Project Prioritization System: Methodology Summary

Technical Report

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1001877

Final Report, Decemberr 2001

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This report describes research sponsored by EPRI.

The report is a corporate document that should be cited in the literature in the following manner:

Project Prioritization System: Methodology Summary, EPRI, Palo Alto, CA: 2001. 1001877.

REPORT SUMMARY

This work provides a consistent and objective method to evaluate and then compare all distribution projects. The output of the method is a multi-year spending plan that reflects corporate objectives, responds to corporate budget and labor constraints, and explicitly considers the consequences of deferring specific projects.

Background
EPRI has been developing methods for distribution planning since 1992. At that time, research on the concept of distributed resources—begun by EPRI, Pacific Gas & Electric and the National Renewable Energy Laboratory—led to further consideration of distribution planning in general. The focus shifted from the question of how to incorporate distributed generation into distribution systems to the broader question of how to identify least-cost infrastructure strategies. The distribution planning problem is to determine the least-cost investment and O&M spending plan for meeting customer needs. The challenge is to develop multi-year transmission and distribution spending plans that meet customer needs, while taking into account the risks associated with deferring specific projects to future years. These spending plans are equivalent to project portfolios, since the plans specify which projects will be undertaken.

Objectives
This project develops a new methodology and accompanying software to:

- Evaluate on a consistent and logical basis the hundreds of candidate projects distribution managers typically need to compare
- Treat fairly and consistently projects with different attributes—that is, large and small, different time horizons, response to different customer and system needs
- Value each project using a collection of attributes that describe financial and system performance implications
- Rank capital and O&M projects with respect to a set of systematically-specified objectives—including costs, reliability, number of customers impacted, service requirements, and revenues
- Select the best multi-year portfolio of projects given a budget constraint, and understand the implications of changes in budget levels

Approach
Investigators applied system analysis, a five-step problem-solving method involving 1) problem formulation, 2) analysis, 3) design, (4) implementation, and 5) testing. Multi-attribute decision

theory was the basis for structuring the solution. A powerful and easy-to-use software implementation allows for automation of custom database design.

Results

A powerful new methodology has been developed and implemented as software. The implementation allows a company to create a customized Project Prioritization (P^2) information and analysis system that explicitly reflects company objectives and diverse project characteristics. The system—based on multi-attribute decision theory—is tailored to distribution project prioritization problems, and is supported by a client-server database system whose contents are automatically customized based on a GUI specification of utility project characteristics.

Project portfolio software is being implemented. The unique feature of the P^2 system is that it permits company-specific project and value information to be analyzed by state-of-the-art portfolio selection software. This creates a portfolio of projects that achieves company goals, rather than a ranking of projects that reflects rudimentary—and potentially misleading—economic considerations. This report summarizes the project prioritization problem and the new EPRI methodology for solving the problem.

EPRI Perspective

Distribution companies face significant asset management challenges. They have reduced budgets and must evaluate hundreds of candidate O&M and capital projects. In addition, they need to treat fairly and consistently projects with different attributes (including large and small projects, projects with different time horizons, and projects that respond to different needs—safety, reliability, and customer requirements). Planners need to rank projects with respect to pre-specified corporate objectives, including costs, reliability, number and type of customers impacted, service requirements, and revenues.

This research addresses the asset management problem by providing a new distribution planning method. The purpose of the new planning method is to evaluate investment and O&M projects fairly and consistently and develop multi-year spending plans that optimize system performance subject to budget constraints. The P^2 system was developed to provide the following benefits:

- Level the playing field for all projects, resolve differences of opinion rationally, and provide defensible logic for peer review
- Be practically applicable with respect to time and cost
- Provide for analysis of uncertainty and risk, and allow the ability to quantify what is lost from insufficient funding

Keywords
Distribution
Reliability
Customer needs

ABSTRACT

Distribution companies face significant asset management challenges. They have reduced budgets and must evaluate hundreds of candidate O&M and capital projects. In addition, they need to treat fairly and consistently projects with different attributes (including large and small projects, projects with different time horizons, and projects that respond to varying safety, reliability, and customer needs). In addition, planners need to rank projects with respect to pre-specified corporate objectives—including costs, reliability, number and type of customers impacted, service requirements, and revenues.

This report describes an objective new project valuation and budgeting method—developed in close cooperation with American Electric Power and Baltimore Gas and Electric—for explicitly valuing distribution projects and developing multi-year spending plans that optimize system performance subject to budget constraints. The output of this Project Prioritization (P^2) method is a multi-year spending plan that reflects corporate objectives, responds to corporate budget and labor constraints, and explicitly considers the consequences of deferring specific projects. The P^2 system features powerful new portfolio selection software for managing and comparing large numbers of diverse activities. The system is supported by a client-server database system whose contents are automatically customized based on a GUI specification of each utility's project characteristics.

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1 BACKGROUND AND PROBLEM

The objective of this project is to create a new distribution asset management capability for the utilities funding the development. This requires designing and implementing a method that systematically evaluates competing distribution system projects and selects projects by allocating given budgets. The asset management capability focuses on the underlying problems in the distribution system and all of the potential project alternatives and options that can be used to solve each problem. The asset management capability will also include analytical methodology, software and training that will allow distribution planners to explore more fully the economics of the potential solutions.

This new distribution asset management capability will allow the company to develop multi-year transmission and distribution (T&D) spending plans that meet customer needs, while taking into account the risks associated with deferring specific projects to future years. These spending plans are equivalent to project portfolios, since the plans specify which projects will be undertaken.

At the highest level, the reason projects are done is that they have attributes that contribute to overall corporate objectives. The decision maker, when evaluating projects with different attributes, can define measures that allow him to trade-off competing values. This trade-off is often done implicitly. The decision framework described below, which is the basis of the method we propose, makes this trade-off explicit.

The explicit trade-off procedure is based on combining three kinds of measurements. First, each project is described with respect to a collection of attributes. These attributes are chosen by the utility company and may include such variables as cost, reliability, power quality, and overloads. Second, each attribute level is compared to the best possible level that can be achieved, thus creating an attribute scale. The scale of an attribute measures the degree to which an intermediate level of an attribute approaches the best possible level. In other words, the scale measures how much is lost by achieving less than the best. The third kind of measurement compares relative values of competing attributes. These relative values can be represented by weights. Thus, each project can be represented, scaled, and weighted based on the attributes provided. Not only is this a natural way to represent projects, it is also a means for decision-makers to understand better what they are basing decisions upon. The process of representation, scaling, and weighting becomes a natural way to consider alternative projects, if the attributes are well defined. In the methodology, we spend significant effort in developing attribute definitions, scales, and weights.

