called irrelevant objectives. Not really on price. Safety, there's a good variation there, fuel as

well, and cool. So we're not going to be able to delete any of these objectives because one of them is irrelevant. The second thing we want to do is look and see if there any **dominated alternatives**. And that would be an alternative that performs poorly compared to any of the other alternatives across all four objectives. So for example, we know we want to minimize price, maximize safety, fuel and cool. So let's go ahead and look at each of these alternatives one at a time, and make sure that none of them are dominated already by another value. And if that's the case, we can eliminate that particular alternative.

Let's start with the Honda. The Honda has these values in its scoring. Let's just ask and focus on the Honda's value and see if this Honda performs poorly than any of the other three options. It performs better in terms of safety than all of the others, so we can't eliminate in terms of safety. And so right away, we know that Honda cannot be eliminated as an alternative.

Let's look at the Mustang. The Mustang performs worst in terms of price. It also performs worse instead of safety. But if you look at miles per gallon and cool, we can't drop that Mustang option out, because it's performing better than some of the other alternatives in the matrix.

How about the pickup? The pickup performs better in cool than the Honda, so we need to retain that.

And the Focus, the Focus is better than the Mustang and pickup in terms of fuel. So we don't have any dominated alternatives in this particular case, and we're going to use this full range of options and full range of objectives.

Okay, the next thing we need to do is to figure out how we're going to give a score for each of these four alternatives based on the information in our matrix. And to do that, we need to do something that's very important, and that is to first standardize these numbers. And what that does is it allows you to put these different objectives, which are all on different scales, roughly into the same language, so to speak. So that we can compare them in a meaningful way. Because right now, if we compared them and made a decision based on price and safety only, then it's hard to compare $10,000 plus 8, and $15,000 and 3.2. Adding those numbers won't really get us very far, because price is measured in dollars, and safety is measured on a score of 0 to 10, and that won't work. So the first thing we need to do is to set up another grid on this portion of the spreadsheet that's going to let us to standardize the numbers that are within this particular box here.

And let's go ahead and do that. And to do that, let's do it quickly by just using your mouse and copying these cells. And I'm going to use my CTRL C button, and then click on cell G2, and just go ahead and paste those values in. And let's shrink this down a little bit. Just so you can see, and spread them out, so that you can read all the column headings as well. Okay, fast way to just duplicate it.

And now we can delete those values. And now these are no longer inputs. These are going to become calculations. And what we're going to do is to enter an equation here that tells you what the price of the Honda is, what the price of the Mustang is, what the price of the pickup and the Focus is relative to the other alternatives in the list. And what we're going for, what we're trying to achieve here, is that since we want to minimize it - we want the alternative with the smallest value, the lowest cost, which is the pickup, to have a value of 100. And we want the alternative with the highest cost, which is the Mustang, to have a value of 0. So that's, as Tony called that - that's setting up our thermometers. So here is the minimum, $5,000, and since we want to minimize it, we're going to give that the best score. And here is our maximum value. Since we want to minimize that, we want to give that value the worst score.

And then we need to let these other two values be representative of how far away they are from the minimum and the maximum. And to do that, we're going to use a fairly standard formula which I'm just going to type in cell B13. If you want to normalize the scores, so that the maximum is the goal. We would use the formula, it's our value - let's just call that 'S' minus the minimum, divided by the minimum minus the maximum, and we're going to take that whole term and multiply by 100.

And if we want to normalize so that the minimum is the goal, we're going to use a slightly different variation of this. We're going to take S, or the value of the score, minus the maximum, divided by the Min, minus the Max, and multiply that times 100. Okay, so here is a formula, and we're going to use these formulae in these cells here.

And let's go ahead and start with price. We said that our goal is to minimize the price, so now we're going to normalize these scores so that the lowest price has the best score, and the highest price has the worst score. So our goal is to minimize it, and so we're going to be entering this equation here.

Let's go ahead and do that. First, let's delete these, but know that this is the answer that we expect to find after we enter this formula. So the price of the Honda is equal to, open

parentheses, the raw value - the raw price for the Honda, minus the maximum, which is in cell B10.

