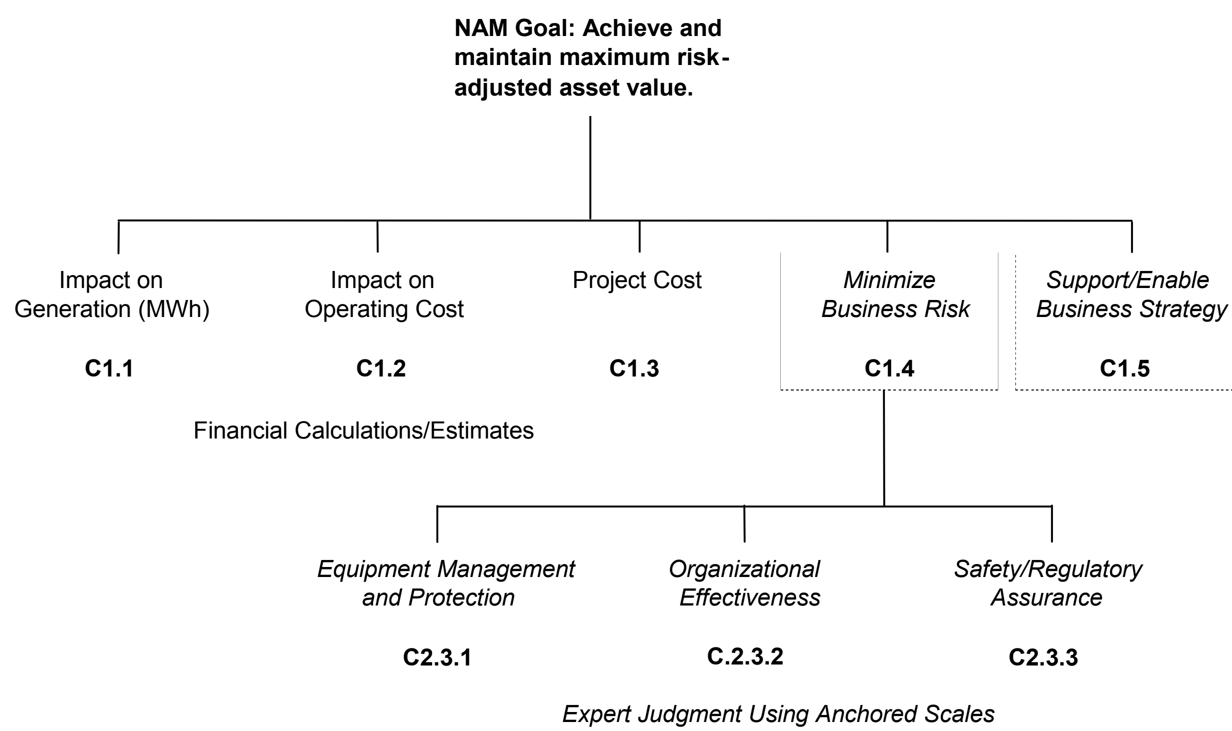
Project Ranking Method for Nuclear Power Plants

Prioritizing Proposed Capital and O&M Projects

Technical Report



Project Ranking Method for Nuclear Power Plants

Prioritizing Proposed Capital and O&M Projects

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REPORT SUMMARY

As the electric power industry becomes more competitive, it becomes ever more important to invest limited budgets only in projects that increase or protect a plant's value and profitability over its remaining operating term. This report describes a robust method that plants can customize to evaluate, rank, and select their O&M and capital projects.

Background

All nuclear plants have some kind of method for prioritizing or ranking proposed projects during the budget cycle. An EPRI survey showed that existing scoring methods are limited in terms of the categories of value they take into account. Generally, they focus on either financial or non-financial (qualitative) value but not both. A proposed project cannot be compared against all others using the same criteria. Accordingly, current methods tend to be incomplete, perhaps overly influenced by the advocacy of individual managers or perhaps not placing the appropriate weight for decision making on the most appropriate factors.

Objectives

To develop an improved method nuclear plant asset managers can apply to rank proposed plant projects on the basis of their contribution to enhanced nuclear plant asset and portfolio value to owners, shareholders, customers, and other stakeholders.

Approach

An expert in rating and ranking proposed projects in industry and government examined currently available techniques and identified the Analytic Hierarchy Procedure as most appropriate for rating and ranking proposed power plant projects. Management experts then identified a hierarchy of factors to be used as ranking criteria for projects that range from physical plant changes to process changes, human and cultural effects, and technology advances. Next they formulated two ways to assign weights to the factors, one based on a plant's quartile of performance among all plants, the other based on the relative importance of a set of critical performance indicators defined by NEI as part of its Standard Nuclear Performance Model.