Indeed, the essence of this utility budget allocation problem is well characterized by Ralph Keeney: “We should spend more of our decision making time concentrating on what is important, articulating and understanding our values and using these values to select meaningful decisions to ponder, to create better alternatives than those already identified, and to evaluate more carefully the desirability of alternatives."[1]

The report has four sections. This section defines the problem to be solved. Section 2 documents the analysis of the problem and the resulting high-level design of the methodology. Section 3 documents the data gathering process design. The last section describes the required steps for implementation at utility companies.

The Business Problem

Building and maintaining the distribution infrastructure accounts for over 40 percent of total electric utility investment. Technical issues constrained by budget levels typically drive distribution planning decisions.

- The traditional objective of distribution system planning has been to maximize reliability within a fixed budget. Distribution planning focuses on the near-term customer demand. The major decisions involve timing, such as determining when to fix equipment that is causing or has the potential to cause reliability problems, and when to add capacity. At present, little attention is given to explicit quantification of (1) the consequences of doing or not doing a project, (2) the risks of deferring projects because of funding constraints, or (3) the long-term implications of resource commitments.

This planning approach was successful in a previous business environment. A series of changes have caused that environment to vanish. These changes include the following.

- Industry restructuring, already under way, is bringing about the disaggregation of the vertically integrated electric utility.
- For many companies, the funds allocated to the distribution side of the business have been reduced. Distribution engineers must build sound business cases for all significant projects.
- New customer needs, which vary by market segment, are beginning to emerge. An increasing number of customers are demanding higher reliability and improved power quality.
- Technology advances in information, communication, power electronics, materials, and distributed generation are providing new options, and potential pitfalls, for meeting customer needs.

Distribution asset management and infrastructure planning must respond to these changes. Today, and in the future, successful distribution planning requires building business cases to support technical engineering decisions.

[1] Ralph L. Keeney, *"Value Focused Thinking: A Path to Creative Decision Making."* Harvard University Press, 1992. pp 4 – 5.

The Analytic Problem

System engineering principles can create a sequence of actions that respond to a specific deterministic trajectory of conditions. However, traditional system engineering principles do not address uncertainty nor the need to develop strategies that take into account the facts that (1) the future is unpredictable, and (2) conditions will change over time. These facts require plans conditioned on future changes.

EPRI is designing new approaches that allow utility planners to develop strategies that respond to uncertain future needs and conditions. In these approaches, system engineering considerations are augmented with analysis methodologies that are based on economic objectives and that explicitly consider the effects of uncertainty on engineering and economic performance

One of the important features of the methodology is that it permits an extension of *optimality* to include objectives other than least cost. For example, it is possible to identify the policy that provides the best power quality or the greatest reliability or any combination of such criteria. This generalization is accomplished by incorporating a specific representation of the importance of each criterion, its relative weighting, and measuring the contribution of alternative strategies to each of the separate objectives. The basis of the representation is a model of the objectives, values, and attributes provided by each of the alternatives considered. These ideas are discussed further below.

Problem Statement

The problem addressed is the following:

Distribution utilities typically do not currently evaluate and compare all distribution projects. The value of doing a particular project is not compared with the values of competing projects. For the projects that are evaluated, utilities are not satisfied with the current procedures. Specifically there is a need for (1) consistent and objective evaluation of all projects, and (2) development of multi-year spending plans that reflect corporate objectives, budget and labor constraints, along with explicit consideration of the consequences of deferring specific projects.

System Objectives

The purpose of this section of the report is to describe further qualities of the distribution asset management methodology. These further qualities can be classified with respect to scope and characteristics. The scope of the methodology includes such considerations as how many projects it can handle and the phenomena it addresses. The characteristics of the methodology refer to how it responds to business considerations and issues. This section ends with a brief statement of what is required in order to apply the methodology successfully at a utility company.

Scope

Large number of projects

The number of projects that the methodology can handle is limited by the computational ability of the software/hardware implementation. There is no logical limitation with respect to number of projects.

Multiple performance measures

The methodology is designed to handle an arbitrary number of performance measures or objectives. The attribute structure, discussed below, should suggest the breadth of possibilities. It would be natural to design portfolios that are least cost or that are most reliable or that provide the greatest power quality. Any of these performance measures, or any combination of them, can be addressed in the methodology.

Analysis of uncertainty

A fundamental aspect of the methodology is that it treats uncertainty directly. Many approaches to uncertainty analysis begin with a deterministic methodology and modify it afterward. These approaches are generally misleading. This approach models uncertainty directly as part of the data gathering process.

Respond to budget signals

The annual budget, specified for each year over a finite planning period, is a fundamental constraint in this methodology. In Figure 2-2 (below) a feedback connection between the *Portfolio (of Distribution System Projects)* and *Budget* permits the portfolio selection not only to be determined by the budget but also to respond to changes in budget. The analysis is designed to modify the optimal timing of projects as a function of budget signals. The optimal portfolio is constrained to be within the budget for each year in the planning horizon.

Characteristics

Level playing field for all projects

The project selection process should be such that all projects compete fairly. The only reason for a project to be selected is that it contributes to the objectives of the project portfolio. No other characteristics should be able to force the choice. All projects are ranked on the same scales and all participants must agree on the measurement of the attributes provided by each project.

Resolve differences of opinion rationally

The methodology provides a system for resolving differences of opinion as well as determining which differences matter. The analysis of project choice will focus on attributes, objectives, and portfolio structure.

Defensible logic for peer review

It will be possible to explain in detail why a particular project or portfolio was selected. Reviews, like differences of opinion, will be based on attributes, objectives and portfolio structure.

Transparent analysis

Not only will the inputs be clear, but the analysis and selection criteria will also be readily apparent. It will be possible to explain why a selection was made. Further, it will also be possible to observe how changing the inputs results in different portfolios. The methodology attempts to eliminate all ambiguity regarding project and portfolio selection.

Completeness with respect to performance measures

The methodology is designed to address multiple performance measures for multiple objectives. It will be possible to compare solutions with respect to different or competing objectives. It is also straightforward to add objectives at some future time by modifying, as necessary, the attribute structure or the value assessment.

Bias- and error-free

The methodology is designed to minimize the effect of individual biases and to eliminate, as far as possible, any cognitive errors. It is difficult to eliminate deliberate misreporting or misassessments, but the transparency of the data and the analysis should tend to prevent such deliberate misstatements from going undetected.

Practically applicable with respect to cost and time

If the methodology is cumbersome and time-consuming, it will not be used. The initial data-gathering process will require significant efforts, but subsequent analyses should be relatively simple and timely.

