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Scenario Planning, Simulation, Sensitivity Analysis and Innovation

Both founders (entrepreneurs or intrapreneurs) and investors (friends, angels, venture capitalists, public markets or a firm's senior management) need to believe that a reasonable case can be made for embarking on any innovative project.

This case is often made using a PowerPoint pitch deck and/or a business (strategic) plan. No matter whether the plan comprises just a few slides, pages, diagrams or even napkins, or a lengthy and detailed document, it almost always includes a financial projection to demonstrate the expected returns. This projection is based on what are assumed to be reasonable costs and timeframes as well as a forecast of strong sales and profits. There is nothing wrong with such a base case or target projection as a first cut. However, it is much more valuable to go a step further and include an analysis of the likelihood of achieving this target as well as the range of results that fall on either side of this projection. Simulation, sensitivity analysis and scenario planning are related tools that can shed light on the probabilities of success and more importantly suggest ways to make the plan more robust.

A six-step methodology for carrying out simulations, sensitivity analysis or scenario planning effort will be outlined, along with an example and some discussion of the ways in which they can be employed.

DEFINITIONS:

Innovation is "the process of translating an idea or invention into a good or service that creates value or for which customers will pay."[1] Innovation involves risk.

Risk is "an uncertain event or condition that, if it occurs, has an effect on at least one project objective" or "the probability of something happening multiplied by the resulting cost or benefit if it does."[2] Hence innovating is undertaken in the face of many uncertainties.

Uncertainty involves a "situation where the current state of knowledge is such that (1) the order or nature of things is unknown, (2) the consequences, extent, or magnitude of circumstances, conditions, or events is unpredictable, and (3) credible probabilities to possible outcomes cannot be *(are difficult to be?)* assigned."[3] "What-if" analysis in the form of simulations, sensitivity analyses and scenarios can be employed to raise awareness of and effectively manage the uncertainties.

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Monte Carlo simulation is used to "model the probability of different outcomes in a process that cannot easily be predicted due to the intervention of random variables. It is a technique used to understand the impact of risk and uncertainty in prediction and forecasting models."[4] It involves computing a large number of "what-if" scenarios by sampling from probability distributions for each input variable and results in a range and probability distribution for the output variable. Identifying the range of uncertainties, the possible variations in the inputs, and the underlying assumptions of the models are critical to the analysis regardless of the detail required or desired. Small scale experiments, like focused market research, can be performed to refine or validate/ invalidate assumptions and reduce the model variance.

Sensitivity analysis is "the study of how the uncertainty in the output of a mathematical model or system (numerical or otherwise) can be apportioned to different sources of uncertainty in its inputs."[5] As a compilation of "what-if" models, it can be performed to various levels of detail from the "back-of-the-envelope" to sophisticated statistically-based computer models. Again, experiments and research can be undertaken to reduce the level of uncertainty in the input variables. The potential value of the refined information can also be estimated and compared to the cost of the experiments or research.

Experimentation is a "research method for testing different assumptions (hypotheses) by trial and error under conditions constructed and controlled by the researcher. During the experiment, one or more conditions (called independent variables) are allowed to change in an organized manner and the effects of these changes on associated conditions (called dependent variables) is measured, recorded, validated, and analyzed for arriving at a conclusion."[6]

Scenario planning is the "process of visualizing (1) what future conditions or events are probable, (2) what their consequences or effects would be like, and (3) how to respond to, or benefit from, them."[7] It usually involves performing a simulation and sensitivity analyses on a number, usually 3-5 different and comprehensive scenarios. Scenario planning and/or sensitivity analysis should drive contingency planning as these techniques assist in the prioritization of the risks and uncertainties.

Contingency planning results in "a plan devised for an outcome other than in the usual (expected) plan. It is often used for risk management when an exceptional risk that, though unlikely, would have catastrophic consequences."[8] It is "undertaken to ensure that proper and immediate follow-up steps will be taken by management and employees in an emergency. Its major objectives are to ensure (1) containment of damage or injury to, or loss of, personnel and property, and (2) continuity of the key operations of the organization."[9] These plans may include proactive components, like ongoing monitoring of competitive R&D efforts. They also include reactive components, like reallocating resources or in-licensing a technology, based on pre-established triggers or early warning systems, like a regulatory change, a court ruling, a price change or an R&D success.

Business Models "describe the rationales of how organizations (do or could) create, deliver, and capture value, in economic, social, cultural or other contexts. The process of business-model construction forms a part of business strategy."[10] "To put together a good business model, you need to know the value proposition for the business. A value proposition is a straightforward statement of what a company offers in the form of goods or services that is of value to potential customers or clients, ideally in a way that differentiates the company from its competitors."[11] The model(s) "should also include projected startup costs and sources of financing, the target customer base for the business, marketing strategy, competition, and projections of revenues and expenses."[12] These factors can all be the subject of scenario planning and/or sensitivity analysis and inform the strategic planning process.

