Decision Analysis Ranks Maintenance Programs

Analytical tool helps justify future budgets based on utility's material condition.

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Fig. 1. A facilitator coordinates the expertise and intelligence of each member of this manager's team in developing an influence diagram.

Electric utilities are changing their spending priorities. In the past, the spotlight focused on building new generating plants, which left transmission and distribution maintenance out of the limelight. Now, with limited growth, active demand-side management and plentiful alternative generation projects, utility spending on generation is more likely to be for environmental projects than for new facilities. At the same time, the push is on for an increased focus on customer service-related issues like power quality, service interruptions and restoration time. This thrust comes from four primary sources:

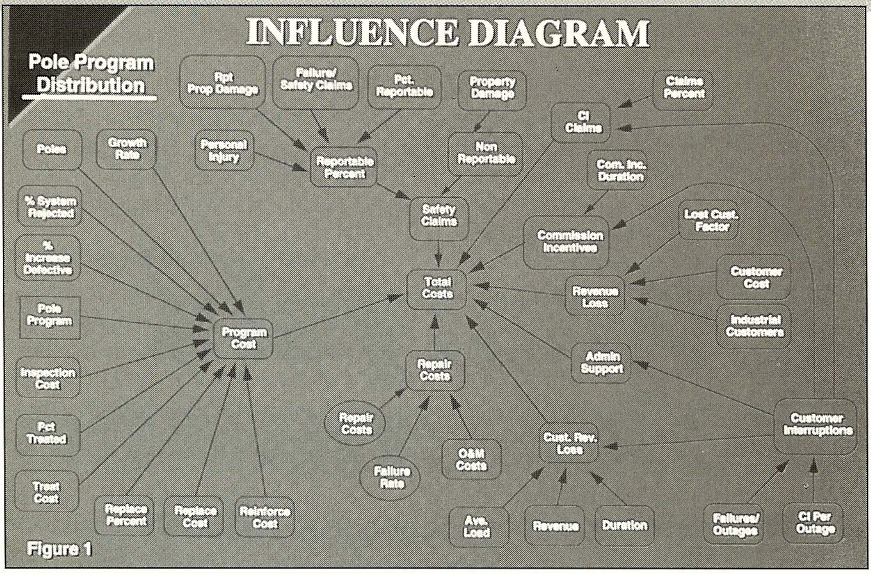

Fig. 2. The wide variety of factors affecting total cost of the distribution pole program is displayed in the influence diagram.

■ Increasing competition.
■ Increased customer demands.
■ Incentive-based regulation.
■ Benchmarking and quality improvement.

As a result, many utilities that used to cut back on T&D projects to fund new power plants are now refocusing spending toward preventive maintenance in T&D.

When utilities decide to spend on preventive maintenance in T&D, they face some difficult budgetary problems. Every utility wants to be more preventive than reactive, but to do so it must get "ahead of the curve," i.e., it must spend money on increased preventive maintenance before it can reap benefits in terms of lower repairs. In addition, in the battle of the budget, preventive maintenance is a tempting place to cut since its effects may not be felt for years. The same delay that makes it hard to get ahead of the curve makes it easy to fall behind without noticing it.

As utilities address the task of budgeting for increased preventive maintenance in T&D, there is a need for the proper analytical tools to make allocative choices among programs. Recently, Consumers Power Co.'s (CPCO) senior vice president of energy distribution challenged his organization to justify future budgets based on the material condition of the system.

This challenge set the stage for the use of formal decision analysis. In response to this need, the Work Management Consulting Group at Energy Management Associates (EMA), the utilities division of EDS, was hired in June 1993 to assist in applying formal decision analysis of material condition assessment data.

Decision Analysis Modeling

The key insight to the decision analysis approach was to focus on the strategic decisions facing T&D preventive maintenance. On the electric side, 12 programs were identified, six each for transmission and distribution:

■ Line clearing.
■ Lightning protection.
■ Pole replacement.
■ Line rehabilitation.
■ Capacity reinforcement.
■ Substation maintenance.

Task force groups were put together to discuss decision criteria. It was agreed that net present value was the appropriate yardstick and that the core analysis would involve only "hard numbers." The effect of intangibles like public perceptions or social costs was modeled through its impact on revenue and cost only.

