Sensitivity Analysis and Decision Quality

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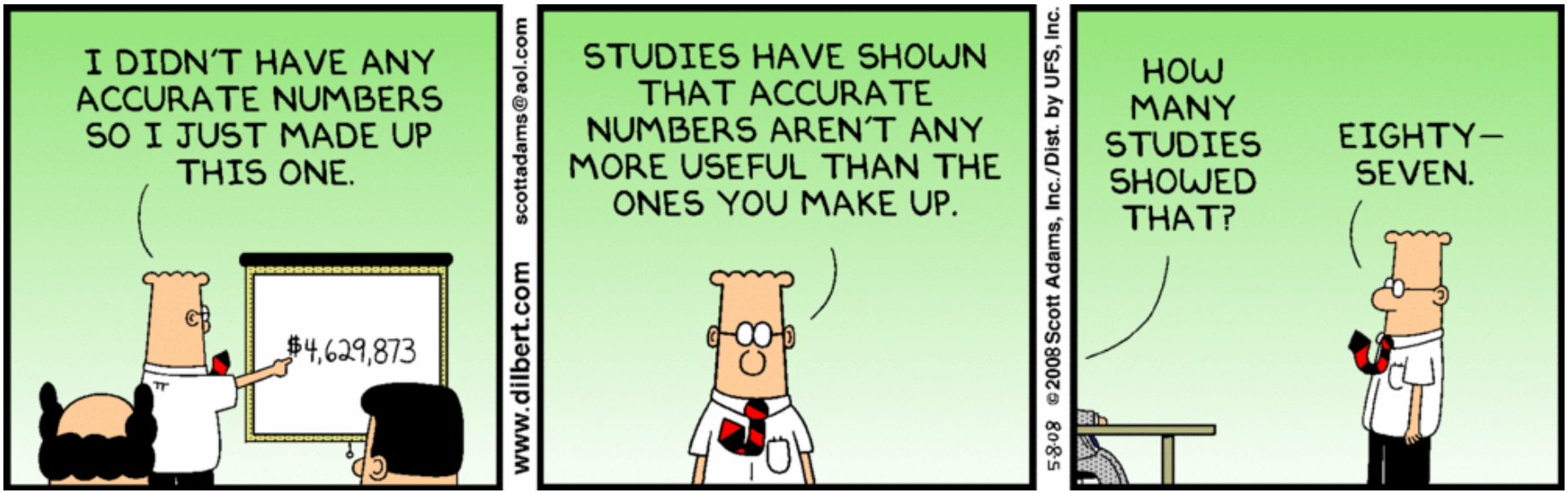
Overview

- Introduction
- Decision analysis cycle
- Decision quality
- Requisite decision modeling
- Sensitivity analysis

(Based on Robert T. Clemen, “Making Hard Decisions: An Introduction to Decision Analysis,” second edition, Chapter 5, Belmont: Duxbury Press, 1996)