Compatible with existing business practices

This criterion is virtually guaranteed since the structure of the attributes is based on utility inputs, and since the objectives are completely flexible and user-specified. .

Requirements

These are self-evident and are listed for completeness.

- Commitment to collect information
- Expertise in using system
- Expertise in analysis of candidate projects
- Access to policy makers
- Time and resources made available
- Commitment to use results

2
ANALYSIS AND HIGH LEVEL DESIGN

Analysis

This section presents a logical description of the solution to the problem stated above. The solution to that problem is a process that takes a collection of inputs and transforms them into the required outputs. The logical description of the solution reveals what the solution is supposed to do, rather than discussing how the problem will be solved.

Inputs

The inputs to the process are the following:

- Corporate budgets specified over the planning period.
- Projects to be evaluated. The projects should include possible alternatives, with particular attention to the consequences of delaying a project.
- An objective or set of objectives to be achieved by selecting various projects. Objectives might include minimizing capital costs, maximizing system reliability, maximizing power quality, or some combination of those and other goals of interest.
- A set of attributes provided by a project. Attributes are items that are readily observable or measurable that describe a project directly. Attributes might include the capital cost of a project, the number of outages per year that are expected to occur if the project is successfully completed, the thermal loading on equipment if the project is successfully completed, and other characteristics that describe or measure some (typically physical) condition that occurs because a project was successfully completed.
- A collection of values provided by a project. Values are measurements of the worth of an attribute or collection of attributes provided by a project or portfolio of projects. That is, an attribute provided by a project is transformed into a value by measuring the degree to which that attribute is important for achieving some goal. Goals might include improving service reliability, minimizing safety risk, controlling thermal loading, and achieving acceptable environmental impacts.

An integral part of the design of the methodology is the approach taken to determine attributes, assign values, and measure objectives. That is discussed further in Section 3. below.

Outputs

The methodology provides the following outputs:

- Project rankings, such that all projects are placed in priority sequence, will be identified.
- The optimal portfolio of projects over the planning period will be specified.
- The optimal timing of projects, specifying when to start, or, equivalently, how much to delay, each project will be determined.
- A measurement of the value of additional budget, which will take into account which additional projects can be done if the budget were to increase, and which would be delayed or dropped. (Note that additional budget could change the optimal portfolio and the optimal timing of projects that were selected initially.) The contribution to the objective of additional budget will be specified.
- The risks associated with the optimal strategy will be measured.
- The costs of the optimal strategy, both capital and operating, will be measured.
- The profits provided by the optimal strategy will be measured.

Transformation Processes

The transformation processes are designed to create the outputs from the inputs. There are four logically necessary transformation processes. The first takes the attributes, values, and objectives and transforms that data into measures of value or benefits. The purpose of the second transformation is to map the collection of possible projects and alternatives into budget requirements. In the third transformation, benefits and budget requirements are traded off to determine the project portfolio, a collection of projects and their timings. The fourth transformation converts a change in budget to the corresponding change in the project portfolio. These transformations are implemented in the programs and routines of the methodology.

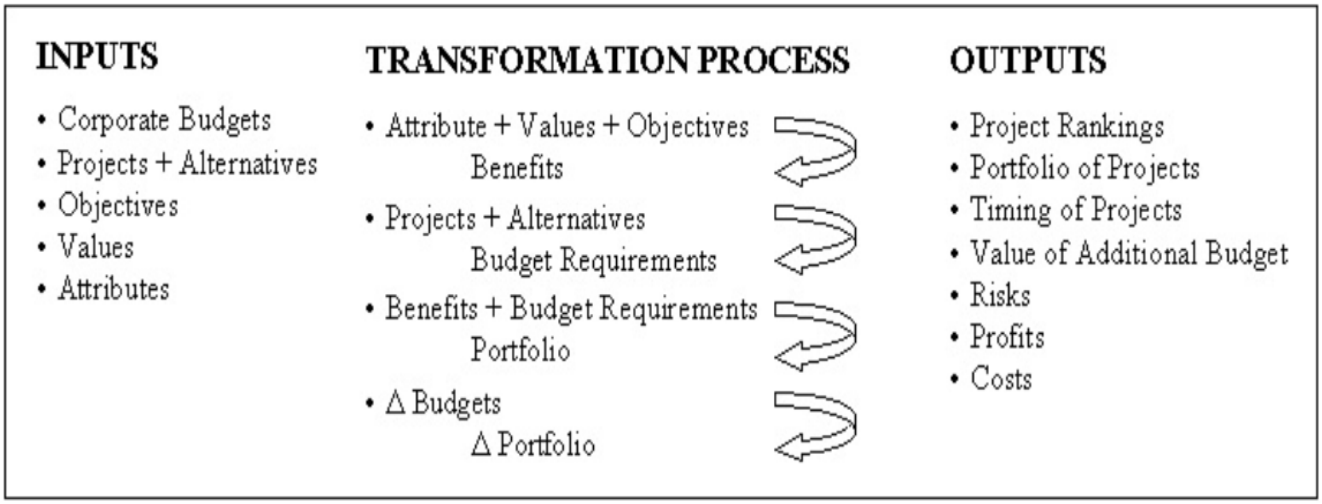


Figure 2-1
Inputs, Outputs and Transformations

High Level Design

The design of the methodology is presented in the flowchart shown by Figure 2-2. The user inputs are noted in the rectangles at the left of the diagram. These include, as noted above, the specification of projects and alternatives, the attribute levels provided by the alternatives, the values associated with the attributes, and the objective to be achieved by the optimal portfolio. The budget specification is an input on the right hand side of the diagram.

At the heart of the design are the two analytic modules, Project Analysis and Portfolio Design. These two modules result from the fact that the methodology performs its analysis on two levels.

At the individual project or local level, the Project Analysis module determines the optimal timing of a project with respect to local budget constraints. Optimality is based on values of the attributes provided by the project. At the system policy or global level, the Portfolio Design module combines the optimal timing of projects and the overall budget constraints into a portfolio of projects that satisfy the constraints and are optimal with respect to the objectives.

The design indicates two feedback loops. There is an internal feedback loop between the Portfolio Design and Project Analysis modules which adjusts the optimal timing of each local project in the Project Analysis module in order to satisfy the optimality and feasibility conditions required by the Portfolio Design module. The feedback loop is actuated by budget signals and rationing with respect to satisfaction of the objective. The external feedback loop is based on user modifications to the budget specifications or the projects and alternatives under consideration, or the objective function. The purpose of this feedback loop is to permit the user to analyze the changes that would result in the optimal portfolio if budgets were changed, projects were added or dropped, or if the objective was changed. This last feedback loop responds to requests for specific capabilities by funding companies.