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Strategic Planning involves "a systematic process of envisioning a desired future, and translating this vision into broadly defined goals or objectives and a sequence of steps to achieve them."[13] It also involves "defining a strategy, or direction, and making decisions on allocating resources to pursue this strategy."[14]

A SIX-STEP METHODOLOGY:

1) **Question-resulting decisions**
Defining the key question that is to be answered is the first step in any scenario planning, simulation or sensitivity analysis exercise. A related and frequently neglected component involves additionally defining the decision outcomes that will be made as a result. Often the question is, "What is the (risk-adjusted) expected return on investment (ROI)?" The resulting decision outcome is a binary invest or don't invest based on this calculated ROI. Having a clear question and a decision tree of pre-determined outcomes adds clarity to the process and removes bias.

However, there are numerous other quantitative and more qualitative questions that can be explored with scenario planning, simulation and sensitivity analysis: Is this the optimum portfolio of projects? How should the limited resources (human and financial capital) be allocated to our portfolio of projects? What is the probability of success of this project? Within what time period will the competitor's product launch? What pricing can be expected? What range of market penetration can be expected for the product/service? What could be the extent (and impact) of the new regulations? Should we merge/acquire company X? How does the price of raw materials, commodities or feedstocks (oil/electricity/gasoline/chemicals/metals) affect the plans/ROI? What is the cost of a 6 month delay? What are the financial and competitive upsides of getting to market 6 months early?

For more qualitative questions, different scenarios should be prepared and efforts need to be made to quantify the effects so that ultimately "apples and oranges" can be compared numerically. Again, where possible establishing go/no go criteria or a range of acceptable outcomes (i.e. ROI >15% for each project) in advance of the analysis instills discipline.

2) **Scenario, simulation or sensitivity?**
The scope of the question and the associated decision outcomes determines whether multiple scenarios should be investigated. Scenario planning is appropriate for big issues that have substantially different, frequently qualitative cases (binary to polyvalent) each requiring an independent and thorough analysis. Simulations and sensitivity analyses are best suited to a given scenario where the uncertainties lie primarily in a reasonable range of values for the inputs or there is reason to believe that a few of the inputs are major drivers of the outcomes.

For an oil company, airline or chemical company, a question like, "What if the price of oil goes to less than $40, remains at current levels, or goes to over $100?" might be better analyzed as separate scenarios than a single simulation or sensitivity analysis. Using a range of gasoline prices from $1-$3 would be more appropriate for a Walmart profit model for which trucking costs are important but not likely the key driver of the ROI. Similarly, for many firms, "What is the impact to our strategy if Amazon, Google, Apple or Tesla enters our market?" (Think food delivery, autonomous cars, solar power, artificial intelligence etc.) represent important scenarios to consider.

Porter's 5 forces model and STEEPLED (PEST) analysis are useful tools to help reveal and develop scenarios.[15,16] Scenario planning can also be undertaken after a simulation or sensitivity analysis reveals that the range or options for a particular input variable or the output variable are so significant that the question warrants such a polyvalent analysis.

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Scenarios are also useful for modelling time (delays) when incorporated with other financial information as these models get complex quickly. Establishing three scenarios: optimistic or best case, expected or base case, and pessimistic or worst case schedules with the related financials and then performing simulations and sensitivity analyses simplifies the process immensely.

3) The Team

Assembling a team to undertake a scenario planning, simulation or sensitivity analysis effort is advisable as the next step. Given the complexity of these analyses, a team broadens the perspectives resulting in more robust models which in turn leads to better insights. At the least, having a diverse group review the model(s) and insights, leveraging their comments to make refinements as necessary.

Scenario planning that involves competitors is often done in a formal business wargaming setting often with supporting software.[17] Participants are divided into groups, each representing a different company so that each firms' strategic and tactical moves and countermoves can be envisioned and evaluated.

In other forums Delphi method research, various brainstorming techniques, discussions and debates are employed to develop rich information with which to build the models and help broaden everyones understanding of the environment.[18,19]

4) Models

Similar to the financial projection found in even the simplest of business plan, most common models are built on a series of assumptions about input variables (like product pricing and market penetration) and produce a financial outcome (i.e. revenue, profit, ROI or Net present value (NPV)). [For simplicity, the example presented only considers revenues]

Typically, the forecast sales revenues are calculated from the number of units sold over a time period multiplied by the price per unit. The costs are calculated by adding the fixed costs of manufacturing to the variable cost per unit multiplied by the number of units. Profits equal sales minus costs. Extending this model over a number of time periods and including start-up costs permits the calculation of cashflows and the return on investment (ROI). Including the cost of capital (i.e. the interest due on borrowed funds) and adjustments for the risk of the project, permits the calculation of a key go-no go value termed the Net Present Value (NPV).[20] Further enhancements include breaking down each of these input components into more detail. For example, the units sold can be calculated by multiplying the number of potential customers by the market penetration. These two inputs in turn can be estimated from data on previous purchasing behaviours and current competitive offerings respectively.

The best way to manage more qualitative data such as the effect of competition on price and market share is to build representative quantitative models. For example, the price and market share could be forecast to decline by a fixed percentages per year as more competitors enter the market.