Results

The project ranking method proposed by this study applies to all types of projects of intermediate size. Smaller projects do not warrant application of this formal method and larger projects warrant more in-depth financial analysis. Also, the method need not be applied to regulatory projects that are absolutely necessary. The method accounts for multiple financial and non-financial factors including impact on generation, impact on operating cost, project cost (investment), business risk (equipment management, organizational effectiveness, and organizational effectiveness), safety/regulatory assurance, and long-term business strategy. Factors are scored by constructing and using “anchored scales” that allow different users to consistently rank proposed projects. The overall score used to rank projects uses conventional “pairwise comparison” for combining weighted scores for all factors into the overall score used to rank projects.

EPRI Perspective

In the competitive era of nuclear power, the key to enhancing plant value is optimum allocation of resources. The ranking method proposed by this study incorporates best practices from literature and lessons learned from utility experience. Decision makers would benefit from relying on a more systematic method tied to corporate strategic goals. The method can be customized to suit each plant or fleet’s situation as viewed by upper management and creates a level playing field for ranking and selecting projects within budget constraints. EPRI is seeking a plant or fleet to collaborate in a pilot application of the method. Once lessons learned from the pilot are incorporated, software may be developed.

Keywords

Project ranking
Project prioritization
Asset management
Nuclear asset management

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1
INTRODUCTION

1.1 Background

All nuclear plants have some kind of method for prioritizing or ranking proposed projects during the budget cycle. Based on responses to a survey of current ranking methods, all plants review the financial aspects of some, if not all, projects.[1] Some plants first assign a project to one of a few different categories, e.g., regulatory or economic, then apply separate ranking criteria within that category. In these methods, proposed projects in a certain category may or may not be ranked against projects in other categories. At most plants, current methods appear to be limited to creating a single relationship between the proposed project and the type and amount of value it is expected to contribute to the plant. Because only a single value linkage is established, these methods focus on either financial or non-financial (qualitative) value but not both.

In general, current methods appear to lack a comprehensive assessment framework that links projects to asset value and addresses the multiple factors and interactions determining the integrated impact of a project. In some cases, a proposed project cannot be compared against all others using the same criteria (a level playing field). Accordingly, current methods tend to be incomplete, perhaps overly influenced by the advocacy of individual managers or perhaps not placing the appropriate weight for decision making on the most appropriate factors. Also, the methods are not easily extended from the plant to the enterprise (fleet) level.

1.2 Objective

The objective of this project is to develop an improved method nuclear plant asset managers can apply to rank proposed plant projects on the basis of their contribution to enhanced nuclear plant asset and portfolio value to owners, shareholders, customers, and other stakeholders (such as employees, regulators, and public). The improved ranking method needs to consider both the financial and non-financial value contributions of any proposed project. The improved ranking method also needs to be applicable to all proposed projects and be able to rank all projects simultaneously. Finally, it is important that the project ranking method can be consistently and readily applied by managers and plant personnel, and that ranking results are accepted as fair and credible.

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[1] This view is based on a review of project ranking methods currently used by selected utilities and information submitted by ten utilities in response to a Spring 2001 Nuclear Asset Management User Group survey of project ranking methods. See Larry Olah, "Project Prioritization," EPRI Proceedings: 2001 Nuclear Asset Management Workshop, EPRI, Palo Alto, CA: 2002, pp. 5-2 through 5-5 (1003049).

1.3 Desired Characteristics of a Ranking Method

A useful and effective ranking method must exhibit certain characteristics and implement specific design principles, which are described in this section. Our goal is to develop a ranking method that can be applied in a straightforward, consistent manner to all applicable projects and yield ranking results that incorporate the most significant dimensions of nuclear asset management. Both the temptation to overly simplify to ensure ease of use, and the inclination to add complexity to achieve rigor need to be resisted. The ranking method described in this report is intended to satisfy all of these requirements.

1.3.1 Scope of Application of the Ranking Method

Project Types

The proposed method must be able to rank the wide variety of projects that may be considered for implementation by nuclear asset managers. Such projects may include physical modifications to the plant including new equipment or replacement of major components, changes to maintenance practices, changes to plant operating parameters and policies, revisions of programs and processes with extensive interactions throughout the operating organization, information technology systems, training and organizational development initiatives, and new strategies for improving plant performance such as predictive maintenance and equipment life cycle management. The potential benefits of implementing these projects range from those that have proximate, quantitative/monetized effects to those that may have qualitative effects manifested over uncertain and extended time periods.