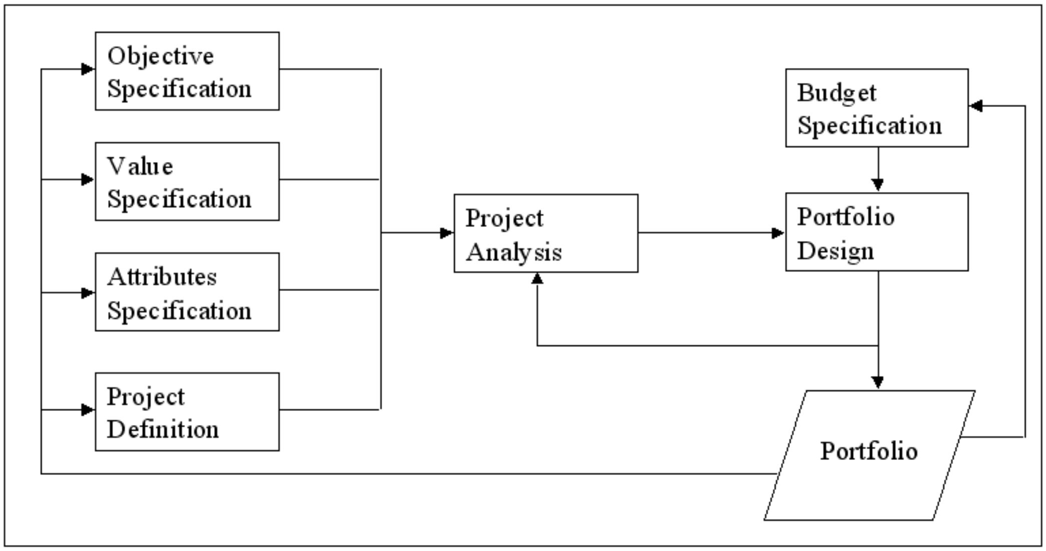


Figure 2-2
System Design

3
MEASURING PROJECT VALUE – DATA GATHERING

Data gathering must establish three things: objectives, values and project attributes. Objectives specify what the portfolio of projects is intended to accomplish, at a high level. It is natural to express the objectives of the portfolio as minimizing or maximizing some important, measurable aspects of system performance. Values capture the relative importance of competing objectives. Specification of values is important because not all projects can satisfy all objectives, hence tradeoffs are fundamental to portfolio design. Project attributes describe the characteristics of each project that measure the degree to which a project contributes to the attainment of objectives.

Some of these ideas are illustrated in Figure 3-1. The figure describes the first two levels of an attribute tree that was developed by the utility / EPRI team. Improving System Performance is the objective for the portfolio of projects. The value of this attribute is a function of four lower level attributes, Net Revenue, Power Quality, Safety, and Reliability. Each of these attributes may be thought of as a separate objective.

Figure 3-1 indicates that System Performance is a function of how well the portfolio achieves the lower four objectives. The lower four objectives are combined based on their relative importance in achieving overall System Performance. The relative importance is measured by a set of weights, and the degree to which each of the lower objectives is satisfied is measured by an additional set, not shown, of more detailed project attributes.

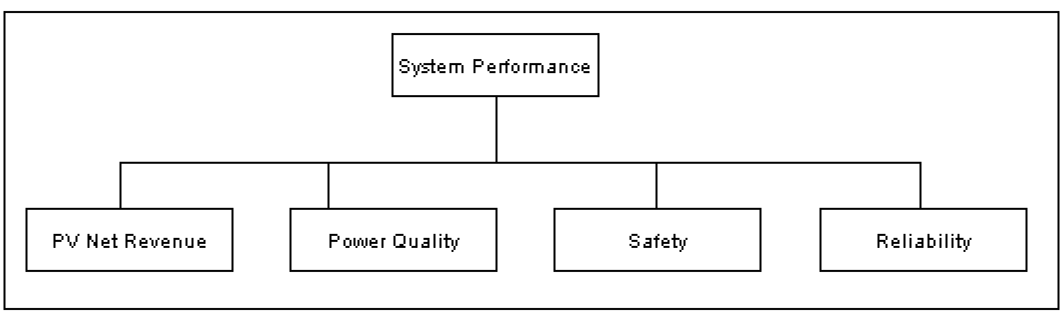


Figure 3-1
Attribute Specification: Objective Level

This section has three parts. Data Requirements, is a description of measurements that must be made in order to implement the high-level design. Assessment Principles, is an outline of the assessment principles that are used for company-specific detailed design and implementation. Data-Gathering Design, is a description of the results of the data-gathering design.

Data Requirements

There are several aspects of the data-gathering process that are important to highlight. These aspects define what is sought in the data-gathering. In this subsection we describe the required specification of objectives, attributes, and consequences of project alternatives,

Specification of objectives

The objectives of the portfolio must be specified as a function of attribute levels. It is natural to express the objectives of the portfolio as maximizing or minimizing some important, measurable aspect of performance. For power delivery, several companies have identified the overall objective as maximizing System Performance, subject to budget and other constraints. We also recognize that System Performance is a function of other objectives such as Safety, Changes in Net Revenue, Power Quality, and Reliability. This structure allows the System Performance objective to be varied, depending on the relative value of each of the five lower-level objectives. This is discussed further below.

Analysis of tradeoffs among competing objectives

Since not all objectives can be met by all alternatives, and since not all objectives are equally important, it is natural to capture the relative importance of competing objectives. The analysis of such tradeoffs is expressed in a set of attribute weights that express the higher-level attribute as a weighted sum of the lower-level attributes. For example, in Figure 3-1, System Performance is a weighted sum of the values for Net Revenue, Power Quality, Safety, and Reliability. As the weights vary, the optimal portfolio varies. Thus, the analyst may use the methodology to investigate the consequences of various tradeoffs among competing objectives.

Specification of actual consequences of alternatives

Each project or alternative is designed to change some aspect of current performance, presumably with respect to the four attributes shown in Figure 3-1. The consequences of performing or delaying each project or alternative should be clearly understood with respect to those attributes. These are the actual consequences of selecting or rejecting a project. If important consequences are left out, then the collection of attributes must be expanded until all consequences are measured. The essential idea is that projects have consequences.