As the models, frequently built in a spreadsheet, incorporate finer details as well as more inputs and assumptions, it is important to analyze all the variables (the so-called multidimensional input space) in terms of their dependent (causality), interdependent (correlation), independent, additive, and synergistic (multiplicative) relation to one another. It is important to track all the assumptions as well as to test the models to ensure they are functioning as expected and are not missing important factors. Sensitivity analyses can assist with these processes.

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AN EXAMPLE: THE SET UP

Question: Should we install Economy or First class suite seating in our airplane to maximize revenues?
Decision: Select the one generating the higher revenues and lower risk (tighter range of outputs)
Scenarios: Economy seating and First class seating.
Assumptions: a) The number of seats in a given area based on existing data.
b) Base case prices for Economy and First class flights (Montreal -> Paris).
c) The long-haul airline occupancy rate (load factor).
d) Three estimated (pessimistic, optimistic and base/expected) prices and,
e) Three estimated percentage occupancies.
Model: Pricing * % Occupancy * # of seats (fixed) = Revenues
Base revenue for Economy and First class are $1,000/seat * 80% occupancy * 100 seats = $80,000 and $5,000/seat * 70% occupancy * 20 seats = $70,000 respectively.
Simulations: Employ continuous triangular functions based on the discrete three-point estimates.

AIRLINE SEATING						
* Two variables: pricing and number of seats						
Assumptions based on research in yellow						
Estimates in orange						
Airbus 380 (800)	Seat width "	Seat pitch"	Seat area "^2	Area "^2	# of seats	Ratio
Economy	32	17.5	560	56,000	100	5.0
First classs suite	81	35	2835		20	
Sources: https://www.seatguru.com/charts/longhaul_first_class.php for seat sizes						
http://rottenraw.com/emirates-airbus-a380-business-class-seating-plan/a380-airline-world-lufthansa-airbus-sit-cmerge-emirates-business-class-seating-plan-in-pictures-singapore-airlines-new-premium-economy-routes-sq/ for seating area						
https://www.airfrance.ca Montreal -> Paris one way Economy and Premiere						
https://www.statista.com/statistics/407650/air-france-klm-passenger-load-factor/ and http://www.aviation24.be/airlines/air-france-klm-group/july-2017-passenger-figures-higher-load-factor/ for occupancy rates						
Scenario 1: Economy Seats						
	Pricing ($ and swing)		Occupancy (%, #, swing)			BASE REVENUE
Pessimistic	$800	-20%	70%	70	-13%	
Base case	$1,000	-	80%	80	-	$80,000
Opptimistic	$1,100	10%	100%	100	25%	
Triangular fcn	$ 950			79		$75,250
Triang P=900	$ 1,090					$86,326
Scenario 2: First class suite						
	Pricing ($ and swing)		Occupancy (%, #, swing)			BASE REVENUE
Pessimistic	$4,000	-20%	50%	10	-29%	
Base case	$5,000	-	70%	14	-	$70,000
Opptimistic	$8,000	60%	100%	20	43%	
Triangular fcn	$ 6,449			14		$88,988

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5) Inputs and outputs

Sensitivity analysis and simulation takes this modelling one step further by assigning a range of values to some of the input variable as opposed to one “best guess.” The possible ranges or distributions of the key variables need to be estimated by the team. Start with 3 or 4 variables that appear key and add more as required. Also, start with conservative ranges to get a feel for how the model responds and expand them as necessary.

In the case of sensitivity analyses, the effects of various values of each input variable, including the optimistic, pessimistic and expected value, on the output is calculated. The resulting calculation can be done manually by rerunning a fixed model multiple times while altering one-factor-at-a-time (OFAT). Setting the price of a product or service successively at $10, $15 and $20 per unit and tracking profitability is an example. With computer assistance, two-factor and higher order analysis is possible. The standard output of a manual sensitivity analysis is a table, with columns represents each particular input variable (i.e. fixed cost, unit cost, unit price, market size, penetration) and the output variable (i.e profit). Each row contains a set of input variables and the resulting output. This data can be visualized a number of ways, with the most common being a data table, tornado diagram or (non-radar diagram) spider plot:[21]

Data Table: A two dimensional table with the range of one input variable on the x-axis (in a row) and a second input variable along the y-axis (in a column), with the respective output variables at the intersections. By creating a series of these tables, the effects of a third input variable (dimension) can also be displayed. (See Page 7)

Tornado diagram: A bar chart in which the range of values for the output variable is plotted as a bar for the range of each input variable. The bars in this chart are usually plotted horizontally in descending order of width such that the most sensitive input variable (the one that causes the greatest swing in the output variable) is plotted at the top. (See page 9).

Spider plot: A two dimensional scatter (XY) plot incorporating each input variable. The input values as a percentage of the base case (x-axis) are plotted against the resulting range of values for the output variable (y-axis). The length and slope of each line represents impact of that variable. (This is NOT the same as the multivariate radar chart that can also be used, but suffers from significant artificial structures.)[22] (See page 9).