Project Size

While the ranking method must be capable of considering a wide range of projects, not all projects that may be undertaken at a nuclear plant will be ranked by the method proposed in this report. Large projects, particularly those that involve principally financial considerations and perhaps the very viability of the nuclear plant asset, should be the subject of a stand-alone business case and in-depth economic analysis. Examples include plant license renewal and reactor vessel head or steam generator replacement. Small projects also may be exempted based on plant/corporate policies, timing, minimal benefit to be gained by ranking, or other considerations that may vary considerably across the industry. The method proposed here applies mainly to intermediate projects.

Safety/Regulation

Projects that are *required* to assure the safe operation of the plant, or are necessary to meet a new or existing regulatory commitment, must be implemented regardless of their economic merit relative to other projects. It should be noted that this latter class of projects should be relatively small - it does not necessarily include projects that may contribute to or enhance the margins of adequately safe operations, or may support regulatory relationships. Such projects are rightfully subject to the ranking process where the process appropriately values and integrates the benefits of regulatory and safety factors.

1.3.2 Goal or Measure of the Ranking Method

Net Asset Value

Fundamentally the project ranking method must be grounded in a specified nuclear asset management goal or measure. The goal of asset management is to maximize net asset value in light of applicable risks. Intrinsic to this definition is a view that asset value should be based on performance that can be delivered consistently, i.e., with high confidence. This measure incorporates the desire to take advantage of opportunities to increase asset value with the need to protect value along the way.

Protecting Value

The ranking method must recognize the value of projects whose goal is protecting (in contrast to increasing) asset value. It is clear that, especially for plants whose current performance is near perfect, sustaining certain levels of performance throughout the operating term of a plant is as important as seeking opportunities for increasing performance and value. In our construct, protecting asset value is also the means for integrating the value associated with safety and regulatory performance.

Risks

Finally, considering risks recognizes that nuclear generation is inherently uncertain. It is a way of determining the value of performance consistency (a particularly important aspect of nuclear generation) and addressing project uncertainties.

1.3.3 Ranking Factors Used by the Method

The term *factors* is used in this report to refer to the ranking criteria used by the proposed ranking method. Multiple, independent factors, encompassing both financial and non-financial (qualitative) factors, will be used to rank projects. The factors will account for the wide variety of ways in which proposed projects can increase or sustain value at a nuclear plant. Factors will need to address project impacts that range from physical plant changes to process changes, human and cultural effects and technology advances. Clearly the measures associated with these various factors will vary and the project ranking method must attempt to normalize and rationalize these measures into a common basis to the degree possible.

The ranking factors will be assigned weights to reflect their relative importance, but the weights can vary from plant to plant or by categories of plants. This means that each plant will be able to specify the relative factors weights based on its individual circumstances or management policies. For example, for plants in the upper quartile of performance, sustaining value may be the dominant consideration since the opportunities for enhancing value are limited. For plants in the lower performance quartiles, both increasing and sustaining value may be important. In a separate area, cost performance, it is well known that plants may operate in different cost "regimes" due to vintage, geographical location and organizational philosophies. A plant that operates with a relatively high cost may not put a high weight on a cost factor if they believe they are already at or near the optimum cost level for their regime.

All nuclear organizations recognize or believe they have unique needs and circumstances. For example, there are differing types of owners with differing strategic objectives at various stages of restructuring to competition, or with differing risk tolerance. The ranking method must be flexible so that it can be tailored to each using organization’s specific needs. The ability to adjust the ranking factors and their relative importance provides a flexible approach that can accommodate each user organization’s specific needs and circumstances.

1.3.4 Other Considerations

Project ranking must address other considerations, such as project interactions and constraints. The proposed method recognizes that in the context of nuclear plants, there are many potential interactions and constraints among projects and the data associated with each project should include information necessary to assess them. In terms of constraints it is our experience that the dominant constraint of interest is dollars or budget. Other constraints such as available outage time, human or equipment resources, etc., are either not dominant or can be worked around. In terms of interactions, these may best be considered following ranking of the individual projects rather than as a dimension that should be optimized against. In other words, the proposed ranking method can identify any interactions but not include them into the ranking itself. This provides the appropriate balance between rigorous complexity and ease of implementation. It may be that a future evolution of project ranking could appropriately seek to optimize across these additional variables.