Specification of attributes that describe alternatives

The consequences of selecting an alternative can be described by the complete collection of attributes. The set of attributes must describe alternatives at the lowest level and consequences at the highest level. The attributes form a natural hierarchy. The essential ideas are that projects have both characteristics and consequences, both are expressed as changed attribute levels, and the characteristics are linked to the consequences. For example, a project attribute might be the average duration of a sustained outage. This is the consequence of the project for the system. The characteristic of the project is that it reduces the average duration of outages, compared with the behavior of the system if the project were not undertaken. Thus, one consequence of such a project is a changed value of Reliability, the higher-level attribute that has sustained outage duration as one of its component attributes.

Role of individual project experts

The performance of the project expert is critical to the performance of the methodology. The data-gathering process must promote accurate judgment and clear reporting. Ideally, all will agree on the values of the attributes describing a project. Differences should be resolved reasonably. The weighting of the higher-level attributes and the budget specification are properly the province of management. This separation of assessment responsibilities is a useful way to improve the quality of the output of the methodology.

Assessment Principles

An overview of the actual assessment and reporting procedures (which includes a discussion of the attribute scales and weights) that are used in the software implementation is presented in Section 4. The principles that support the design of the measurement procedures are described here. The following five principles specify how the data should be gathered and are included in this report for reference.

Principle of Measured Observations

For each attribute, the principle states that one must assess the consequences of any possible outcome, so that the range of outcomes must span the space of possible outcomes. The principle requires each attribute to be exhaustive. An example is the scale for outage duration, ranging from zero to several days.

Natural Units Principle

For each attribute, performance should be measured in natural units. Natural units are readily observable and measurable quantities, such as number of outages per year or average outage duration in hours. The quantities should be familiar to project planners. The natural units are converted to scale values that indicate the relative importance of different performance levels. The scaled values need not be proportional to the natural units. For example, the scale for outage duration might range from 0 for a 24-hour outage to 10 for a 0-hour outage (no outage), with an in-between value of 2 for a 1-hour outage. This would imply that it is four times more important to avert a one-hour outage (gaining 8 scale points) than it is to reduce a 24-hour outage to 1 hour (gaining 2 scale points).

Risk Assessment Principle

The principle requires that when lives are at stake, risks should be encoded directly, using either lotteries or expected values. For example, when assessing the risk to the public one should use a probability distribution on deaths and injuries, as opposed to stating any results with certainty.

Comparison Principle

If an attribute proves difficult to assess, it may be possible to identify a proxy, so that the actual consequences of the attribute can be related to known consequences of another attribute. A typical example is the socioeconomic impact of a project. The proxy for the attribute can be taken as the intrusiveness of living in certain conditions, such as a crowded, noisy neighborhood, or next to a three-shift factory, or next to a city dump. The intrusiveness can be measured naturally by the number of complaints received per week. The constructed scale can then be based on the number of complaints received per week. Thus, the principle recommends the use of a proxy.

Principle of Relative Importance

The principle defines the way that weights can be specified. There are two parts to the principle. Part 1 requires assessment of the relative importance of moving from the worst to the best outcome for any two attributes, which specifies the relative importance of the full spans of the constructed scales. Part 2 identifies the indifference point between the full span of the relatively less important span and a partial span of the more important full span. Since both spans are measured in units of the constructed scales, the weights are in the inverse ratio of the partial to full spans.

Data-Gathering Design

Attributes

Figure 3-2 shows an example, taken from an actual study, of a complete set of attributes in a tree structure. Each project is scored based on the contributions that the project makes to attainment of the objectives. As discussed above, the project score is a function of the scores for four lower-level objectives: PV Net Revenue, Power Quality, Safety and Reliability.

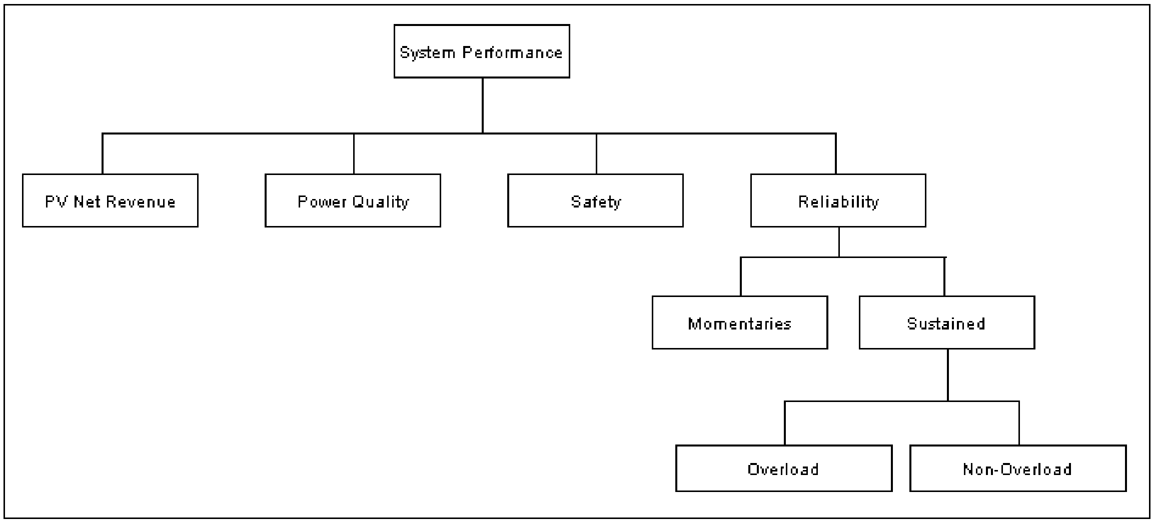


Figure 3-2
Complete Attribute Specification

In summary, a project is valuable because it provides levels of valued attributes. In other words, the attributes are categories of things that are valuable, such as reliability or safety. The level of an attribute measures the degree of satisfaction provided. The attribute structure, Figure 3-2, reveals how attributes of projects are combined into system objectives. For example, the project attribute *number of sustained outages per year experienced by residential customers* is an attribute of the system objective *reliability*. A project's performance with respect to number of sustained outages experienced by residential customers -- which may be a number, such as 22 per year -- contributes to the value of sustained outages, which, following the structure upwards, contributes to the value of reliability, which in turn contributes to the overall objective system performance

Indeed, the figure indicates that many attributes can be structured, such that a higher level attribute, such as reliability, is composed of lower level attributes, such as momentary outages, sustained outages, and overloads. Each of those in turn may consist of lower level attributes, such as several types of overloads. The structure is represented conveniently as a tree. The structure also guides assessment of project attribute levels and relative importance of attributes, as discussed below.