The underlying idea

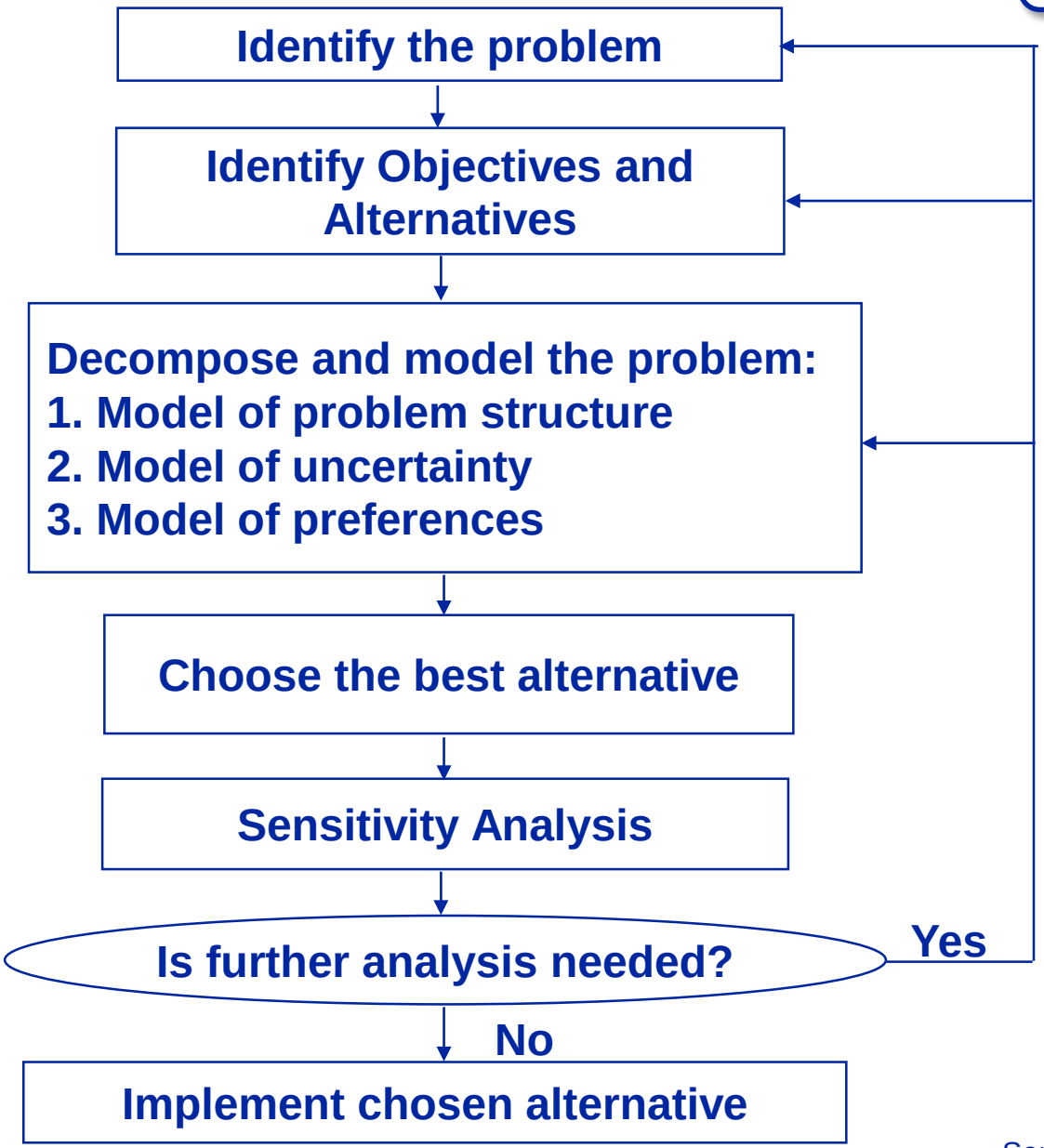


The underlying idea

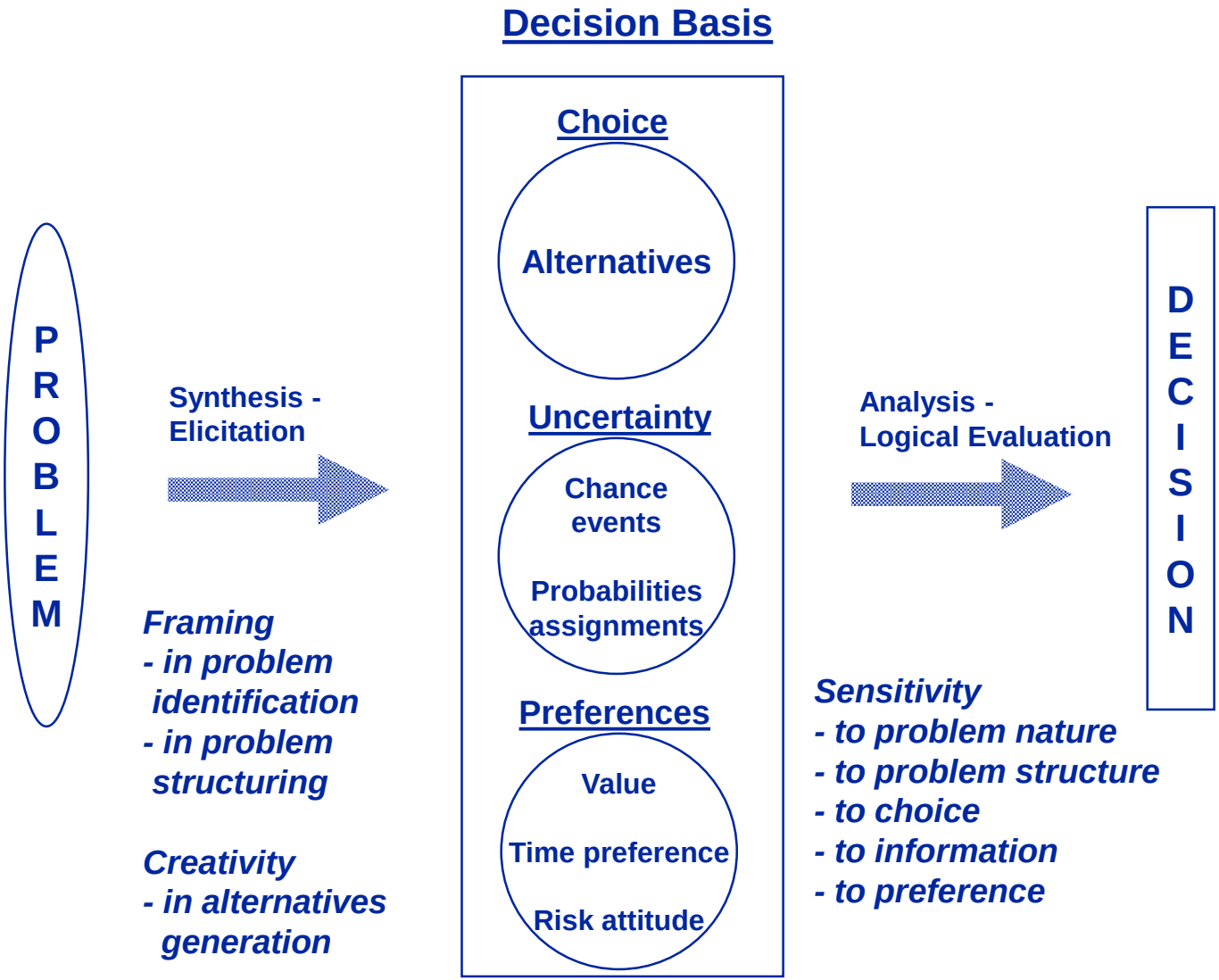
“One must be a god to be able to tell successes from failures without making a mistake.”

-- Anton Chekhov ☺

The decision analysis cycle



Elicitation and evaluation of decision basis



Decision quality

What influences the quality of decisions?

Decision framing – "The Right Challenge"

Was the proper problem analyzed?

Information excellence

Was there information excellence?

Was the most cost-effective information sources used?

Creativity – Significantly different alternatives

Was there an adequate search for promising alternatives?

Clear values

Were the values unambiguous?

Decision quality

Integration and evaluation with logic

- Were any mistakes made?
- Were appropriate sensitivities developed?
- Were the right conclusions drawn?

Balance of basis

- Was allocation of effort within the analysis balanced?

Commitment to action

- Was the right course of action clearly indicated and communicated so that the decision maker developed a clear commitment to action in that direction?

Requisite decision modeling

- A requisite model contains everything that the decision maker considers important in making the decision. Different level of detail may be appropriate at different modeling stages.
- How do you know that a model is requisite?
- Issues addressed in a requisite decision model are those that matter, and those issues left out are the ones that do not matter
- Clarity test ensures that everything in the model is clearly defined and unambiguous.
- Sensitivity analysis plays a key role in facilitating structural change, in showing the extent of disagreements, and in resolving disagreements about the implications of differing assumptions and judgments that can be tolerated for a give decision.

Requisite decision modeling

- It is expected that people will change their view of the problem during the development of the model.
- That is why the process has to be iterative. In fact, many iterations may be necessary.
- In short, requisite decision modeling treats problem solving as a dynamic process in which all relevant actors become clearer about the problem and develop a deeper understanding of it over time.

Sensitivity analysis

Every model rests on a variety of assumptions regarding:

- **the decision options available**
- **possible states of nature and the probabilities associated with these states**
- **the values of different outcomes**

- **In many cases we will be uncertain about the validity of some of our assumptions. Or, in social settings, different people may differ in what they find reasonable to assume.**
- **The purpose of sensitivity analysis is to determine which assumptions really do have a substantial impact on the decision.**
- **Once we know which assumptions matter most, we can focus our attention there.**

Sensitivity analysis

Sensitivity analysis answers the question: "What matters in this decision?"

Determining what matters requires incorporating sensitivity analysis throughout the modeling process.

It is important to keep in mind that the purpose of sensitivity analysis is to refine the decision model, with the ultimate objective of obtaining a requisite model.

