Formal decision analysis process guides maintenance budgeting

Collaborative needs assessment by managers results in fact-based, cost-effective, consistent allocations

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A formalized, collaborative decision analysis process has transformed preventive maintenance funding at Consumers Power Co. This process cost-effectively focuses spending to improve public safety and customer service while avoiding unnecessary costs.

Maintaining a gas distribution system never has been easy. Most capital budgets are earmarked for new business construction. Then, there are the necessary projects to support civic improvements such as road reconstruction along with sewer and water projects. Often, little is left over for true preventive maintenance.

Yet today, with increasing public interest in safety, preventive maintenance is needed more than ever. Cast iron and bare steel pipe are being aggressively replaced and cathodic protection effectiveness is being scrutinized. Companies that once used preventive maintenance as off-season, fill-in work now find they must separately fund pro-active maintenance programs.

When gas distribution companies decide to focus on preventive maintenance, they face difficult budgetary problems. Every company wants to be more preventive than reactive, but to do so it must get "ahead of the curve." Preventive maintenance spending must be increased now before the company can reap benefits later in terms of lower repairs. Additionally, in the budget battles, cutting preventive

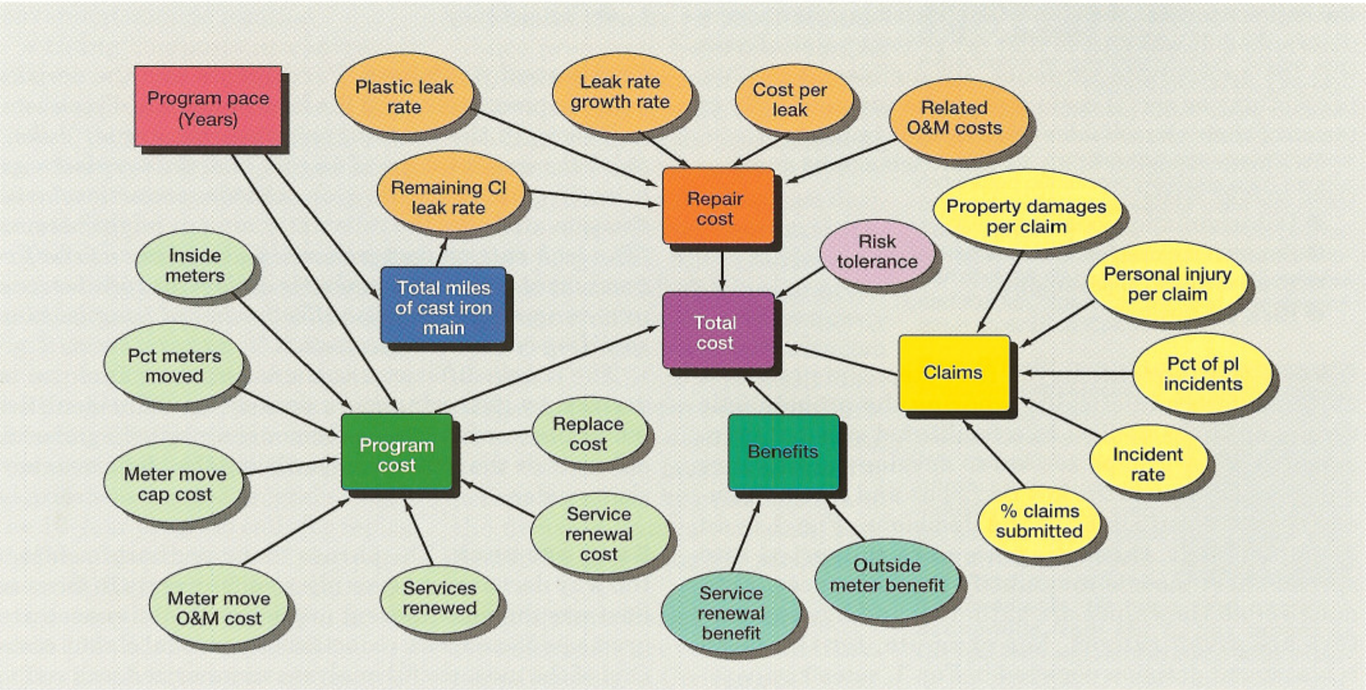

Fig. 1. Cast iron main replacement influence diagram used in decision-analysis process.

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maintenance dollars is tempting since the 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.