Scales

The level of each attribute provided by a project, or as a result of doing nothing, is specified by the user in *natural units*. Natural units vary depending on the attribute. The natural unit of sustained outages is usually characterized as the number of outages per year. The natural unit of overload is a percentage. In some cases, natural units must be invented. For example, the natural unit of the safety attribute might be the pair likelihood and consequence. The main idea is that the natural unit of an attribute is what one observes.

The user must specify the natural units for each project, with respect to each attribute affected by the project. The details of this specification are determined in the detailed design and implementation that are specific to individual electric power delivery companies.

The relative importance of each level of a particular attribute is measured by the *scaled value.* The scaled value is a number from, say, 0 to 10 points, such that the value of moving from one attribute level to another is proportional to the difference in scaled values. Generally, moving from worst to best is worth all 10 points on the value scale, if the best is set at 10 and the worst at 0. Moving from worst to some intermediate level will generally receive less than 10 on the value scale, and will be the difference between the scaled value of the intermediate level and 0. Moving from that intermediate level to the best will also generally receive less than 10 on the value scale, and will be the difference between 10 and the scaled value of the intermediate level.

The user must specify the scale values for a set of levels of each attribute. A discrete set of scales, corresponding to a discrete set of natural units, must be used. Intermediate values are found by linear interpolation. An example of constructing a value scale for outage duration is shown in Figure 3-3.

Value Scale	Natural Units
10:	None
9:	< 1 hr.
8:	1 - 2 hr.
6:	2 - 8 hr.
4:	8 - 12 hr.
3:	12 - 24 hr.
1:	1 - 3 days
0:	> 3 days

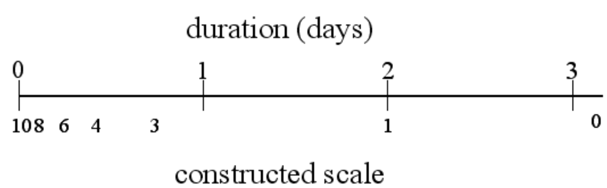


Figure 3-3
Value Scale Example

Weights

The relative importance of each attribute in the collection is measured by a set of weights. The relative importance of attributes is based on the relative value of moving from the worst level of the attribute to the best level of the attribute. Consider a situation where there are only two attributes. Suppose that the scaled values of the natural units of each attribute vary from 0 to 10. Then, moving from worst to best level of each attribute receives 10 on the value scale for each. That does not mean that each movement is equally valuable. Suppose it is twice as valuable to move the first attribute from worst to best as it is to move the second. Then the weights are in the proportion 2:1. This can be expressed as either the pair of weights (100, 50) or (2/3, 1/3).

The score of a project is the weighted sum of the scaled values provided by the project. In the example above, the weighted sum is either 1500 or 10, depending on which weighting scheme is used. Projects are selected based on the score.

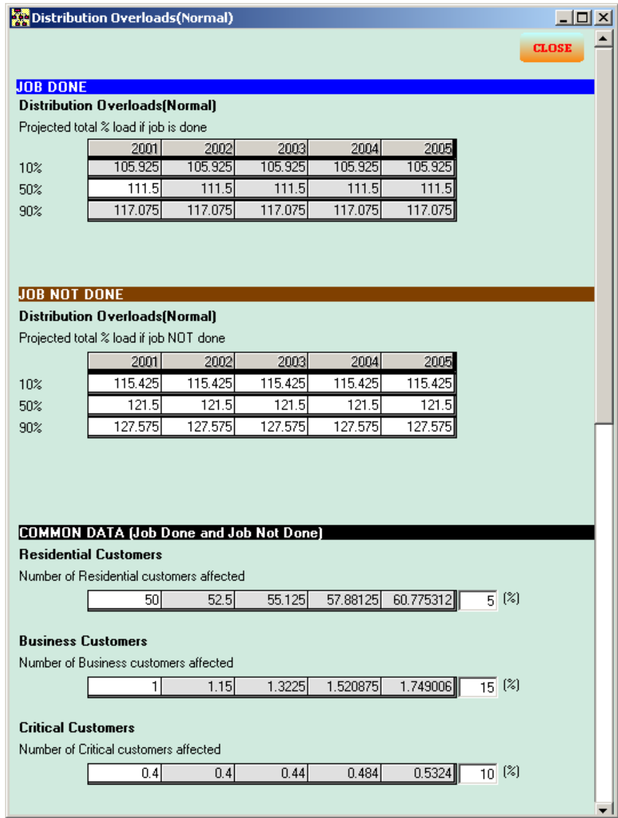
The weight of each attribute is assessed directly, with reference to the attribute structure, Figure 3-2. The assessment procedure for attribute weights begins at the "deepest" level of the attribute tree. Consider Sustained Outages. As indicated in Figure 3-2, this attribute is composed of two lower-level attributes, Outages caused by Overloads and Outages caused by Non-Overload events. The relative importance of moving from the worst to the best level of each of these lower-level attributes is compared. The most valuable change is given 100 points, and the others are scaled relative to that value. The most valuable one represents the next higher level attribute, i.e., Sustained Outages. At that next level, that single change is compared to a similar change for Momentary Outages. The most valuable between these changes is given 100 points, the other is scaled accordingly, and the most valuable one represents the value of Reliability, at the next higher level. Finally, the weights for the four top-most attributes are determined with the more valuable one receiving 100 points and the others valued accordingly. This completes the assessments.

The basis of the procedure is that, at any level, attribute changes from worst to best levels are compared, the most important receives 100 points, and the most important change is promoted to represent the attribute at the next higher level. The procedure repeats until the top level is completed. This scheme has proven to be the most appealing for this type of exercise. It is mathematically equivalent to the more traditional way of ranking using weights that sum to one at each stage.

Project Data

The attributes, values, and weights describe the data and logic that must be assembled so that projects can be described and valued on a consistent basis. We now turn to methods for describing individual projects. This is a fundamentally important data gathering step and considerable effort has been spent to date to design and test the approach for project reporting. There are three aspects to the project reporting procedure. First, the consequences of undertaking a project must be described with respect to the lowest-level attributes in the attribute structure (Figure 3-2). Second, the consequences must be reported over time, for each year in the planning period, assuming that the project began in year 1. Third, the consequences of doing nothing must be specified, in terms of the attributes, for each year in the planning period. Comparing the dynamic behavior of the attribute levels provided by the project and those which would occur if nothing were done will permit the analysis of the consequences of delaying a project. Analyzing the consequences of delay is one of the underlying goals of this methodology, since a critical decision variable is project timing.

An example of project data input (from a utility implementation) is given below. This input form was created by the utility using the Project Prioritization database software.