Sensitivity analysis can lead to reconsidering the very nature of the problem ("Are we solving the right problem?")

There may be synergy effects among various model parameters, so the problem is very complex in general. No optimal procedure exists for performing sensitivity analysis. It is essentially an art with a few basic heuristics, most of which are covered in the textbook.

Sensitivity analysis in problem identification

Sensitivity analysis can lead to reconsideration of the very nature of the decision problem – framing the problem

Type III errors: "Are we solving the right problem?"

e.g., Decision to treat a symptom instead of a cause.

Consider lung diseases for which expensive medical treatments have been developed

What is the objective?

Reduce deaths from lung disease?

Are treatments as effective as antismoking campaign?

Is the objective really to reduce death?

Or is the objective really to reduce the chance of second-hand smoke?

Sensitivity analysis in problem identification

How to avoid a Type III error?

Keep asking whether the problem on the surface is the real problem

What exactly is the “heart of the problem”?

e.g., For a better public transportation plan in Pittsburgh, should we decide to increase the number of taxis or to plan for an better overall transportation system?

Sensitivity analysis in problem structuring

A decision may be sensitive to the structure

There may be different ways to structure a problem

Example: Consider a problem involving the setting of standards for pollution from oil wells in the North Sea [von Winterfeldt & Edwards, 1986]

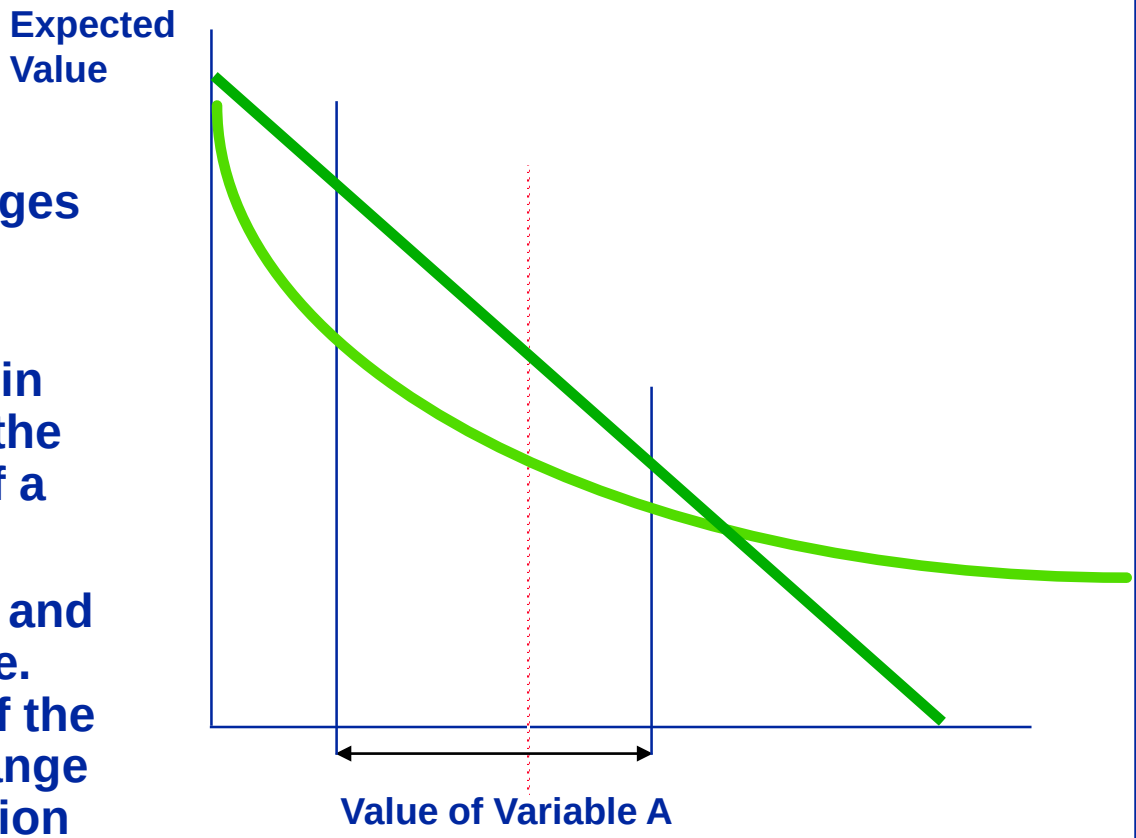
- A standard regulatory problem
  - Alternatives: different possible standards and enforcement policies
  - Objective: to minimize pollution while maintaining efficient oil production]
- A competitive situation
  - Important players: the regulatory agency, the industry, and the potential victims of pollution

Sensitivity analysis in problem structuring

- How can sensitivity analysis help to resolve multiple representations?
  - Identifying the appropriate perspective
  - Identifying the specific issues that matter
    - What variables really make a difference in terms of the decision at hand?
    - Does it matter that we can make an intermediate choice?
    - One-way and two-way sensitivity analyses

One-way sensitivity analysis

- Indicates the sensitivity of a proposed decision to changes in the value of a single parameter.
- Plots the graph of variations in total value with respect to the possible range of values of a parameter.
- Very often we have the lower and the upper bound for a value. We can check the values of the outcome variable for the range of possible values of decision variables and uncertain quantities between their upper and lower bounds.



Tornado diagrams

A graphical one-way sensitivity analysis technique.

Amounts to varying each parameter independently between its lowest and highest value (the other parameters are held constant) and looking at the resulting interval of the outcome variable.

