SYSTEM DYNAMICS AND UNCERTAINTY:

Results of Two Applications of Formalized Sensitivity Analyses with System Dynamics Models of the Electric Utility Industry

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Well structured system dynamics models are often quite useful in the analysis of policy impacts in the face of multiple sources of uncertainty. Simulation searches for a "robust" policy that performs well under widely varying conditions are often the most rewarding portion of a system dynamics study. This paper reports the results of two studies where the analysis of uncertainty is carried a step further. Here, we are interested not only in policy impacts under widely varying conditions but in whether a policy can reduce the uncertainty of the system.

The paper begins with an important example from the electric utility industry. Utility planners are interested in learning the extent to which efficiency standards for new homes and businesses lead to an important reduction in the uncertainty of the electric utility system. The planners generally agree that uncertainty in the number of new homes and businesses translates into less uncertainty in electric load if the new buildings are more efficient in their use of electricity. And many planners feel that reduced uncertainty in electric load growth will lead to reduced uncertainty in other variables like the average price of electricity.

Two recent studies have been completed which combine system dynamics models of electric utility systems with a formalized statistical analysis techniques described at the 1983 International System Dynamics Conference. One study was performed for the California Energy Commission for a hypothetical California utility; the second was performed for the Bonneville Power Administration for the Pacific Northwest electric system. (The Bonneville model is explained in papers at the 1985 and 1986 conferences.)

The paper provides a short review of how utility planners commonly represent the long term uncertainty in system performance. Key differences between the system dynamics/statistical analysis approach and the more common methods are identified. Selected results are presented to illustrate the usefulness of the method. We conclude with a discussion of several highly unusual findings from the Bonneville study. The discussion of the "counter intuitive" results focuses on the key role of information feedback in the Bonneville model.
THE IMPACT OF PERFORMANCE STANDARDS
ON THE UNCERTAINTY OF THE
PACIFIC NORTHWEST ELECTRIC SYSTEM

A FINAL REPORT ON THE HYPERSENS ANALYSIS OF CPAM

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BONNEVILLE POWER ADMINISTRATION
OFFICE OF CONSERVATION
CONSERVATION AND UNCERTAINTY:
AN ILLUSTRATIVE ANALYSIS FOR THE
CALIFORNIA ENERGY COMMISSION

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A SIMPLE NUMERICAL EXAMPLE OF UNCERTAINTY REDUCTION
ANALYSIS WITHOUT PRICE FEEDBACK
USING HYPERSENS WITH CPAM

Demand-Side Uncertainty
- Market Shares
- Gas Prices
- Potential Savings
- Program Compliance
- Economic Growth

Supply-Side Uncertainty
- Rate Making
- WPPSS
- Construction Costs
- Intertie Operations
- Aluminum Industry

HYPERSENS
- Randomly samples values from each distribution for each variable.
- Produces a rerun file with a user-specified number of "tests".

DYNAMO
- Runs CPAM from the rerun file.
- Puts the output into a file for further analysis.

HYPERSENS
- Analyzes the results from the CPAM runs.
- Produces a variety of reports.

Off-line comparison of results with the results of other runs.
THE ITERATIVE APPLICATION
OF HYPERSENS

START

RANGE OF PLAUSIBILITY ON ORIGINAL SET OF INPUTS TO THE ELECTRIC UTILITY MODEL

DESIGN SET OF RERUNS USING LATIN HYPERCUBE PROCEDURES

PERFORM RERUNS OF ELECTRIC UTILITY MODEL

NEW SET OF PARAMETERS AND THEIR RANGES OF PLAUSIBILITY FOR ALTERED ELECTRIC UTILITY MODEL

CALCULATE PARTIAL CORRELATION COEFFICIENTS TO SELECT MOST IMPORTANT INPUTS TO ELECTRIC UTILITY MODEL

CALCULATE TOLERANCE INTERVALS

ALTER THE ELECTRIC UTILITY MODEL TO REMOVE THE CORRELATION AMONG TOP INPUTS

ARE THE TOP INPUTS INDEPENDENT?

NO

YES

INTERPRET TOLERANCE INTERVALS
HYPERSENS TOLERANCE INTERVALS FOR REGIONAL DEMAND

25.

19.

13.

6.3

0.00

1984.0 1989.0 1994.0 1999.0 2004.0

TIME

9 = 90 PERCENT COVERAGE

7 = 75 PERCENT COVERAGE

M = MEAN
STANDARDS' IMPACT ON REGIONAL DEMAND WITH THE INITIAL AND FINAL VIEWPOINTS

**Graph:**
- **X-axis:** Mean Reduction (Gw)
- **Y-axis:** Uncertainty Reduction (Gw)
- **Reference Result**
- **Initial Example:** (1994)
- **Final Viewpoint:** (2004)

**Legend:**
- ● Final Viewpoint
- ✦ Initial Example
STANDARDS' IMPACT ON
BONNEVILLE LOAD WITH THE
INITIAL AND FINAL VIEWPOINTS

![Graph showing uncertainty reduction vs mean reduction with data points for 1994 and 2004. The graph includes markers for final viewpoint and initial example.]
RELATIVE IMPORTANCE OF THE REDUCED OPTIONS COSTS MADE POSSIBLE BY THE REDUCTION IN DEMAND UNCERTAINTY

<table>
<thead>
<tr>
<th>SIMULATED IMPACT OF PERFORMANCE STANDARDS UNDER BASE CASE CONDITIONS</th>
<th>DISCOUNTED UTILITY REVENUES</th>
<th>DISCOUNTED ENERGY SERVICE COSTS</th>
<th>AVERAGE RETAIL ELECTRIC RATE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BENEFIT OF $2.835 BILLION</td>
<td>PENALTY OF $1.262 BILLION</td>
<td>BENEFIT OF 0.01 mlls/kwh</td>
</tr>
<tr>
<td>EXTRA BENEFIT FROM THE REDUCTION IN OPTIONS COSTS</td>
<td>$0.177 BILLION</td>
<td>$0.177 BILLION</td>
<td>0.12 mlls/kwh</td>
</tr>
<tr>
<td>RELATIVE IMPORTANCE OF THE REDUCTION IN UNCERTAINTY</td>
<td>6%</td>
<td>14%</td>
<td>VERY LARGE</td>
</tr>
</tbody>
</table>