Distribution Overloads(Normal)

CLOSE

JOB DONE

Distribution Overloads(Normal)

Projected total % load if job is done

	2001	2002	2003	2004	2005
10%	105.925	105.925	105.925	105.925	105.925
50%	111.5	111.5	111.5	111.5	111.5
90%	117.075	117.075	117.075	117.075	117.075

JOB NOT DONE

Distribution Overloads(Normal)

Projected total % load if job NOT done

	2001	2002	2003	2004	2005
10%	115.425	115.425	115.425	115.425	115.425
50%	121.5	121.5	121.5	121.5	121.5
90%	127.575	127.575	127.575	127.575	127.575

COMMON DATA (Job Done and Job Not Done)

Residential Customers

Number of Residential customers affected

50	52.5	55.125	57.88125	60.775312	5	(%)

Business Customers

Number of Business customers affected

1	1.15	1.3225	1.520875	1.749006	15	(%)

Critical Customers

Number of Critical customers affected

0.4	0.4	0.44	0.484	0.5324	10	(%)

Figure 3-4
Example of Form for Project Data Input

4
DETAILED DESIGN AND IMPLEMENTATION

In the previous sections we described the methodology that underlies the project prioritization decision framework. Detailed design and implementation are company specific. This section summarizes the steps required for implementation. The purpose of this section is to indicate what is required of companies that wish to apply the methodology. EPRI strategy for implementation is to provide the project prioritization software to companies that have created, with EPRI support, the appropriate data sources, data gathering procedures, and administrative responsibilities.

Scope of Application

The first implementation step is to establish the scope of the problem for application of the Project Prioritization methodology. We have found it helpful to begin by formally stating the problems that the company wishes to solve. A typical problem statement was given above (1-3). Additional problems that companies have posed include the following.

- Planners do not have a satisfactory quantitative method to allocate budget. Nor do planners know how best to respond to changes in budget.
- There is no satisfactory quantitative method to resolve differences of opinion about budget allocation.
- The current annual budget process is not forward-looking. The time horizon of the budget planning process is too short and multi-year consequences of decisions are not considered quantitatively.
- Planners do not know how to communicate or specify to the company corporate level decision-makers the effects, including risks and rewards, of changes in budget. Further, it is not known how best to quantify risk.
- Planners do not know how best to respond to corporate choice of risk level.
- Planners do not know how to select projects according to strategic alternatives.
- Past practice specified separate budget categories. Now, all projects compete. The problem is to determine how different projects can compete fairly. Some aspects of this problem are related to the different project types (IT, advertising, customer connection, etc.).
- The company does not have a uniform financial measurement of the consequences of selecting or deferring projects.
- No method currently provides any *ex post* validation. Planners do not know whether the benefits or risks of projects were as claimed.

The advantage gained by a precise statement of the problems present in a company is that the statement makes clear what the new methodology is supposed to accomplish. The collection of problems to be solved serves as a guide for the design and implementation team, which includes both EPRI and company personnel.

In addition to the problems statement, various parameters associated with the methodology and the data required to describe projects must be specified. Although it is useful to define the parameters and data requirements at this stage, the decisions made here are often reviewed and revisited at subsequent steps. Among the items specified that determine the scope of the system are the following.

- *Classes of competing power delivery projects for consideration by the project prioritization methodology – all or some subset*. Some projects are not considered candidates for deferral and do not enter the competition. Some companies must consider the degree to which electricity and gas projects compete for the same budget.
- *Planning period for budgeting purposes*. This is an important variable, since it determines how much data must be provided. We define two time periods. The shorter time period, at least two years, and preferably (our current default) five years, known as the deferral period, is the time over which the most precise data that describes the behavior of projects is supplied to the project prioritization software. The project prioritization methodology will defer projects up to the end of this period. The longer time period, often twenty years, is a terminal time for the planning period and represents the period over which projects will have a useful lifetime. The economic consequences of selecting projects, such as risks, deferral of planned capital investments, or long-term cost savings, among other considerations, are described in summary fashion when such consequences occur between the shorter time period and this terminal time. The choice of terminal time is somewhat arbitrary.
- *Budgets that will be allocated based on the new methodology*. At minimum, the capital budget should be specified for each year during the deferral period, the shorter of the two time periods selected above. In addition, the operating and maintenance budgets can be specified annually. It is assumed that these budget constraints are what determine the total allowable cost of the project portfolio in any year. Further, labor constraints can be specified, so that some guidance can be given to creating hiring plans consistent with the project portfolios.

These considerations comprise the scope of application of the methodology. Thus, the scope of application is described by four items: problem(s), projects, planning period, and budgets.

Attribute Specification

The purpose of this step is to describe in a formal sense why projects are undertaken and what benefits projects provide. In our experience, the reasons for undertaking projects and the benefits projects provide vary across companies, although there are some important similarities. The Project Prioritization methodology defines *project attributes* as measurable quantities that describe the benefits or consequences provided by projects.

There is not a one-to-one correspondence between attributes and reasons for doing projects. Therefore, we find it useful to list the reasons that projects are undertaken in detail. Such reasons as connecting new customers, increasing reliability of poorly performing feeders, and replacement of aging equipment are typical of the reasons found on such a list. Then, we go deeper and determine what measurable quantities describe conditions before and after undertaking a project. These quantities are the attributes. For example, a measurable consequence of adding new customers is a change in revenue to the company. Thus, change in revenue is an attribute of a project. Similarly, CAIDI is a measure of how well a feeder is performing, so the change in CAIDI is one measure of how valuable a project that improves a feeder might be. Hence, CAIDI could be an attribute. A typical attribute specification was given above (Figure 3-2, p. 3-4).

The task of defining the attributes is best accomplished over a set of joint meetings of EPRI and company personnel. The process is typically initiated in a multi-day workshop facilitated by the EPRI team. Indeed, we have successfully combined the specification of scope and the initial discussions of the attributes in that first workshop.

After the attributes are defined, four items remain to be determined. These are (1) how attributes are measured (in natural units); (2) how different levels of an attribute are compared; (3) how different attributes are compared; and (4) how a project is valued. As noted in chapter 3, above, the attributes are measured in natural units; different levels of natural units are compared by an attribute scale; different attributes are valued relative to each other by specifying weights; and a project is valued by adding the weighted scaled values of all the attribute levels.

We think of the process required to determine the attributes, scales, weights, and project values as following a “V”, from top left to bottom center to top right. At the top left of the “V” the reasons for doing projects are described. These reasons are not measurable or comparable directly, so one proceeds down the left branch of the V towards the measurable attributes at bottom. The deepest analysis consists of defining the actual attributes and their natural units. These are the items that can be reported by project designers and field personnel. Therefore, one subtlety in attribute specification is that the attributes and their natural units must be actually measurable and reportable by company personnel or found in company databases.