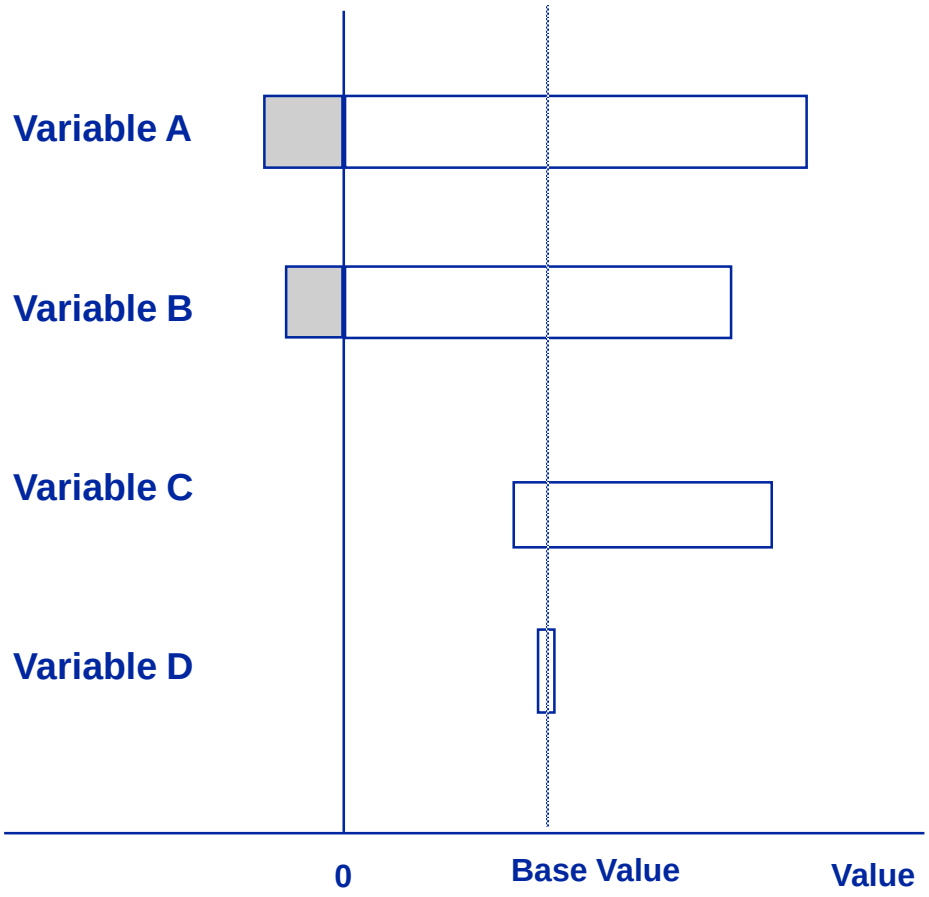
The length of this interval for each parameter represents the extent to which the outcome is sensitive to that parameter.

We subsequently order the parameters from those that matter the most (top), i.e., those that are the most sensitive, to those that matter the least (bottom), i.e., those that are the least sensitive.

The resulting diagram resembles a tornado, hence the name "tornado diagram."

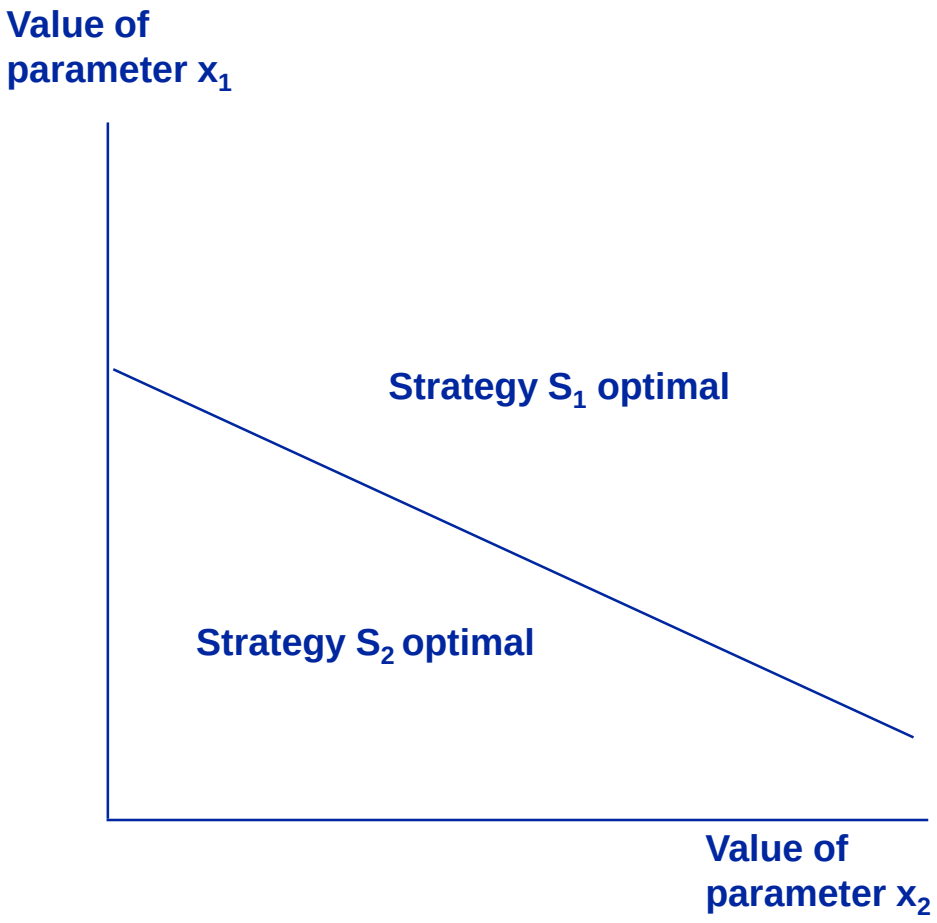
Tornado diagrams: Procedure

- Calculate values assuming best guess for each model parameter.
- Vary one parameter at a time. Calculate value assuming lower bound and upper bound for the variable. (Hold all other parameters constant at their base values.) The bigger the range in values, the more the variable matters.
- Plot range of values resulting from varying each parameter. (often, will do this separately for each decision option.) If you plot biggest ranges on top, smallest on bottom, get "tornado shape".