Ultimately, effects of deferred maintenance may not really be evident until a catastrophe occurs, such as a series of incidents in the same territory. That is when money "saved" in earlier years is lost many times over in repairs and in responding to public reaction.

Analytical tools. To effectively address increased preventive maintenance budgeting, proper analytical tools are needed to make allocation choices among programs. At Consumers Power, the senior vice president of energy distribution challenged his organization to justify future budgets based on quantitative assessments of the system's material condition. The company responded by gathering all available material condition data. However, a framework for analyzing the data and determining priorities was missing.

Dan O'Neill, an external consultant, was brought into the process. He had used formal decision analysis to prioritize capital projects in electric power generation and suggested the company apply that industry's proven methods to distribution maintenance projects.

The key insight in the decision analysis approach was to focus on strategic decisions. Ten programs were identified:

- Civic improvement
- Cathodic protection
- Cast iron main replacement
- Bare steel main replacement
- Bare steel and copper services replacement
- Inside medium-pressure meter moves
- Regulator station facilities maintenance
- Service record automation
- Industrial meters inspection and maintenance
- Mobile homes built over main relocation.

Task forces were put together with participation from the region operating headquarters. Decision criteria were determined. It was agreed that net present value of costs was the appropriate yardstick. Intangibles like public perceptions or social costs were to be included only in terms of their shareholder or ratepayer impact.

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

- Deterministic modeling
- Sensitivity analysis
- Probabilistic assessment
- Risk preference.

Influence diagram. In the first step, the process is modeled deterministically, ignoring the probabilistic nature of the variables. In a facilitated session, management focus groups are led to develop an influence diagram, laying out the key decisions and all the influences on the outcomes of the decisions. Fig. 1 is an example. Next, these diagrams are converted into spread sheet models to quantify the influences. Estimates of all the values are gathered, and key parameters are given ranges. For example, for the main replacement decision depicted in Fig. 1, some key parameters are:

- Main replacement cost
- Main leak rate
- Leak repair cost
- Leak incident probability
- Average claim paid per incident.

Sensitivity analysis. With parameter ranges determined, the second step involves a sensitivity analysis.

While the process of developing influence diagrams and deterministic models is intentionally open and wide-ranging, the sensitivity analysis allows managers to identify critical variables by showing that, for reasonable value ranges, some theoretical impacts are not important to the decision. This allows managers to focus on refining data for the important values.

Probability distributions. The next step involves developing probability distributions for key parameters. Known distributions were used like the normal or exponential as well as empirical distributions derived from structured interviews with company subject-area experts.

Risk preferences. Once probability distributions were modeled, decision analysis software was used to compute joint probabilities for a full decision tree. The final step assessed the company's risk preferences. Again, structured interviews were conducted at various levels. The interviews produced sufficient information for a composite risk preference, indicating an overall aversion to risk, as is appropriate for prudent management, but one that is scaled by the extent of the impact on the company and its shareholders.

With the foundation laid, the decision analysis itself was straightforward. Some programs were scaled back and others were accelerated.

Benefits determined by this approach were apparent to all participants. These included:

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

Fact-based decisions. Participants said the decision analysis process elevated the level of funding discussions.

Where, in the past, managers might argue, *"I don't think the money we spend on cast iron main replacement is as effective as spending on cathodic protection,"* with decision analysis, the relevant comment might become, *"The leak rate on cast iron main would have to be five times what it is now to make the dollars we spend on cast iron main replacement as effective in reducing leaks as spending on cathodic protection."*

The subtle difference is the latter statement can be verified by gathering more data on specific, identified parameters, whereas the former essentially is unverifiable outside the context and modeling that decision analysis provides.

Bang per buck. The phrase "bang per buck" refers to the way decision analysis allowed managers to focus on how spending on different preventive maintenance programs impacted leak reduction or potential claims costs. One of the most useful analyses summarized leak reductions per program-cost dollar for different programs.

Consistency. With four regions involved in funding decisions, dollar allocation is always an issue. Decision analysis offers firm information for basing allocations on parameter values instead of manager-presentation eloquence. In fact, the company now is applying models developed for strategic, program-level decisions to the micro-decisions involving funding priorities for individual projects within programs, such as which main segments to replace.

It is difficult to summarize so much analysis in a way that readers can get a sense of the impact. Here is a good example.