And let's go ahead and anchor that - because we're always going to be referencing that cell, divided by the minimum minus the maximum for that particular attribute. The minimum minus the maximum, and both of those need to be anchored. So you can hit your F4 key, and it will apply the dollar signs, and then multiply by 100. And now if you click Enter and drag that formula down, you will have the normalized scores for price where the worst score is a 0 and the best score is 100. And these scores are relative on that thermometer to the minimum and the maximum. Make sense?

Now that you know how to do the minimum values, the next thing we need to do is to normalize the safety values. And in this case, we want to maximize safety, so our thermometer will register 100 for the alternative that has the highest safety, and a 0 for the alternative that has the lowest safety. And we're going to use this equation right down here.

So let's go ahead and choose cell H4. And we're going to enter the equation equals C4, minus the minimum in C9, closed parentheses, divided by the minimum minus the maximum. And that whole term needs to be multiplied by 100 to set our thermometer between 0 and 100. And again, we need to anchor the cells C9 and C10 so that we're always referencing those cells.

And then press Enter, and we see that we have a score that is negative. And that can't be correct, so that means there's a problem with my equation someplace, and the problem is that I have these backwards in the denominator here. So let's go ahead and just change that so that we're on the same page here. When the goal is to maximize something, it needs to be maximum minus the minimum.

Okay, so let's adjust this particular formula here. I'll go ahead and start it over again. It's equal to S minus the Min, close the parentheses around that, divided by Max minus Min. Max minus Min, and that whole term multiplied by 100. And push F4 to give that dollar signs, and then press Enter.

So that's what we would expect. The Honda has the highest safety rating. We need that result to be 100, and it is. And now if we drag this formula down, we need to show that the lowest, the Mustang is a 0 on the thermometer. So far, so good. If you don't want to look at all of those decimal points, just select those numbers and then go up to the ribbon and choose the

Decrease Decimal button. Those need to be numbers, so first let's choose the Number format, and then decrease the decimal points.

Okay, now fuel and cool are two more attributes that we need to standardize, and so we are going to maximize both of those, as well.

Pause the video: See if you can enter equations in there and fill out this grid, and then come on back and we'll pick it up from there.

For fuel, we're going to enter the equation - equals the fuel of the Honda minus the minimum, divided by the maximum, minus the minimum. And make sure you have all of your parentheses closed. So we've got the numerator is defined following order of operations. First we're going to do the subtraction. Then we're going to do the subtraction here. And then take each of those results and do division, and then we'll multiply by 100.

And let's just double-check that result. The Honda has the best fuel, and so we expect that to be rated as a 100, and it is. And we see that the pickup has the worst fuel, so we're expecting that that number in cell I6 should be 0.

PAUSE the video: And I got some mistakes in there. Can you think of what I did wrong?

Right. I need to anchor the maximum and the minimum, because when I drag my formula down, I'm dragging into these cells, and I need to anchor these cells so that we're always referring back to those maximum and minimum values. So I'm going to go ahead and anchor those, and then press Enter. And then copy that formula down one more time. Let's go ahead and make those numbers and hide the decimal points.

For the cool factor - the formula is equal to, open parentheses, the value of the cool, the raw, unstandardized value, minus the minimum, divided by the maximum, minus the minimum, and multiply that term by 100. And then copy that formula through. Oops, and I forgot the same mistake. Let's go ahead and anchor those values for the maximum and minimum and then press Enter. And let's change that set of numbers to a number format, and there we go.

So now we have our standardized attributes, and let's go ahead and label that 'Standardized Attributes' up on top here. And select all of those cells and merge them and bold them. So here are our unstandardized values, and here is a grid of our standardized values.

So what we've done is taken some very different attributes measured on very different scales. And in order for us to do some calculations across attributes, it's important that we first standardize them. And so these equations become very important and are used in many different situations.

Now an important part of the **Smart Technique** is that each of these objectives could be weighted. And you would weight them on a scale of 0 to 100, where 100 is the objective you feel is most important. And let's go ahead and put some weights in right down in this space in our spreadsheet. So let's go ahead and enter 'Weights' in cell G9. And this is going to be a heading, so let's shade it and label it so that it looks like a heading. And here in cells G10 through J10, we're going to enter our weight inputs. And so we'll shade those green to signify those are inputs. And you would weight those objectives in these particular cells, and these are, again, cells that you can change and see how your results will be affected as you change these weightings.