Unlike a sensitivity analysis where the input variables are generally examined one-factor-at-a-time (OFAT) in relation to the base case, a simulation examines the combined and synergistic effects of all the input variables concurrently. The output of a simulation is a good estimate of the output variable (accuracy) and a feel for the range of possible values (precision) in the form of a probability distribution. A simple probability distribution can be generated manually applying a three-point estimation to one or two of the inputs.[23] Three-point estimates are frequently used in project management calculations as they are simple, easy to explain, approximate a normal distribution, and generally fit uncertainties well being a combination of the pessimistic, optimistic and expected values.[24] The optimistic and pessimistic values for an input variable are each assigned a 1/6 weighting, whereas the best case is assigned a 4/6 rating (i.e. 1x (16.7%) at $10 and $20, for every 4x (66.7%) at $15 for the above mentioned example). (See Page 8.)

More sophisticated models assign probability distribution functions to numerous input variables and employ repeated random sampling (Monte Carlo simulation) to examine a wide range of inputs and their interactions.[25] For these, in addition to fixed sets or three-point estimations, a uniform distribution ($10-$20), a triangular distribution (0% probability at $10 and $20, peaking at $15), a normal distribution, or other relevant distributions including skewed or long-tailed ones (Weibull, Gamma. Lognormal) can also be incorporated.[26,27,28] These models output one overall probability distribution that incorporates all of the input variables and the ranges that they can assume. (See Page 8).

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It is important not to make the model and especially the inputs too complex, as there is a risk of over analyzing (overfitting) the situation.[29] Three consequences of this are: unforeseen errors cropping in, results that cannot be interpreted, and ranges or probability distributions that are so wide as to be uninformative. Models should be made as complex as necessary, but not more so. The purpose of the model is to inform decision-making, not generate an exact (accurate and precise) output.[30]

Performing a simulation and a sensitivity analysis generates not only a good estimate of the output variable (accuracy) and a feel for the range of possible values (precision), but also information on the relative contribution of each variable to the range of values and the probability distribution.

THE EXAMPLE RESULTS:

The results of two scenarios (Economy and First class suite seating) and the associated simulations and sensitivity analyses are presented as data tables, discreet and continuous distributions, tornado diagrams and spider plots. These calculations where performed in Excel using the SimVoi and Sensit add-ins from TreePlan Software.[31]

Data Tables for the Two Scenarios			
(3 Prices * 3 Occupancies)			
Scenario 1: Economy Seats			
Price/Occup	70%	80%	100%
$800	$56,000	$64,000	$80,000
$1,000	$70,000	$80,000	$100,000
$1,100	$77,000	$88,000	$110,000
Scenario 2: First class suite			
Price/Occup	50%	70%	100%
$4,000	$40,000	$56,000	$80,000
$5,000	$50,000	$70,000	$100,000
$8,000	$80,000	$112,000	$160,000

In the discrete (three-point estimate) simulation, the mean revenue and range are more favourable for Economy seating. In the continuous simulation, the means are very close however the distribution is tighter and hence less risky for Economy seating. The decision should thus be made in favour of Economy seating.

From the sensitivity analyses (tornado diagrams and spider plots), both scenarios are sensitive to the seat pricing and seat occupancy rate. In absolute terms, the First class suite produced wider swings in the output revenues. This indicates that it would be beneficial to run an experiment or collect better data on the expected occupancy rates at different prices (price sensitivities).

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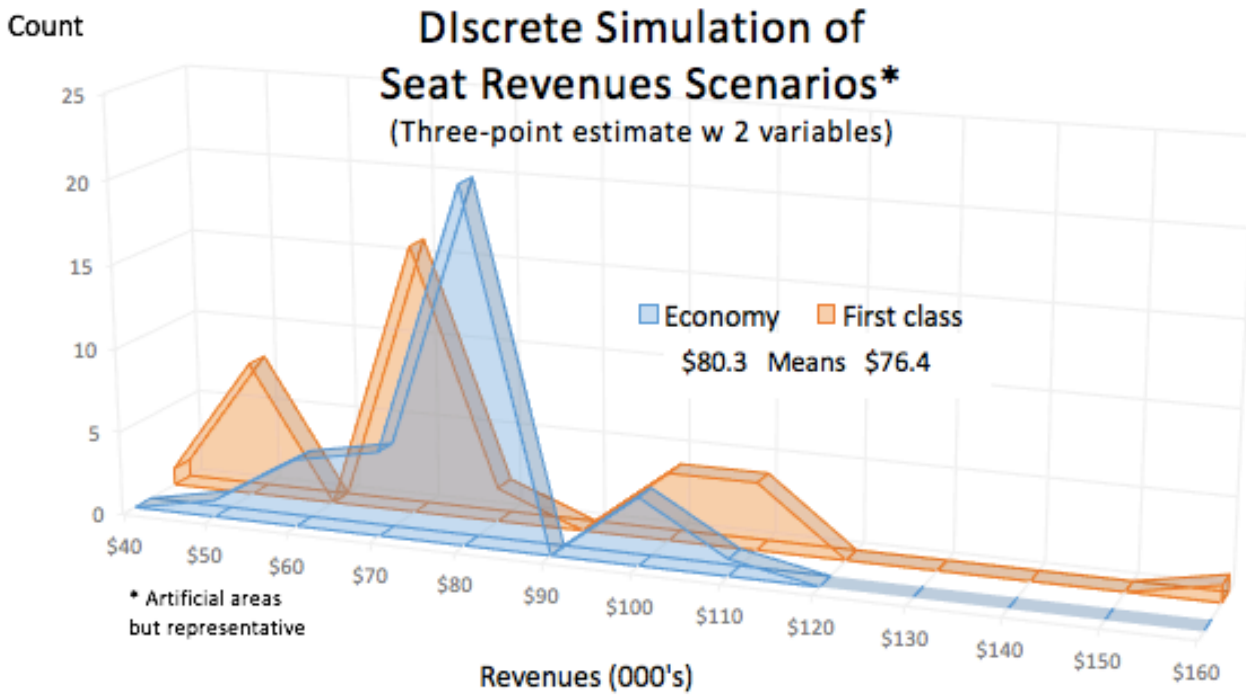