The basic approach in decision analysis can be summarized in three steps:

1. Deterministic modeling.
2. Sensitivity analysis.
3. Probabilistic assessment.

Influence Diagrams

In Step 1, the process is modeled deterministically. Deterministic modeling considers historical fixed data. For example, if a utility experiences outages to customers for 25 of every 50 pole failures, it would be logical to expect this 0.5 relationship between outages and failures to continue. The probabilistic nature of the variables is ignored during this step of modeling. In facilitated sessions, focus groups of managers are assisted by the facilitator (one who is trained in the use of these tools and acts like a catalyst) in the development of an influence diagram, laying out the key decisions and all the influences on the outcomes of the decisions (Fig. 1). An example of such a diagram is shown in Fig. 2.

Next, these diagrams are converted into spreadsheet models to quantify the influences. Estimates of all the values are gathered and key parameters are given ranges. For example, for the pole-replacement decision (Fig. 2), some of the key parameters are:

■ Cost of inspection.
■ Cost of pole replacement.

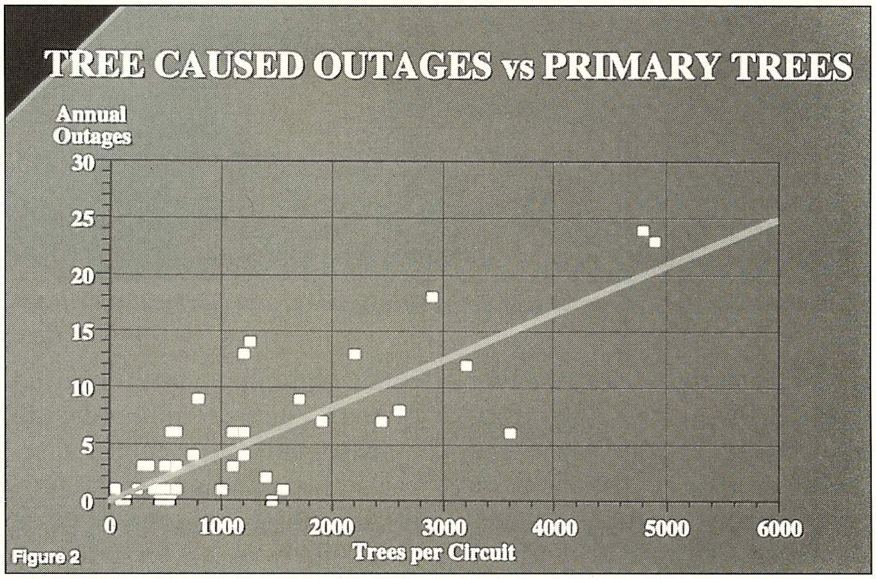

Fig. 3. Tree-caused outages versus number of primary trees.

- Pole failure rate.
- Cost of repair.
- Outages per pole failure.
- Customer minutes per outage.

Sensitivity Analysis

Once ranges for the key parameters are determined, the second step of the process, sensitivity analysis, is performed. The process of developing influence diagrams and deterministic models is intentionally open and wide. However, the sensitivity analysis allows one to narrow the real channels of influence by showing that, for reasonable ranges of values, some theoretical impacts are, in practical terms, not important to the decision. This reasoning allows one to focus one's efforts on getting refined data for those values that really matter.

Step 3 involves developing probability distributions for key parameters. Normal distributions, exponential distributions, as well as empiric distributions derived from specially structured interviews with subject area experts from CPCO, were used in various models. Knowledge and years of experience, along with data assembled as part of a material condition assessment conducted during the previous year, were used to determine appropriate ranges for critical parameters.

Impact on Reliability Programs

Once the probability distributions were modeled, decision analysis software was used to compute the joint probabilities for the full decision tree. Once a solid foundation was laid, the decision analysis itself was straightforward. Some programs were scaled back and others were accelerated. Benefits of this approach included:

- Fact-based decisions.
- Bang per buck.
- Consistency.

Regarding the first benefit, participants remarked that the decision analysis elevated the level of discussion of the funding of these programs. Where in the past managers might argue, "I don't think the money we spend on line rehabilitation is as effective as lightning protection," with decision analysis the relevant comment might be, "I don't think the failure rate due to deterioration of crossarms and pins is high enough to justify the funding, especially compared to the improvement in outage minutes, which can be achieved through the same spending on repairing grounds and installing lightning arresters."

The subtle difference is that the latter statements can be verified by gathering more data on specific, identified parameters, whereas the former are essentially unverifiable without the context and modeling that decision analysis provides.