1.3.5 Variability in Asset Value and Project Impact

The value of a nuclear asset can vary over time, reflecting the variability of the asset’s underlying operating, cost, and market price contributors. Managers can control, or at least influence, some of these contributors. Typically nuclear projects are thought of as ways to increase the nominal or mean asset value. However projects may also contribute to preserving current level asset values by preventing performance degradation and volatility.

A proposed project may have estimated impacts on both the mean asset value and asset value range or confidence level. These estimated impacts are themselves subject to some variability based on the effectiveness of project implementation. For example, implementing a plant power uprate would be expected to increase the mean asset value based on increased generation output. The actual increase might be subject to some uncertainty associated with the detailed thermal hydraulic characteristics of the plant. In addition, some changes associated with power uprates, such as operating limits, could result in greater variability of plant operating performance. The net effect of the power uprate may be characterized by the expected value and a range plus or minus.

While consideration of variability in project effectiveness complicates the ranking process, its importance lies in the reality that often the best projects to implement are those that provide the highest *confidence* of a given value outcome - versus the largest contribution to mean value.

Nuclear managers often implicitly account for these multiple uncertainties based on their experience or "gut feeling." The challenge for a project ranking method is to provide a more explicit and structured approach.

1.3.6 Plant/Enterprise

Most project ranking occurs at the plant asset level. Many utilities own only a single plant with one or multiple units and thus can address projects at this one level. Increasingly though, the nuclear industry is consolidating and there are now a number of nuclear enterprises. The enterprise may be a nuclear business unit, responsible for a fleet of nuclear generating plants; a generation business, which has to consider both nuclear and non-nuclear resource requests; or the corporate level of an integrated energy company. These enterprises need to consider project ranking in the context of resource allocation across the plants and other management strategies to maximize the value of their portfolio. The ranking method developed by this project needs to be viable and useful for an individual plant but must also be extendable to the nuclear enterprise.

The enterprise context raises issues regarding how to rank projects across multiple plant assets and how to integrate with enterprise level financial analysis rules and capital allocation methods. Inevitably it also raises issues as to the degree of independence accorded managers of individual assets versus the need for control, consistency and enterprise-wide asset management. This report discusses the considerations involved in extending project ranking to the enterprise level, recognizing that individual enterprises may be sufficiently different to prevent a single approach from being necessarily preferred. Section 4 further addresses enterprise level considerations.

The result of project ranking methods at either the plant or enterprise levels is an input to the process by which capital and other resources are allocated to specific activities and investments. Allocation of capital resources will entail considerations beyond those used by the ranking method such as the balance among various uses and timing. For example, uses might include replacement of existing assets, investments that offer growth opportunities (and risks), strategic initiatives, investments required for safety or regulatory purposes, and whether capital is being directed to regulated versus unregulated business activities. In the current business environment, it appears that utility enterprises will be following conservative policies on capital investments and the availability of capital will be unusually constrained. Thus, flexibility in the timing of an investment may allow better alignment with the availability of capital and could add option-based value. (See Appendix C for a discussion of the use of options techniques, including real options, in evaluating nuclear projects.)

1.4 Overview of Ranking Method

The principles above were followed in constructing the ranking method described in this report. The method consists of three parts:

(1) Establishing an assessment framework (hierarchy, scales, and weighting factors) -- see Section 2. This is done by plant or fleet management at the beginning of each budget cycle.

(2) Implementing the ranking process (project screening, evaluation of scores, and ranking of projects) -- see Sections 3.1 through 3.6. This is done by project sponsors.

(3) Selecting and approving projects for implementation – see Section 3.7. This is done by management.

2
ESTABLISHING AN ASSESSMENT FRAMEWORK FOR PROJECT RANKING

The model for the plant level ranking method is an assessment framework that specifies the relationship and relative importance of certain factors contributing to nuclear asset value. The framework consists of the following elements:

- A multiple level hierarchy of factors contributing to a top level measure of overall project value,
- "Anchored scales" used to quantify scores for qualitative factors,[2] and
- Weights assigned to each factor indicating the factor's relative importance to project ranking.