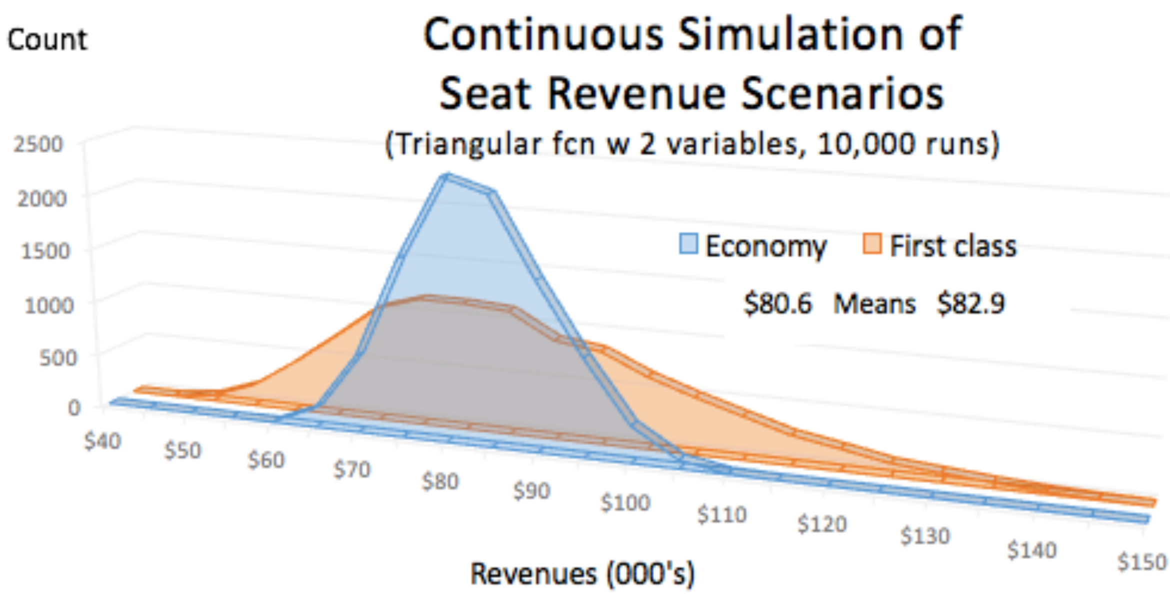

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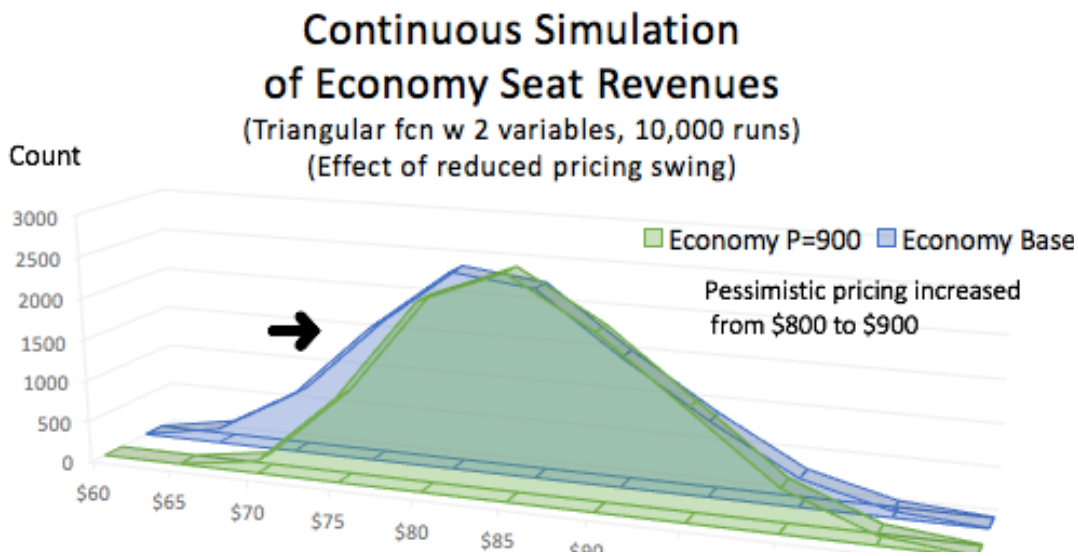
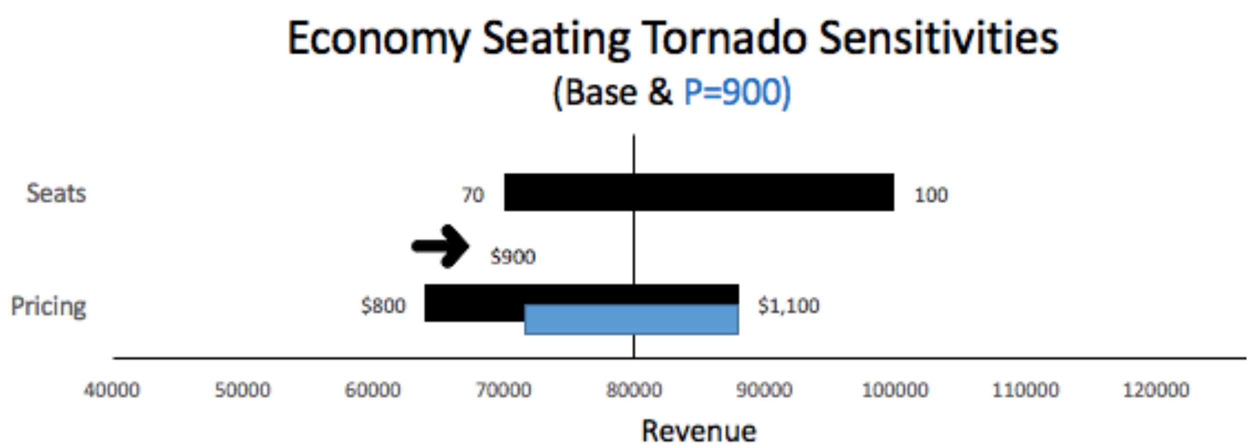
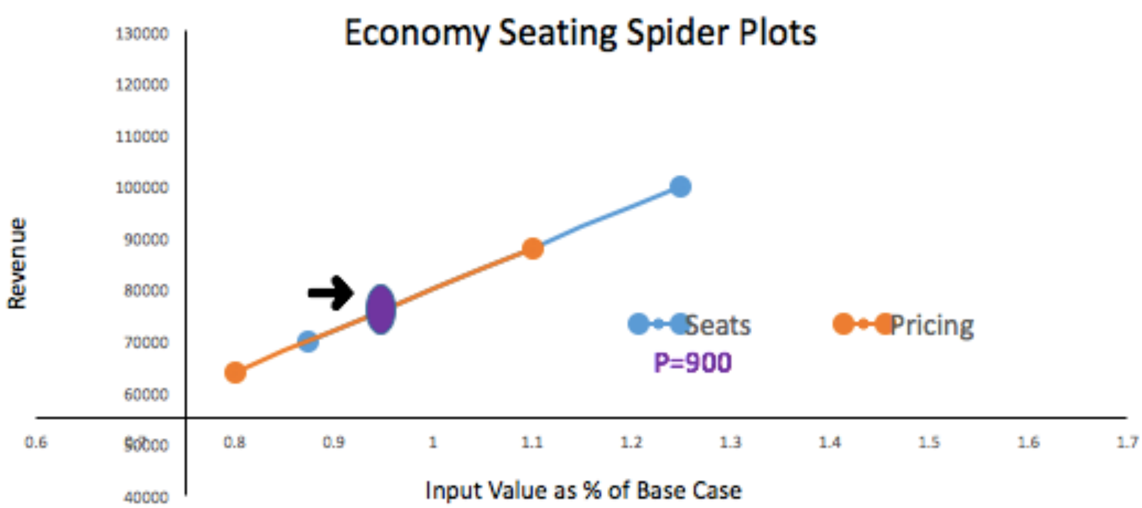
In addition to the calculated results, the effects