: How does sensitivity analysis differ from "What if?" analysis?

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In the early days of decision support deployment, one of the major "selling points" of vendors and academics was the ability to do "What If?" analysis. In the 1970s, model-driven decision support for sales and production planning helped a manager change a decision variable like the number of units to produce and then immediately get a new result for an outcome variable like profit. As decision support has gotten more sophisticated and become more diverse in its use, "What If?" as a concept has broadened. The decision support community has also introduced more precise terminology from the mathematical modeling literature.

In most decision support and analytic applications, sensitivity and "What If?" analysis refer to quantitative analyses. In some of the decision making and planning literature, "What if analysis" is also discussed as a qualitative, brainstorming scenario approach that "uses broad, loosely structured questioning to investigate contingencies." In the context of business intelligence and data-driven decision support, "What If?" is often used as a descriptor for ad hoc queries of a decision support data base.

According to a vendor website, Applix.com, planners use models to address "What If" questions such as: 1) What profits can we anticipate next year if inflation is 7 percent and we continue current pricing policies? 2) If we open a new plant, what profits can we expect? 3) What if we were to hire 55 people in Sales, 10 in Marketing and 35 in R&D? 4) What is the impact on manufacturing and shipping if the price of oil increases 15% during Q2? and 5) What would be needed for raw material and inventory if the demand of a product went up 20%?

In the decision support literature and in common discourse, we don't have agreement about the difference between "What If?" analysis and sensitivity analysis. Microsoft Excel documentation defines "What-if analysis" as a "process of changing the values in cells to see how those changes affect the outcome of formulas on the worksheet. For example, varying the interest rate that is used in an amortization table to determine the amount of the payments." Four tools in Excel are commonly categorized as "What If?"

or sensitivity analysis (Winston, 2004) tools: Data Tables, Goal Seek, Scenarios, and Solver. The simplest type of "What If?" analysis is manually changing a value in a cell that is used in a formula to see the result. Excel experts seem to use the terms sensitivity and "What If?" analysis interchangeably.

To get a better understanding of what is possible, let's briefly examine how one would implement "What If?" or sensitivity analysis using MS Excel tools. First, a data table is a range of cells that summarizes the results of changing certain values in formulas in a model. There are two types of data tables: one input variable tables and two input variable tables. "Two-variable data tables use only one formula with two lists of input values. The formula must refer to two different input cells." In Microsoft's Mortgage Loan Analysis example, a two-variable data table would show how different interest rates and loan terms would affect the mortgage payment amount. The table shows the decision maker how sensitive the payment amount is to the interest rate. The Goal Seek tool is helpful when you know the desired result from a model and want to find the appropriate input or decision variable levels. "What If?" involves incrementally changing an input until the goal is reached. Goal Seek automates this trial and error process. Scenarios let an Excel user construct strategies where multiple decision variables are changed in each scenario. For example, a decision maker may have best case, most likely, and worst case scenarios. Finally, Solver is an optimization tool that includes a sensitivity analysis capability. Monte Carlo simulation in Excel can also be used to assist in "What If?" or sensitivity analysis. Spreadsheets models with probability distributions for inputs can simulate outcomes for a range of input parameters.

According to Parnell (1997), "a decision variable is a variable over which the decision maker has control and wishes to select a level, whereas a strategy refers to a set of values for all the decision variables of a model. An optimal strategy is the strategy which maximises the value of the decision maker's objective function (e.g. profit, social welfare, expected utility)." In general, mathematical methods assess the sensitivity of a model's output to the range of variation of one or more inputs. Sensitivity analysis is used to determine what inputs, parameters or decision variables contribute more to the variance in the output of a model and hence are the most important and most "sensitive".

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Let's check some definitions from Web sites. Wikipedia (wikipedia.org) notes "What-if analysis of a model considers the question: 'What happens to the result if we make a particular change to a parameter?'. If the change of a parameter is small this is also called sensitivity analysis: 'How sensitive is the result to a small change of a parameter?' Wikipedia also defines sensitivity analysis as "the study of how the variation in the output of a model (numerical or otherwise) can be apportioned, qualitatively or quantitatively, to different sources of variation." Wikipedia shows the differing usage of these terms across various disciplines. The sensitivity analysis entry notes that in a business context "sensitivity analysis can provide information to managers about which elements of the business require more concentration. For example if sales, variable costs, fixed costs or output were to increase or decrease by 10% which would have the most effect on profit?"

The Web Dictionary of Cybernetics and Systems defines sensitivity analysis as "a procedure to determine the sensitivity of the outcomes of an alternative to changes in its parameters (as opposed to changes in the environment; see contingency analysis, a fortiori analysis). If a small change in a parameter results in relatively large changes in the outcomes, the outcomes are said to be sensitive to that parameter. This may mean that the parameter has to be determined very accurately or that the alternative has to be redesigned for low sensitivity. (IIASA)"

Finally, the Michigan Department of Environmental Quality (www.michigan.gov) defines a sensitivity analysis as "the process of varying model input parameters over a reasonable range (range of uncertainty in values of model parameters) and observing the relative change in model response."

Parnell (1997) identifies uses of sensitivity analysis in decision making, communication, understanding systems and in model development. Based on his discussion, a model-driven DSS with appropriate sensitivity analysis should help in 1) testing the robustness of an optimal solution, 2) identifying critical values, thresholds or break-even values where the optimal strategy changes, 3) identifying sensitive or important variables, 4) investigating sub-optimal solutions, 5) developing flexible recommendations which depend on circumstances, 6) comparing the values of simple and complex decision strategies, and 7) assessing the "riskiness" of a strategy or scenario.

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The most common "What If?" analysis in model-driven DSS is changing an input value in an ad hoc way and seeing the result. This type of analysis has severe limitations. The analysis is likely to be more complete if an input object like a spinner or a slider is used to change values. Such an approach is much faster and easier than typing in individually new input values. A range sensitivity analysis evaluates the effect on outputs by systematically varying one of the model inputs across its entire range of plausible values. According to Frey and Patil "results of nominal range sensitivity are most valid when applied to a linear model."

What are the limitations of "What If?" analysis? If the analysis is ad hoc rather than systematic, the analysis is likely to miss potential problems and solutions. Managers may not understand the assumptions of the sensitivity analysis, e.g. assuming a linear relationship. Also, in general it is impossible to audit the thoroughness of sensitivity and "What If?" analyses and their impact on decision making. My general sense is that systematic sensitivity analysis using a one or two-variable data table should be required in all model-driven DSS based upon algebraic models. Relying on an ad hoc manipulation of single variables in a quantitative model is always problematic and limited.

So "What If?" analysis is used broadly for techniques that help decision makers assess the consequences of changes in models and situations. Sensitivity analysis is a more specific and technical term generally used for assessing the systematic results from changing input variables across a reasonable range in a model. The current frontier is animated sensitivity analysis where a visual display like a chart or graph is sytematically varied showing results of changing model parameters. Check the Planners Lab review (Power, 2006).

As always your comments and questions are welcome.

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