2.1 Hierarchy of Factors

The structure of the assessment framework is consistent with one of the leading methods for project ranking: the Analytic Hierarchy Procedure (AHP).[3] The top of the hierarchy is total project merit and factors contributing to merit are decomposed hierarchically below. At each level, each factor for each project is evaluated and weighted. Results are combined based on the relative importance of each factor and the hierarchy relationships. The procedure used to combine the results is described in Section 3.4.

Consistent with the discussion of desired characteristics in Section 1.3, the hierarchy includes factors that address both benefits and costs of a project. Benefits are: (1) increased revenues associated with improvements to expected (mean) plant generation or preservation of revenues that would be lost without the project; (2) reduced operating costs (also on an expected or mean basis); (3) preservation and enhanced asset value through management of business risks and improved consistency of asset performance; and (4) addition of strategic value through current projects even though such value may accrue over extended time periods. Costs are: (1) project implementation cost and (2) any incremental operating or other costs that may be incurred as consequential costs. Thus the hierarchy includes factors that can be monetized (revenues and costs) and those that are largely qualitative (business risk and strategic factors). All factors will

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[2] "Anchored" means the qualitative rating statements for any given factor are sufficiently well-defined that, given the same input data, different raters would usually select the same rating. Rating statements are associated with numerical values between 0 - 10, producing the desired quantitative output. Sample anchored scales for selected ranking factors are shown in Appendix A.

[3] Joseph P. Martino, Research and Development Project Selection, John Wiley & Sons, 1995, pp. 15-23. The bases for choosing the AHP method for this work are discussed in Appendix E.

go through quantification and data normalization processes to derive a set of relative values that can be combined into an overall project score.

One of the significant advantages of this approach is that it integrates monetary analysis with approaches for quantifying non-monetary value. Thus it delivers an integrated answer - maximizing the use of valuable monetary inputs whenever they are available, yet not limiting consideration to only monetary value. Through pairwise comparison and data normalization, all value contributions are placed on a common scale, thereby allowing a comparison of monetary to non-monetary contributions. This applies also for those contributions that go toward managing risk and preserving asset value. The hierarchy is shown in Figure 2-1 and described more fully below.