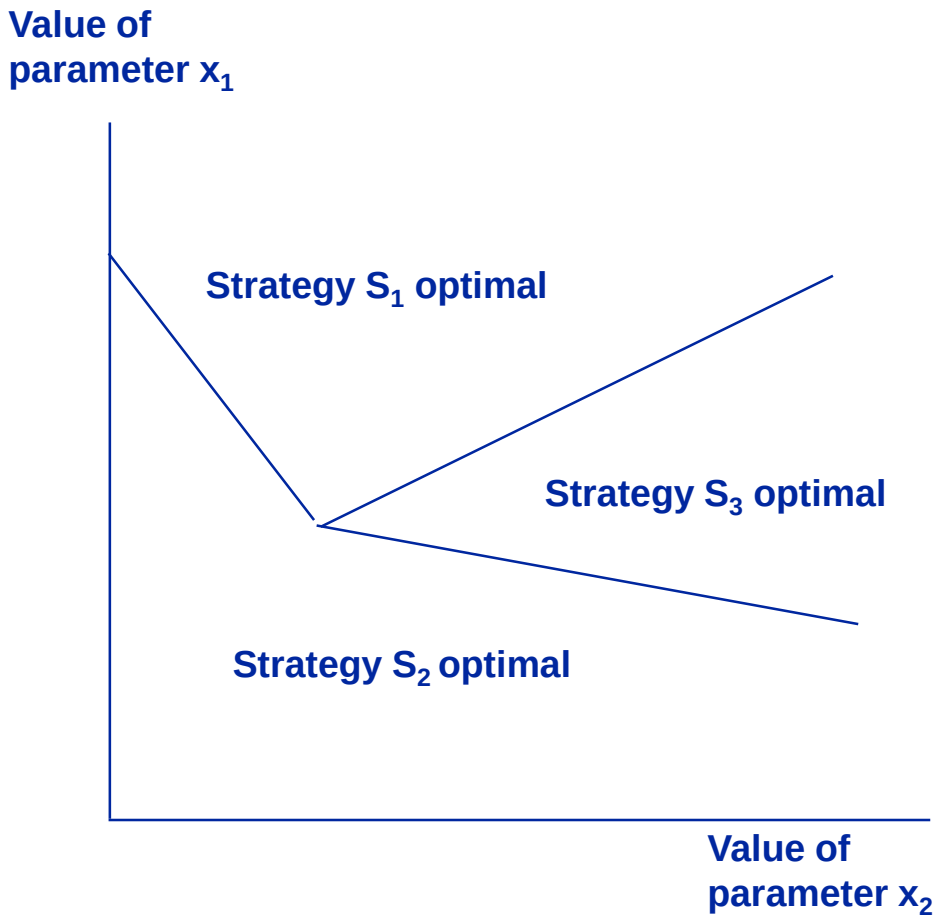
Two-way sensitivity analysis

- Sometimes we may want to consider sensitivity to two variables at the same time.
- Derive an analytical solution for the joint interaction between two values for a the value of the outcome variable that makes the two decision options equally attractive. The solution (a line) divides the plane into two strategy regions.
- You can clearly see which combinations of values of the two parameters determine different strategies.
- Crossing the line implies a change in the optimal strategy.



Two-way sensitivity analysis with three alternatives

- This is similar to the two-way sensitivity analysis of the previous page but it is done for three decision alternatives.
- Essentially, you make three pairwise comparisons between the three expected values (generally, functions of the two parameters).
- The solution (how many lines?) divide the plane into three strategy regions.
- Crossing any of the lines implies a change in the optimal strategy.

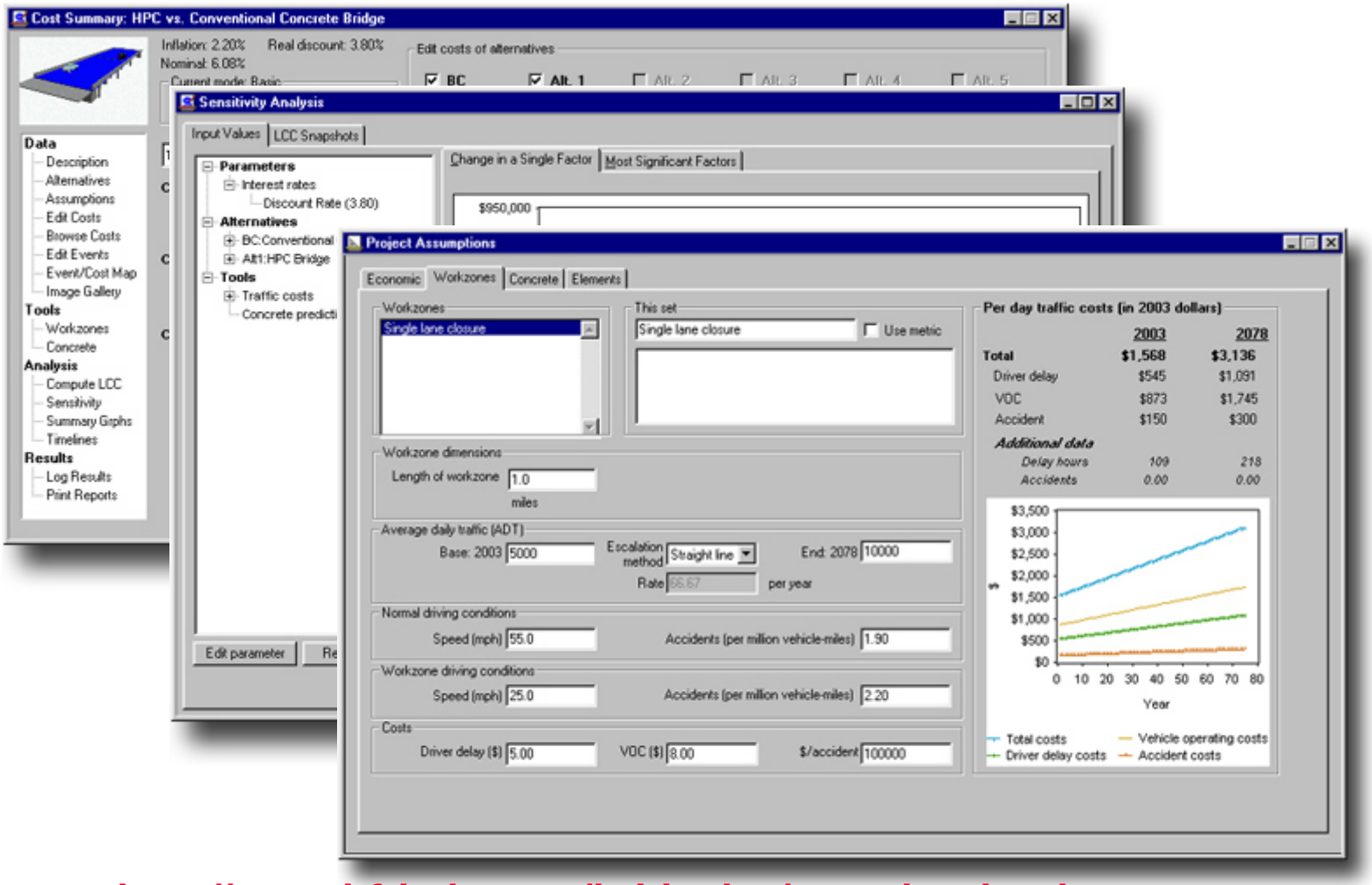


Sensitivity analysis by computer

This is the only reasonable way to go.