on the simulation distribution, tornado diagram and spider plot of a later refinement in the range of the pessimistic Economy seat pricing from $800 to $900 is shown.







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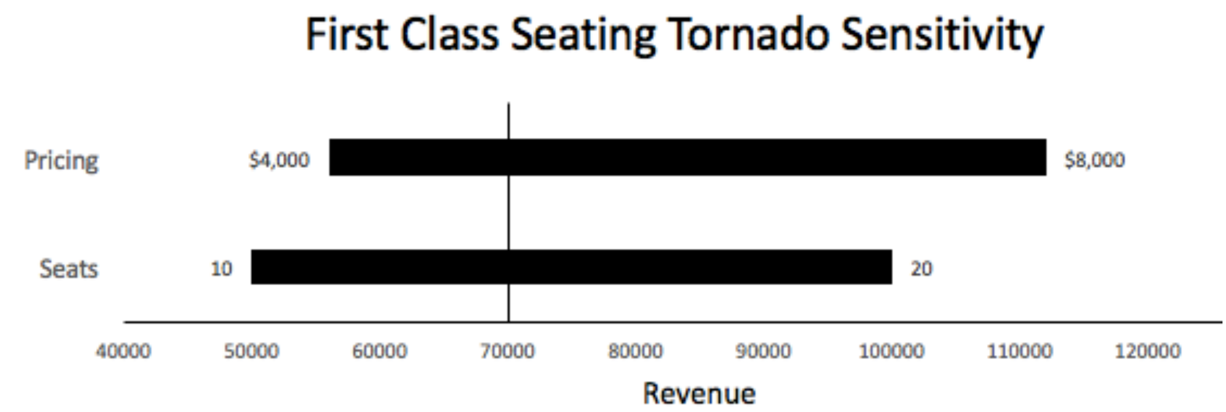