The phrase "bang per buck" refers to the way that decision analysis allowed us to focus on how different amounts of spending on different preventive maintenance programs had different impacts on reducing customer outage minutes or overall cost. In fact, CPCO has committed to the Michigan Public Service Commission to accomplish significant reliability improvements by the end of 1996. The use of decision analysis models is a key element in meeting this commitment.

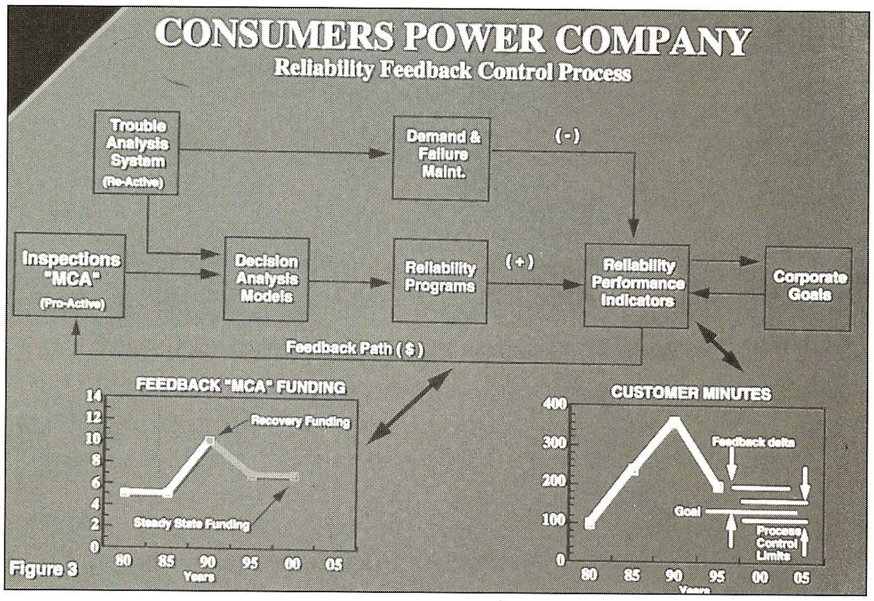

Fig. 4. The reliability feedback control process illustrates how material condition assessment recovery funding reduces the number of minutes of customer outages.

Consistency was an additional benefit of the analysis. With three distribution regional operations, along with transmission operations involved in the funding decision, there was always an issue of whether the funds were being allocated properly. Decision analysis offered the capability to base the allocations on parameter values instead of on which manager was most eloquent in his presentation. In fact, a project is now underway to apply the same models that were used for the strategic, program-level decisions to the micro-decisions involving funding priorities for individual projects within programs, such as how feeder reinforcement projects should be ranked.

Better Decisions

It is difficult to summarize the content of so much analysis in a way that readers can briefly get a sense of the impact. Perhaps one good example will help. As part of the probability assessment to determine outage rates associated with line clearing, we analyzed data gathered during the material condition assessment. We looked for relationships between line clearing activities and tree-caused outages. Figure 3 shows a scatter diagram depicting the relationship between a 3-year average for tree-caused outages and the number of trees for 39 circuits that had been picked at random.

The relationship is quite strong with a correlation coefficient of 0.81, meaning that 66% of the variation in tree-caused outages can be explained by the number of trees. The slope of a regression line fitted through the points is approximately one over 200, implying that for every 200 trees removed, one outage could be avoided on a given feeder. If those 200 trees cost $50 each to remove, then it would cost $10,000 to avoid one outage. Since each outage affects an average of 150 customers, then the cost to reduce an outage is $67 per affected customer. Better understanding of relationships like this can improve a utility's ability to make sound reliability decisions.

Reliability Feedback Control

The overall concept for bringing the reliability of an electrical system back into equilibrium and keeping it there can best be illustrated as a feedback control system (Fig. 4). Reliability programs are shown as a positive input to reliability performance indicators, which act to neutralize the negative signal shown coming from demand and failure maintenance activities.

When reliability improvement becomes a major issue, then the first step toward bringing a system back into equilibrium should be the funding of a data-gathering process illustrated by the feedback control loop. Material condition assessment (MCA) and decision analysis are the catalysts needed to energize the reliability improvement process. Initial investments in MCA in the range of 4% to 5% of current O&M budgets should be expected with this activity falling below 3% once a system reaches reliability equilibrium.

As a final comment, we believe that decision analysis allows utilities to develop predictive models and relationships that will sharpen their ability to direct scarce resources toward those projects that will be most effective in avoiding costs and improving customer service. **T&D**

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