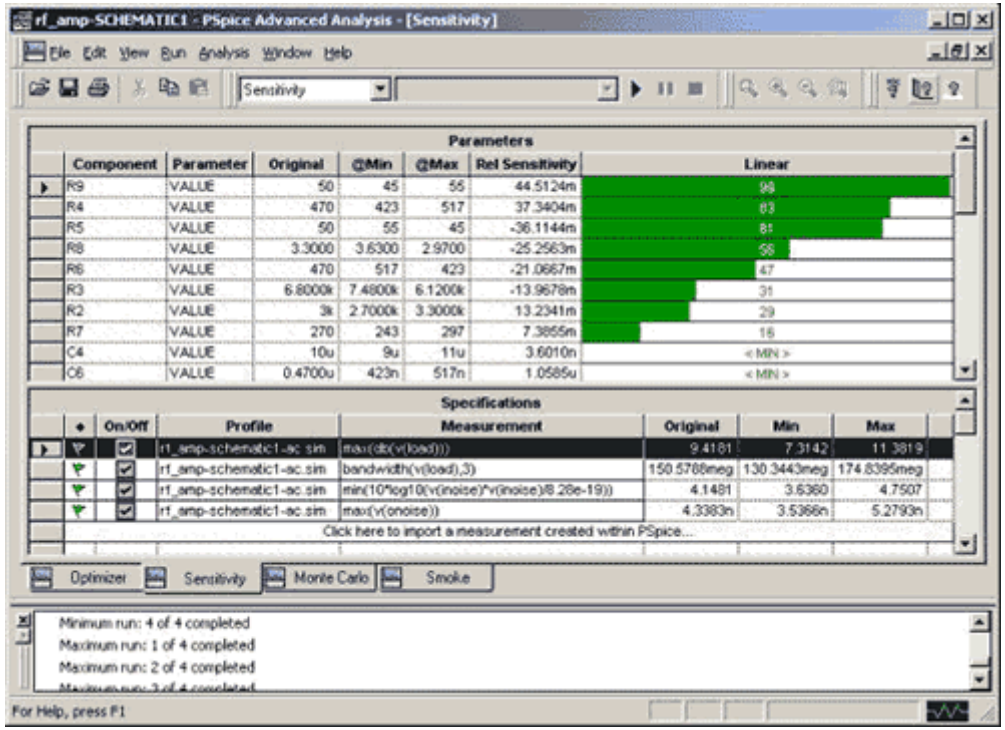
- **Deterministic sensitivity analysis (Analytica, spreadsheets)**
- **Importance analysis (Analytica)**
- **Monte Carlo approaches**

BridgeLLC



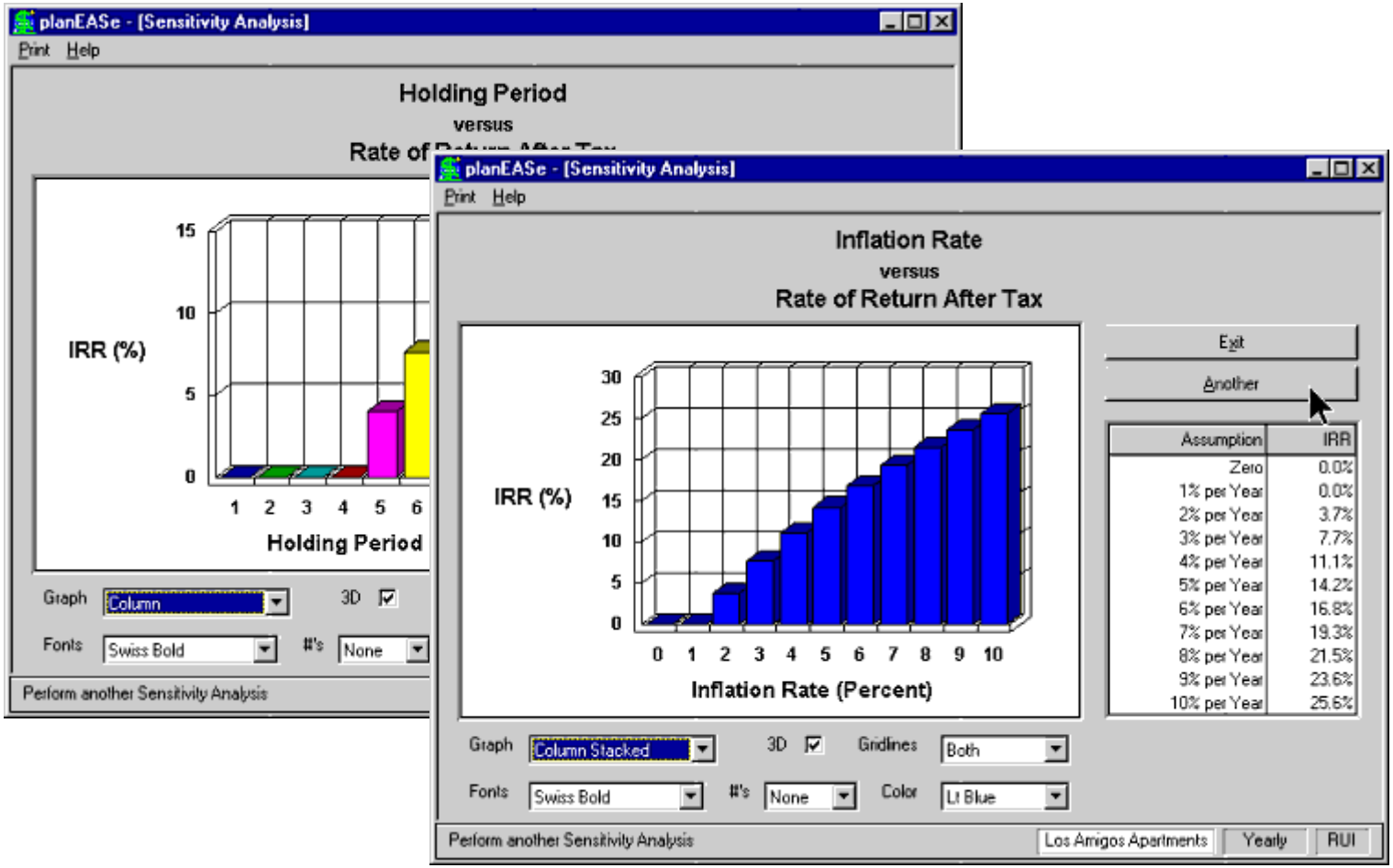
http://www.bfrl.nist.gov/bridgelcc/overview.html