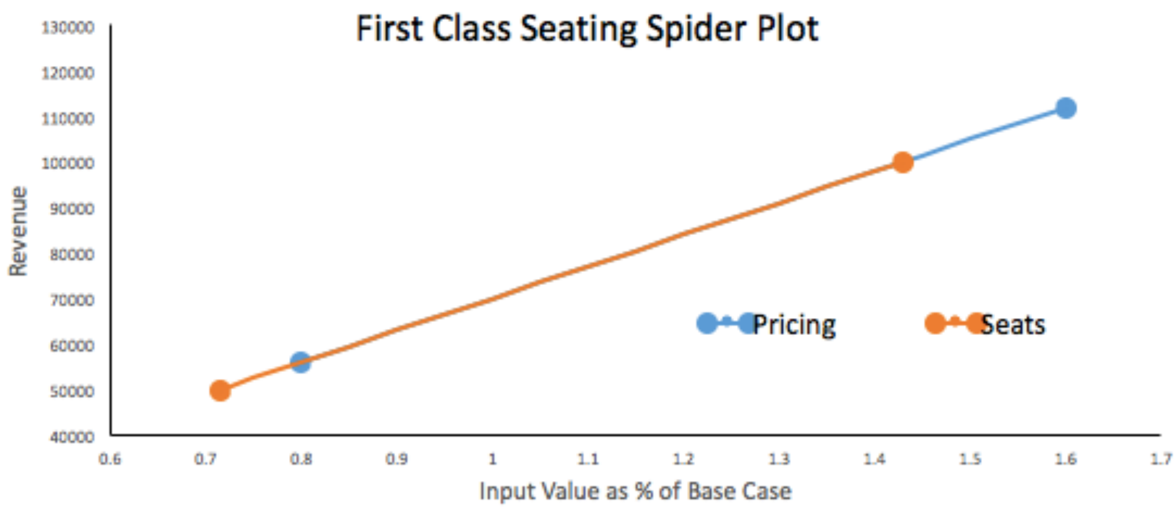

6) Analysis and action

The primary purpose of developing scenarios, simulations and sensitivity analyses is decision support and communication. In order to achieve this, a robust model or set of models need to be developed, that are clear and not overly complicated. In doing so, the assumptions and relations between the various components can be understood and actionable insights uncovered. Relatively complex sets of information are thus made digestible so that appropriate decisions can be made. Part of that process may involve allocating additional resources to improve the accuracy (correct) and precision (variance) of key input variables or test the relationships through primary and secondary market research.[32] In many cases, refinements may not be possible and only time and further development can serve to resolve some of the uncertainties.

