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**BUS 443 Business Analytics**

**Monte Carlo Risk Simulation using Analytic Solver Platform (ASP)**

**Case Description: The Advertising Budget Model**

A product-marketing manager needs to prepare recommendations to the Executive Committee as to how advertising expenditures should be allocated. Last year’s advertising budget of $40,000 was spent in equal increments over the four quarters. Initial expectations are that we will repeat this plan in the coming year. However, the committee would like to know whether some other allocation would be advantageous and whether the total budget should be changed.

Our product sells for $40 and costs us $25 to produce. Sales in the past have been seasonal, and our consultants have estimated seasonal adjustment factors for unit sales as follows:

Q1: 90% Q2: 110% Q3: 80% Q4: 120%

A seasonal adjustment factor measures the percentage of average quarterly demand experienced in a given quarter. In addition to production costs, we must take into account the cost of the sales force (projected to be $34,000 over the year), allocated as follows:

Q1 and Q2, $8000 each;

Q3 and Q4, $9000 each;

the cost of advertising itself; and

the overhead, typically around 15% of revenues.

Quarterly unit sales seem to run around 4,000 units when advertising is around $10,000. Clearly, advertising will increase sales, but there are limits to its impact. Our consultants several years ago estimated the relationship between advertising and sales. Converting that relationship to current conditions gives the following formula:

Unit sales = 35 x seasonal factor x

**Instructions:**

1. Open the Advertising Budget spreadsheet on Moodle and click the **Base** tab.
2. **Base-Case Analysis.** In the Advertising Budget example, most of the input parameters such as price and costs are forecast for the coming year. What values should we assume for the decision variables in the base case? A natural choice is to take last year’s advertising expenditures ($10,000 each quarter) as the base-case decisions, both because this is a simple plan and because initial indications point to a repeat for this year’s decisions.
3. **Simple What-if Analysis**. Perform simple What-if Analysis by varying a parameter. Vary the cost parameter from $25 to $26.
4. If unit cost rises to $26 from $25, then annual profit drops from $69,662 to $\_\_\_\_\_\_\_\_\_. In other words, an increase of 4% in the unit cost will reduce profit by nearly 23%. Thus, it would appear that profits are quite sensitive to unit cost, and in light of this insight, we may decide to monitor the market conditions that influence the material and labor components of cost.
5. The nonlinear relationship between advertising and sales plays a fundamental role. We can ask how different our results would be if we were to replace this this relationship with a linear one. For example, the linear relationship: Sales = 3000 + 0.1 (Advertising x Seasonal Factor) lies close to the nonlinear curve for advertising levels around $10,000.
6. We may have assumed that our competitors will not change their prices in the coming year. If we then determine that our own prices should increase substantially over that time, we might ask how our results would change if our competitors were to react by matching our price increases. This is an example of varying one input at a time.
7. What would be the result of doubling the selling price? Would profits double as well? They more than double, telling us that this sensitivity test shows that nature of the cost structure. It is not proportional. There is one possible limitation of the model – that there is no link between demand and price.
8. **What-If Analysis using Scenarios.** Use Scenario Manger on this spreadsheet. Each scenario tells a coherent story that has meaning to the decision makers and is implemented in the model through a set of two or more parameters. Select Data, What-if Analysis, Scenario Manager and view the following two scenarios.
   1. An ***optimistic*** scenario in which prices are high ($50) and costs are low ($20), yielding a profit of $285,155.
   2. A ***pessimistic*** scenario in which prices are low ($35) and costs are high ($30), leading to a loss of $77,991.
9. **What-If Analysis using Parametric Sensitivity.**
   1. Perform Parametric Sensitivity on the spreadsheet to analyze the sensitivity of an output to one input. Using a low value of 20 and an upper value of 30 for cost, we will see the effect on profit.
   2. Perform Parametric Sensitivity on the spreadsheet to analyze the sensitivity of an output to two inputs. We will build a table showing how profits are affected by both Q1 advertising and Q2 advertising. We now analyze the results. We can benefit more by spending more advertising dollars in Q2 than in Q1. This pattern tells us that we can gain more from spending additional dollars in Q2 than from the same additional dollars in Q1. We could improve profits by shifting dollars from Q1 to Q2. We also note from the table that the relationship between profits and advertising expenditures is not linear. Rather, profits show diminishing returns.
10. **Analysis using Tornado Charts.** Create a tornado chart for this model to see how sensitive an output is to *all* inputs. Tornado charts are an extremely useful tool for determining quickly which parameters are most important in a model. It calculates the change in the output caused by a change in every input that influences the output.
11. Click on the Profit Cell and choose Parameters/Identify.
12. We now analyze the tornado chart. The horizontal axis at the top of the chart shows profits and the bars in the chart show the changes in profit results from ±10% changes in each input.
13. After calculating the values, the bars are sorted from largest to smallest for display in the diagram.
14. The largest span (the most sensitive inputs) appear at the top; the smallest on the bottom. In this example, we can see that the price cell has the biggest impact (a range of more than $108,000) with unit cost next in its impact on profit.
15. **Simulation Analysis using the Monte Carlo Risk Method.** Whereas sensitivity analysis is a necessary first step, and can often reveal unexpected relationships in the model, **a simulation analysis is required to analyze the combined effects of changes in many inputs**. The goal is to uncover those input parameters that have the biggest impact on the outcomes and the likely range of uncertainly for each parameter. Monte Carlo simulation is an important and flexible tool for modeling situations in which uncertainty is a key factor.
    1. Earlier we assumed that price would be $40 and cost $25, assuming that these and other input parameters are accurate forecasts of next year’s values. Now, let’s consider the more realistic case in which next year’s price and cost are both subject to considerable uncertainty. Assume that the most likely value of the price is $45, but it could turn out to be as low as $30 or as high as $50. Similarly, the most likely value for cost is $20, but it could be as low as $10 or as high as $35. Given this uncertainty in the price and cost, we naturally want to know the implications for annual profit.

Let’s perform Monte Carlo Risk Simulation on the spreadsheet to analyze the result of changing many parameters on a model and viewing the effect on profit and the probability of these events happening.

* 1. Let’s use a **triangular** probability distribution of price ranging from $30 to $50, with $45 being the most likely. This distribution reflects the assumption that not all values between $30-$50 are equally likely, but that in fact, high values are somewhat more likely than low values. We can also do the same for cost, showing a **triangular** distribution in which low values are somewhat more likely than high ones.

Our simulation will perform the following steps:

* + - 1. Start with a base-case model and determine which of the input parameters to represent as uncertain.
      2. Develop probability distributions for those inputs.
      3. Take random samples from those inputs and calculate the resulting output, repeating the process until a clear picture of the output distribution emerges.
      4. Create a histogram of the outcomes and interpret it.

Having chosen probability distributions for the two uncertain input parameters, it is a relatively simple process to determine the probability distribution for that profit. We draw random samples from the distributions of the inputs and for each pair of sample values for price and cost, then calculate the resulting profit. One such pair shows at the top of the spreadsheet, but of course, one pair is not very useful by itself. The only way to develop a realistic picture of the range of possible outcomes and their likelihoods is to repeat this process many times. ASP does this 1000 times for us. The histogram tells us:

* The mean, or expected value, is $147,144. This is the simple average of all 1000 outcomes.
* The likelihood of making a profit can also be determined by calculating the percentage of positive outcomes among the 1000 repetitions. In 91.2% of the cases, the profit exceeds zero.