PSpice Studio



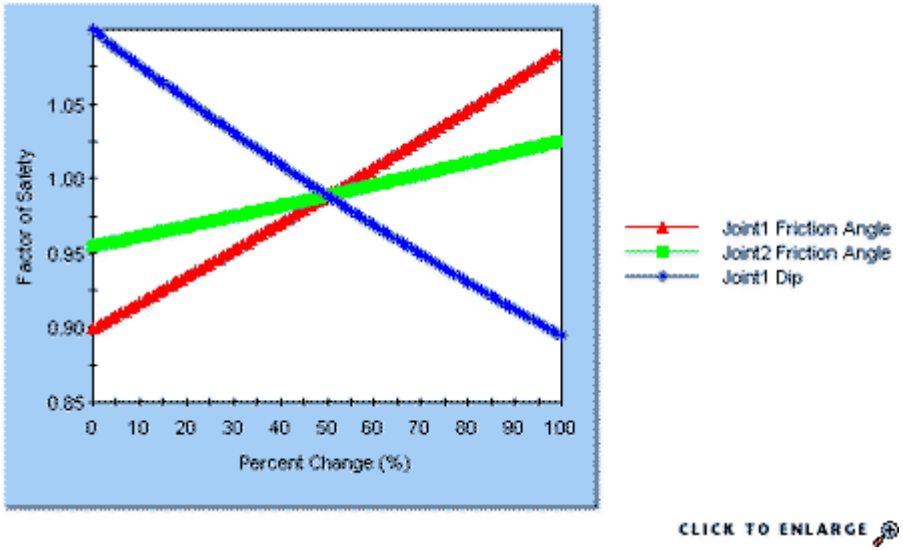
http://www.hw-server.com/software/pspicest.html

planEASe



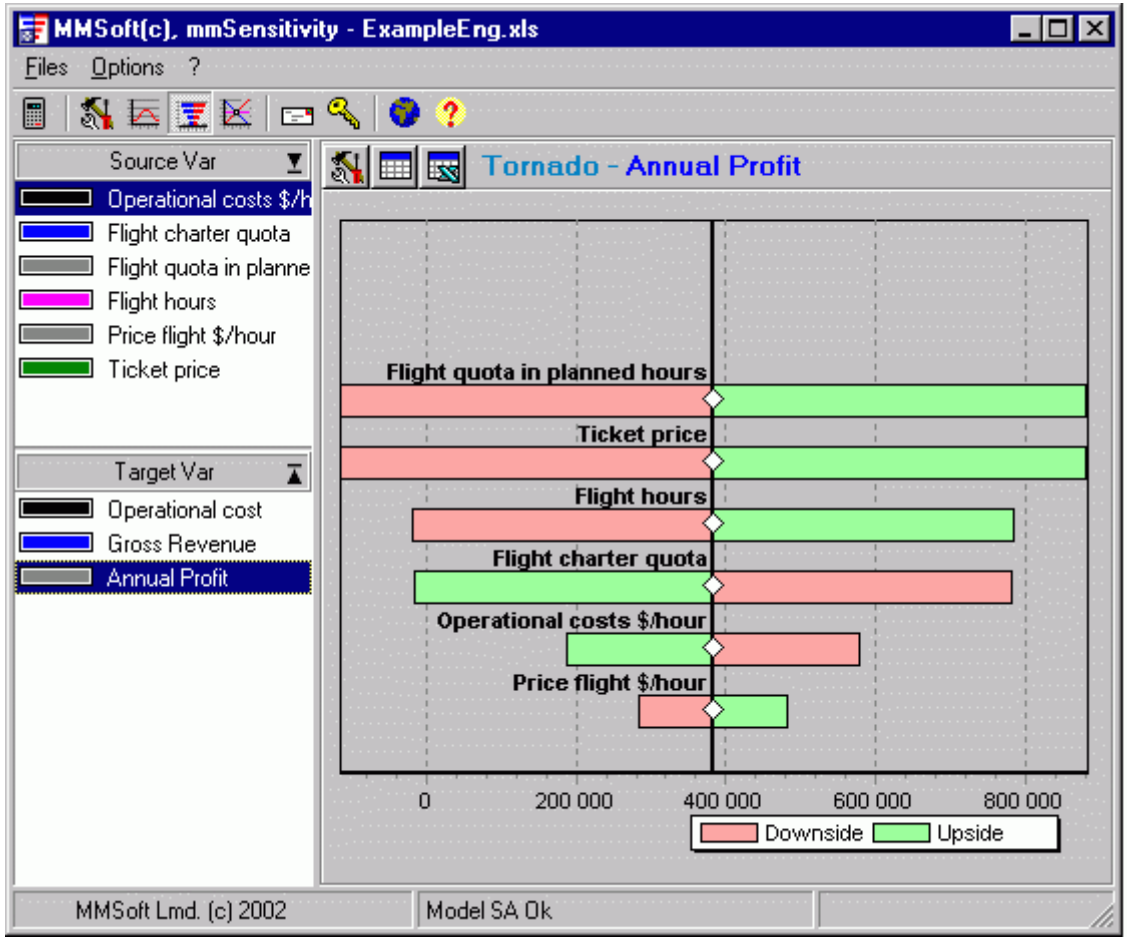
http://www.planease.com/product/analysis/sentx.aspx