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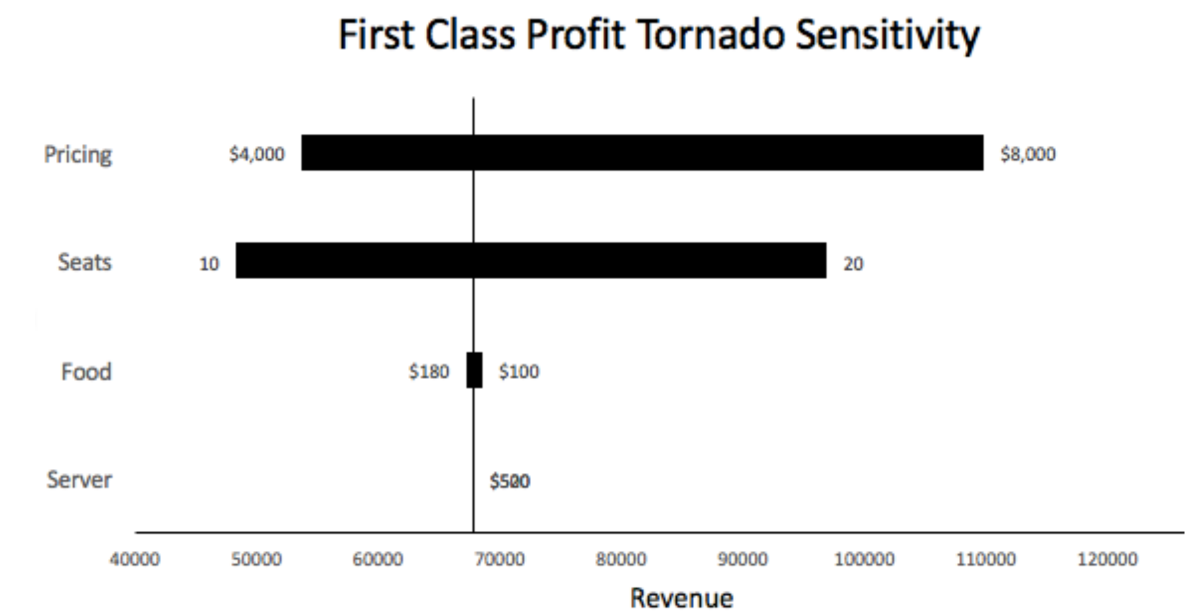
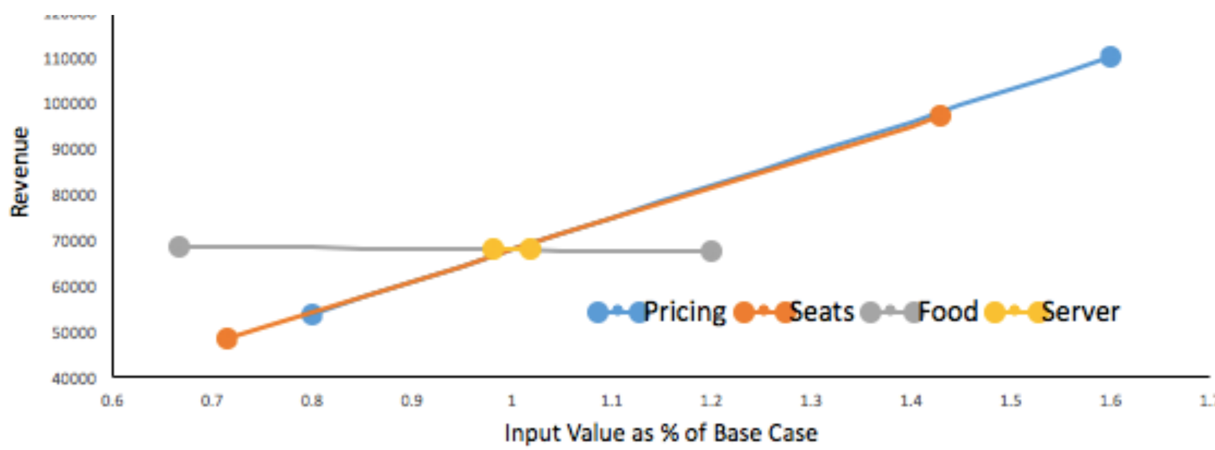
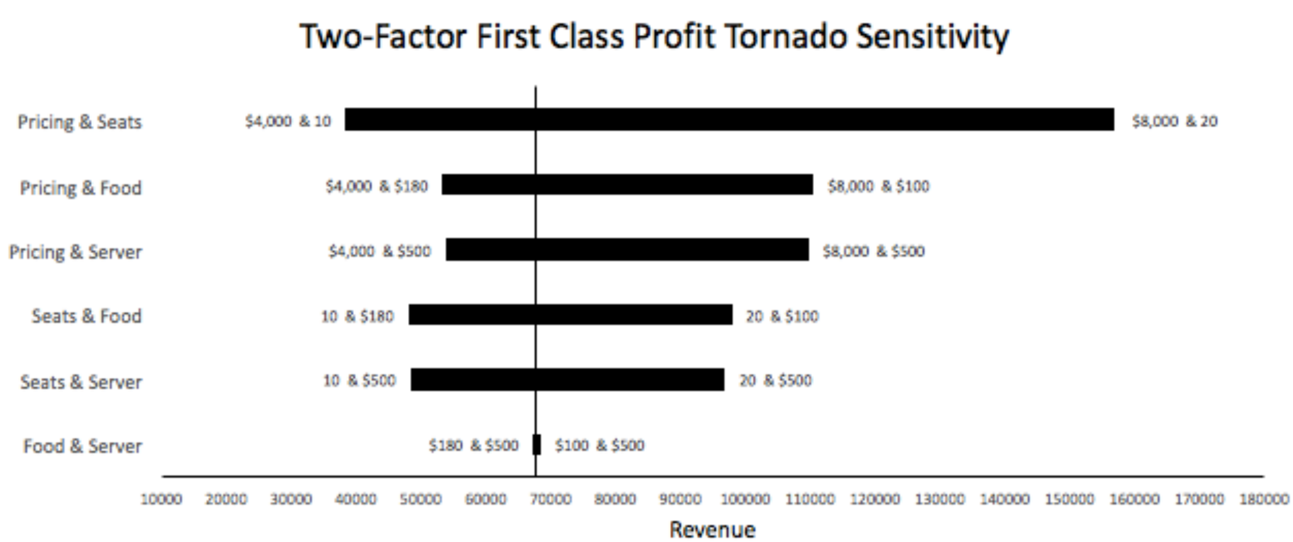
EXAMPLE 2 RESULTS:
Results of a more complex profit model: (Pricing - Food costs) * Seats - Server costs = Profit to illustrate more complex tornado diagrams and spider plots.







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[1] http://www.businessdictionary.com/definition/innovation.html

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[3] http://www.businessdictionary.com/definition/uncertainty.html

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