The top right of the “V” represents the value or score of a project. This score is a function of the attributes provided by the project; or, more precisely, the value of changing the attribute levels from their current state to the preferred values provided by the project. Moving up the right branch of the “V”, the attribute levels are scaled, so that the relative importance of changing the attribute level, compared with moving from the best value to the worst value, is measured. Often, the scale is nonlinear, indicating decreasing marginal returns as the best value possible is approached.

Further, some attributes may be combined hierarchically, as indicated in figure 3-4. This means that the relative importance of a single attribute may not be directly related to all other attributes. In such a case, the importance of an attribute depends on how it influences the behavior of a higher-order attribute. Returning to the “V” representation, moving further up the right branch, the lower-order attributes are combined by determining their relative importance. The relative importance is determined by weights. The value of a higher-order attribute is a weighted sum of the scaled values of the lower order attributes. In figure 3-4, the value of Sustained Outages is the weighted sum of the scaled values of the Overload and Non-Overload attributes. The value of Reliability is the weighted sum of the scaled value of Momentaries and the value of Sustained Outages.

At the top of the "V", the weighted sum of the values of the highest-order attributes is the value of the project. Thus, in figure 3-4, the Project Score is the weighted sum of the scaled values of the Present Value of the Net Revenue, Power Quality, Safety, and Reliability.

There can be many subtleties involved in specifying the attributes and the values of a project. The specific attributes and their combination dictate the degree of difficulty of the tasks. Hence it is not possible to catalog all the issues in this report. Nevertheless, we can identify the following issues.

- Natural units must be readily measurable.
- Attribute levels in natural units should be described using uncertainty assessment methods. EPRI will guide the development of methods for capturing the uncertainty in attribute values. These are both attribute- and company-specific. The reason for requiring this kind of reporting is to incorporate uncertainty into the Project Prioritization methodology in the most direct and natural way.
- Hierarchically related attributes are combined either by weighting lower-order attributes or by specifying analytic functions that perform the combination.
- Scales must capture the value of changing attribute levels from worst to the level assessed, relative to changing from worst value to the best.
- Scales are nonlinear when the marginal value of a given change in natural units is variable. One must be particularly sensitive to this near the extremes of the attribute.
- The scale of one attribute does not influence the value of another.
- Weights compare the value of changing attributes from their worst to their best levels.
- Weights can be dynamic – they can be changed over time to reflect changing corporate strategy.
- Sensitivities and alternative strategies can be expressed by changing weights.
- Weights can be thought of as measurements of corporate-level objectives.

In sum, then, at the conclusion of this step, the following tasks have been accomplished by the EPRI team and company personnel.

1. We have identified the relevant attributes for measuring project performance.

2. We have created a logical attribute structure. The structure combines lower-order attributes into higher-order attributes, such that the project score is directly based on the values of the highest-level attributes.

3. We have identified practical measures for quantifying each attribute, including uncertainty (natural units).

4. We have specified the relative values of different levels for each attribute (scales).

5. We have specified the importance of each attribute relative to one another (weights).

Software Implementation – Administrator Setup

The Project Prioritization software is first implemented at an administrative level within a company. The project prioritization methodology design requires an administrative function that is different than the data reporting function. In particular, the administrator controls the attribute hierarchy, the attribute scales, and the attribute weights. The administrator setup implements the attribute structure as a database system.

There are several reasons for separating the administrative and the data-gathering (project reporting, as compared to project scoring) functions. The project reporting function should be based only on the most accurate assessment of project attributes. "Gaming" the system must be avoided. Therefore, those that report project data should not be biased, even unconsciously, by knowledge of attribute scales or weights.

EPRI typically creates the database structure and trains the utility administrator to use the administrative level software. This step requires:

- Identification of the database language to be used (e.g., Access, Oracle).
- Implementation of a database system based on the Attribute Structure.
- Definition of the project input forms for the observable measurements.
- Testing the project information system.
- Writing a company-specific user manual.

Software Implementation – Project Data Input

After the administrator level of the system is set up, the system is ready for use by planning engineers. The basic requirement of the system is that appropriate planning engineers must enter attribute data for all proposed projects that fall under the scope of the system. This step is facilitated by careful consideration, in step 2, of the measurability of project attributes. It is not impossible that the attribute definitions and reporting requirements are revisited in this step.

The Project Data Input phase entails the following tasks.

- Train company managers to use the system.
- Input project data by the planning engineers.
- Budget inputs by the company administrator.
- System testing.

Analysis and Reporting

In this step, the system is used to develop a multi-year project portfolio based on the analyzed projects and subject to the budget constrain. EPRI and company personnel will jointly analyze the results to be sure that the Project Prioritization software is providing portfolios that respond to company needs. This requires:

- Developing a project portfolio using base-case assumptions.
- Performing sensitivities with respect to key uncertainties
- Performing sensitivities with respect to alternative objective specifications
- Performing sensitivities with respect to changes in budget.

As part of the Analysis task, the data required to perform the tasks above must be specified. In particular, the EPRI team will provide guidance with respect to setting up a complete base case and designing the sensitivity runs. The key uncertainties can be identified based on the base case output. Alternative objective specifications, which have likely been identified in the course of completing earlier phases, can be specified by varying attribute weights. This analysis can reveal how sensitive the portfolio selections are to changes in corporate strategy. Sensitivity with respect to changes in budget is a straightforward exercise, requiring additional software runs.

If requested, EPRI can help structure and write a report on the results of the initial analysis of the Project Prioritization methodology.

Schedule and Costs

Implementation requires a serious commitment by the company considering whether to use the system. Typically, implementation requires six to seven months to complete. The EPRI technical team will spend 70 or more person-days during this period and the utility team will spend an equal amount of time. For this effort, the company will have a superior system for allocating scarce resources and balancing project portfolios in a way that will maximize the value of expenditures. In many companies there are tens to hundreds of millions of annual dollars at stake.

Target:
Distribution Systems

About EPRI

EPRI creates science and technology solutions for the global energy and energy services industry. U.S. electric utilities established the Electric Power Research Institute in 1973 as a nonprofit research consortium for the benefit of utility members, their customers, and society. Now known simply as EPRI, the company provides a wide range of innovative products and services to more than 1000 energy-related organizations in 40 countries. EPRI's multidisciplinary team of scientists and engineers draws on a worldwide network of technical and business expertise to help solve today's toughest energy and environmental problems.

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