SWEDGE



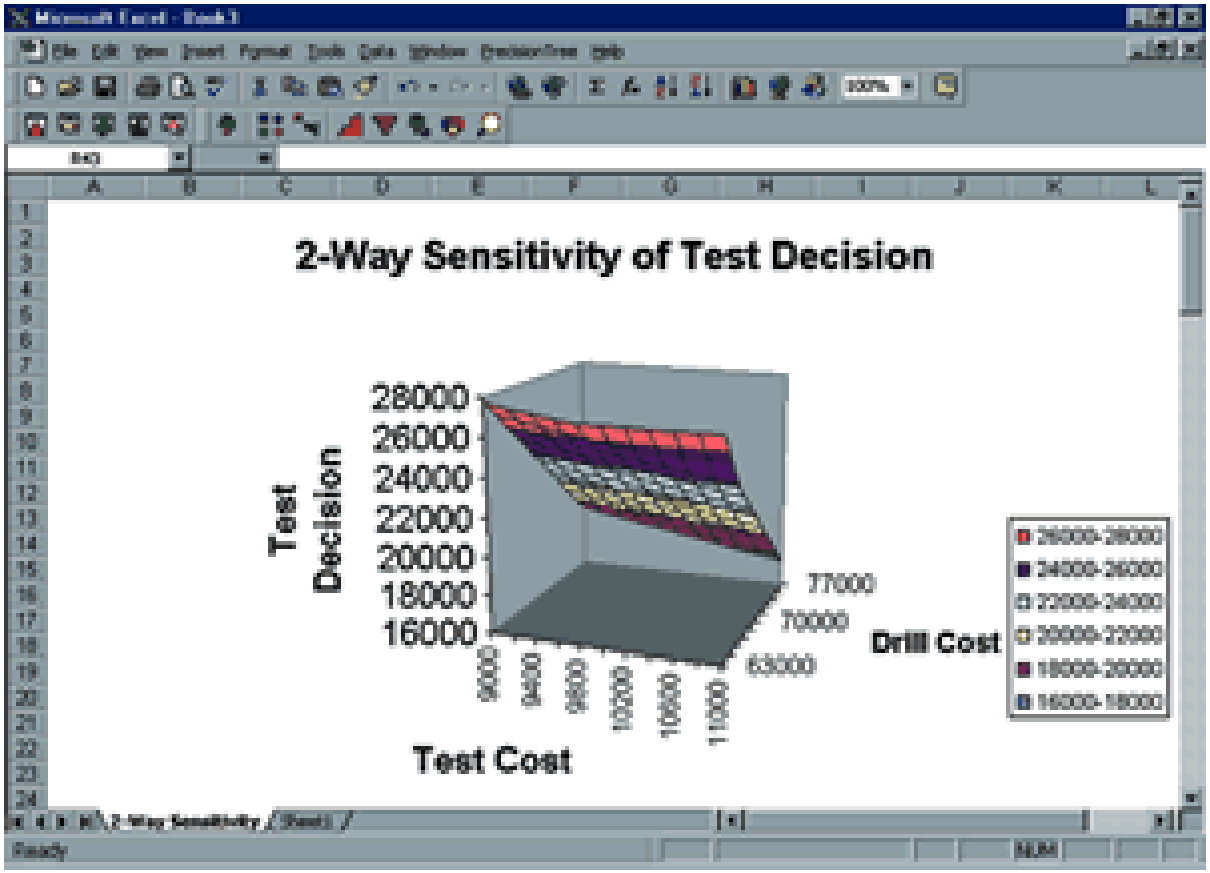
http://www.rocscience.com/products/Swedge.asp

mmSensitivity



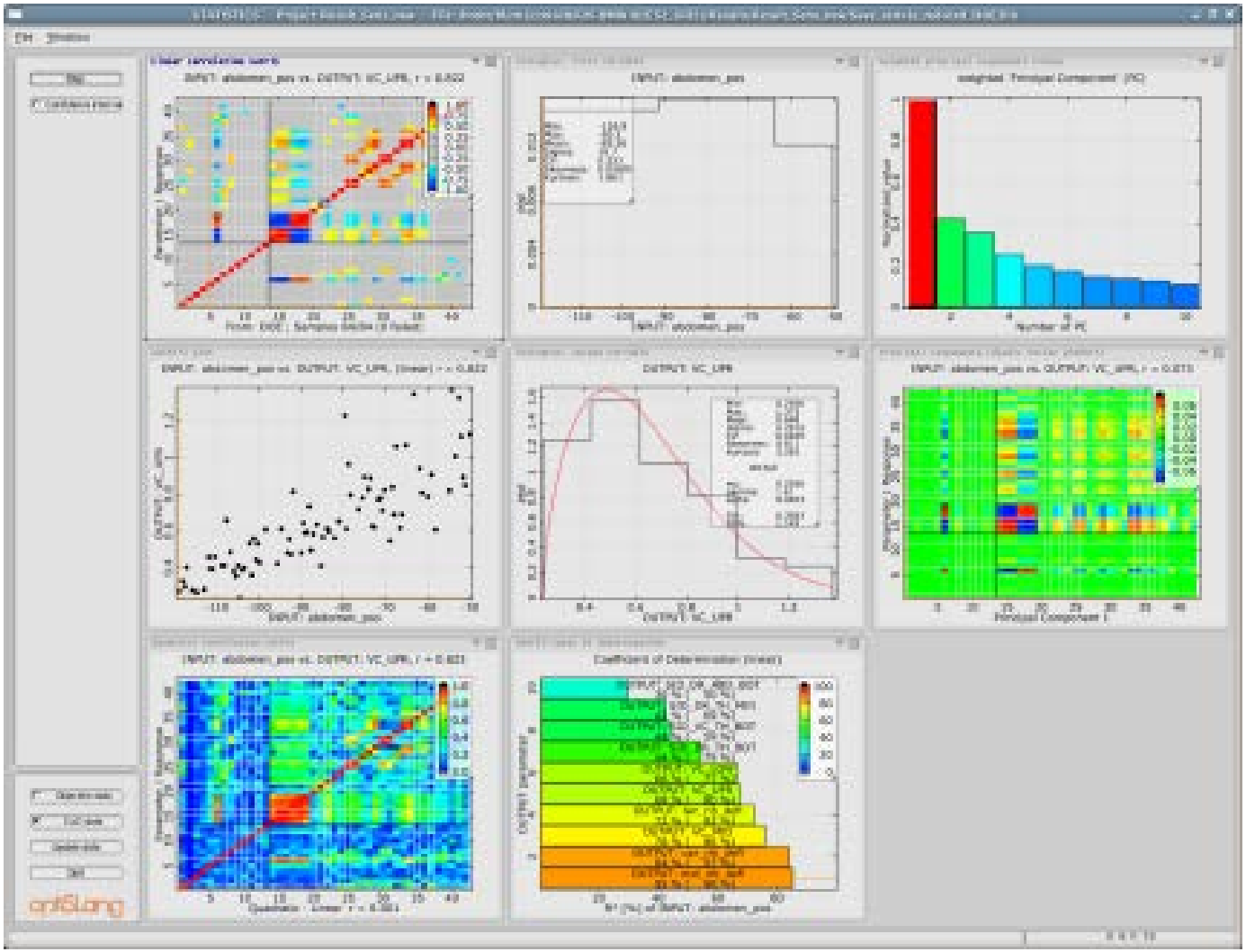
http://www.sharewareplaza.com/mmSensitivity-download_33450.html

Precision Tree



http://www.intesoft.com/produits/tech/risk/ptree.html

optiSlang



http://www.science-computing.de/en/software/optislang.html

Concluding remarks

When you want to elaborate on your model, start with a best guess value and initial bounds on it, that you should ideally not move out from. What you do is to narrow them down.

You can achieve that by a better elicitation procedure or by adding new variables. In any case, you should obtain a more narrow interval.