Cast iron main replacement has received considerable public attention from the Office of Pipeline Safety and state public service commissions. Consumers Power has about a thousand miles of cast-iron mains, less than 5% of total main miles. But, the cast iron leak rate is almost 10 times that of cathodically protected coated and wrapped steel. Whenever cast iron is found to be seriously deteriorated, it is replaced. The issue is how much to programmatically replace with plastic each year to reduce overall leaks.

Realistic cast iron main replacement options might include a 10-year, 25-year, or 50-year replacement program. Within such programs, other factors must be considered:

- Replacing bare steel services at the same time
- Moving indoor meters to a more convenient outside location
- Using company or contractor crews
- Insertion or direct burial.

Also, there is the option to do nothing where cast iron is judged stable because of soil conditions and noncorrosivity.

Decision analysis helped managers focus on the critical parameters and make optimal comparative decisions. Fig. 2 shows an example of one analysis output. The vertical axis measures the program's net present value, including all direct costs and associated costs and benefits. The horizontal axis measures the program length. The 10-year program calls for replacing the targeted cast-iron pipe population in 10 years. The target population may be all the pipe, or the worst 20%, or the worst 80%.

The graph shows two curves, each depicting the cast iron program's net present value for different program durations. The lower curve shows net present value without risk-preference adjustment. This is the appropriate decision criterion if the company is risk neutral. The upper curve shows the result of applying risk preferences to the decision process, with a degree of risk aversion. Under the risk-neutral criterion, the optimal program length is longer than 50 years. With risk aversion, the optimal program is 40 years. Not shown on the graph is a narrower target population under the risk-neutral criterion.

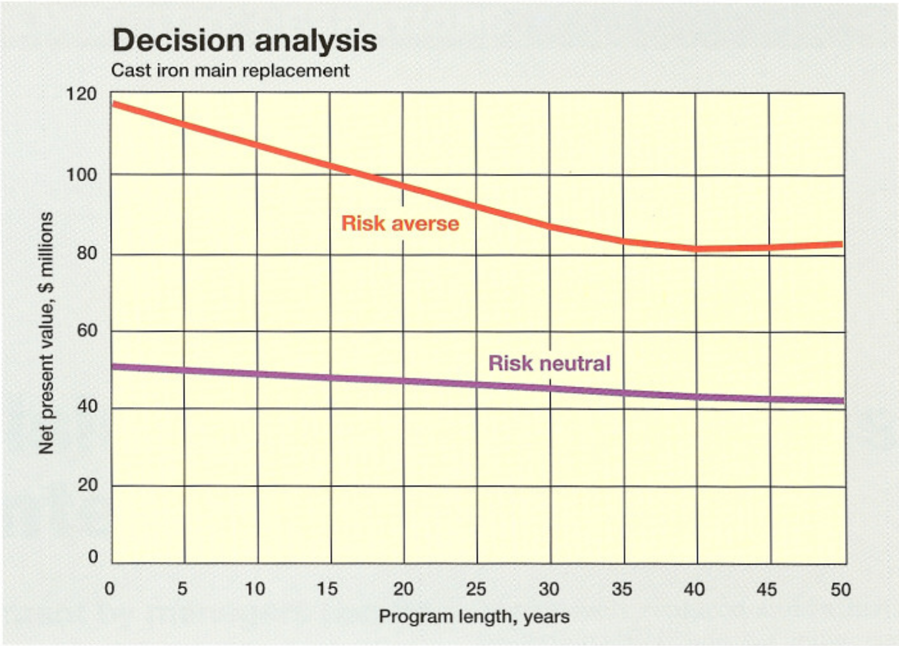

Fig. 2. Decision analysis—cast iron main replacement.

Similar graphs for other maintenance programs were used to find optimal values for each. The net present value curves were used to make funding tradeoff decisions among programs to allocate a given level of funding. Once major allocation decisions are made between maintenance programs, micro-models can be used to select individual projects. For cast iron mains, the company uses a cast iron main optimization system (CIMOS) to rank individual projects. Data from individual projects can then be used the following year to provide more informative estimates of the key parameters in the decision analysis models, continuously improving the process.

Conclusion. Decision analysis has transformed preventive maintenance funding at Consumers Power. This process derives its benefits from relying on system data to develop quantitative models, allowing effective scarce-resource deployment to avoid costs while improving public safety and customer service. The gas company is committed to the process. ■

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