So let's say that price was 50 percent of the weighting, safety was the most important, and fuel economy was the most important, and that the cool factor drops down to a weighting of 25. And these, we're going to go ahead and center those. And again, these are values that can change. If you want to do an unweighted analysis, you would simply set them all to the same value. Before I go further, I'm going to go ahead and change these from a green color to a blue color so that we're not confused. We cannot change any of these numbers, because these are calculations based on the values in this grid over here.

Okay, so our goal now is - we've done a few things. First of all, we set up our grid with raw numbers. Then we've standardized them so that there is a thermometer reading where the bottom number is 0 and the top number is 100. And all of these values are now scaled appropriately the same way.

We've set up some weights at the bottom, and now we're going to use the numbers in this blue grid and the weights to arrive at a scoring for each of our different alternatives. And we'll do this a little bit on the right-hand side of the spreadsheet, so I'm going go to the bottom left corner and zoom out a bit so that you can see what I'm doing over here. And we're going to compute what is called the Weighted Sum for each of these different options. So Row 4 is going to be our weighted sum for the Honda, Row 5 will be for the Mustang, and so on. These are going to be outputs for the model. And all we're going to do is take the price for the Honda and multiply

it by its weight. Then we're going to add to it the safety for the Honda and multiply it by the safety weight. Then the fuel for the Honda by the fuel weight. And then add the cool factor multiplied by the cool weight. So this can be done very quickly with a Sum Product function.

I'll show you how that works. Let's just first do this by hand, though. So that is equal to the price times its weight, plus safety times its weight, plus fuel times its weight, plus cool times its weight. And there's our answer for the weighted sum for the Honda. Now if I anchor all of the weights in this equation, then I could just drag this formula down and have calculated the weighted sum for the Mustang, pickup and Focus, as well.

You can also achieve this formula more quickly with the Sum Product function, and so let's just look at how that works. Go up to the Insert Function" key and type in 'sumproduct'. There it is. It returns the sum of the products of corresponding ranges or arrays. In our first array is the Honda data. In our second array are the weights. In here we want to anchor the weights by pressing F4 so that as we copy this formula down, everybody's equation will be correct. And we press OK. And you should see that the result is the same as we had before. It's just a very nice function to use in Excel.

Now that's our weighted sum. And what we want to do is divide the weighted sum by the total of the weights. And so let's calculate the sum of all of the weights using the sum function, which is just SUM, open parenthesis, and then use your mouse and select cells G10 to J10 and then press Enter. That's the sum of our weights. That's the total weights we're dealing with. And so now we can calculate our final score as the weighted sum divided by the total of the weights. So let's label this 'Total' in cell K9. And here we're going to calculate our final score. And these will be outputs, so again, we'll shade those in blue and give them a border. And that's simply going to be the weighted sum divided by the total weight. And anchor that K10, so that as you drag that formula down, the references are always going to reference cell K10.

So what you have here is your final scoring for the Honda. A final score for the Mustang. A final score for the pickup. And a final score for the Focus. Even though you started off with very different objectives that were measured on very different scales. And so now things have been standardized. And now you can show and report on this particular analysis. And you would choose based on the final scoring. In this case, the Honda would be your first choice, but the Focus is a close second.

Some people like to look at these results graphically, and so let's go ahead and make a quick

chart of these results. Select cells M4 through M7, then go up to your ribbon and choose the Insert tab. And we're going to insert a Column graph and choose the 2D Column option. And here we have the results of our particular analysis.

We need to work on what's on the bottom here and make these our options that are labeled clearly. And so now that our graph is selected and the design tab is already selected, let's just go to Select Data. And then in the dialogue box, under Horizontal Axis Labels, we want to edit those. We don't want them to be 1, 2, 3 and 4. Instead, we want to find the set of cells that labels our actual alternatives. And so just use your mouse and highlight cells A4 to A7 and press OK, and OK again. Now we see that those are labeled clearly on the bottom.

We're not finished yet, because we need to label our axis, and so choose the chart again and choose the Layout tab. And let's go ahead and label our Axes Titles. For the horizontal axis, we have 'Alternative'. And then for the vertical axis, we have the 'Final Score'. Now I don't really need this series marker here in the legend, so we can delete that.

And there is a graphic representation of our results.

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