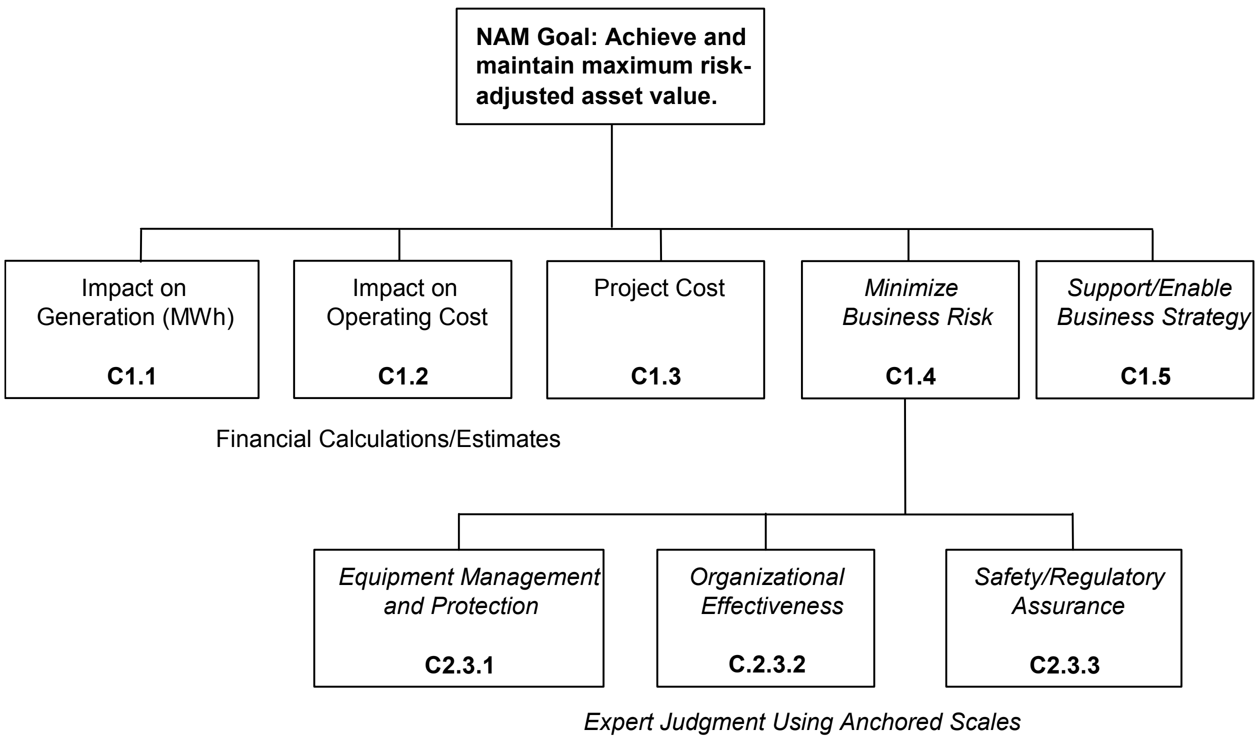


Figure 2-1
Hierarchy of Ranking Factors

2.2 Top Level Value Measure

The Nuclear Asset Management (NAM) goal is the top of the hierarchy and represents the desired focus and measure of project ranking. The measure of goal attainment includes both enlargement of asset value where possible as well as protection of existing value. Both components are subject to certain costs and business risks - risks that may be associated with undertaking specific projects (or not) and those intrinsic to the operation of nuclear plants. Asset value is also taken to be "total value" with respect to owners, shareholders, customers, and other stakeholders (such as employees, regulators, and the public). Total value includes safety (employee and public), financial, reliability, and environmental elements. Acceptably safe plant operation is most important. The project ranking method addresses this goal both inherently and directly via the Safety/Regulatory Assurance factor discussed later.

Below the NAM goal, the hierarchy is comprised of a first level, with five factors, and a second level, with three subfactors associated with the Minimize Business Risk factor. Each factor is annotated with an alphanumeric identifier which will be used later in conjunction with assigning weights. Factors shown in normal font are quantified using financial calculations and/or estimates. Factors shown in *italics* are quantified based on expert judgment calibrated against anchored scales.

2.3 First Level Factors

2.3.1 Impact on Generation (mWh)

This factor is associated with an increase in expected plant generation, i.e., the average or statistical mean of total megawatt hours (mWh) produced in a period. Revenue equals generation times the market price of power, which is not a separate factor because it is the same for all projects for a given plant.[4] Generation includes the effects of planned and unplanned outages, power level of the reactor, and heat rate. It is expected that projects involving plant equipment replacement/repair and/or management policies will have a large impact here since they are often directly linked to addressing generating losses (as measured by INPO's Unplanned Capability Loss Factor) or operating characteristics. The financial value of this factor should be calculated using a net present value (NPV) analysis of future revenues using accepted methods and assumptions.[5] The principal driver of value is the amount of incremental annual net generation, in mWh.

The following are four primary means of increasing generation:

> **Plant Power Level**: Recent experience has shown this to be a fertile way for asset owners to increase the nominal or rated capacity of their plants. Power level increases may require equipment modification/replacement, and changes to operating limits and policies.
>
> **Plant Efficiency**: This would include actions to improve the heat rate of the plant by eliminating heat losses, reducing fouling, calibrating equipment, etc. Note that because of the time dependent characteristics of efficiency, the future benefits of these actions may decay over time.

---

[4] Relative prices across generating assets and price volatility will be brought into the ranking analysis later when considering fleet and enterprise ranking issues. For an individual plant, higher power prices mean the revenue value of proposed projects will be higher relative to project costs.

[5] A different financial technique could be used. The important point is that the same financial technique be used to evaluate all proposed projects so that the results can be normalized and compared. See Appendix D for a discussion of financial evaluation techniques.

Operating Policies: Management actions taken to adjust the way the plant is operated, alone or in conjunction with other hardware changes, can reduce sources of lost generation. Examples include elimination of ramping prior to refueling shutdowns, changes to the fuel cycle, equipment testing frequencies, etc. Some or all of these may involve other performance tradeoffs (e.g., fuel costs) or require regulatory approvals.

Improved Reliability/Availability: Equipment modifications are probably the most active contributor to this branch and include repair, replacement and modification of plant equipment. Some of these modifications will be the result of life cycle management and equipment reliability decisions to mitigate potential equipment failure risks; others take advantage of new technologies.

2.3.2 Impact on Operating Cost

This factor accounts for identifiable reductions in expected operating costs and budgets.[6] The focus of this value contributor will be where project investments are used to achieve cost savings or efficiencies, such as investments in equipment upgrades or information technology (IT). Some projects, such as IT projects, may have a significant direct impact on cost through process efficiencies, staffing reductions, reduced errors and smaller inventories. Other projects, like equipment replacements, may result in reduced maintenance costs as an ancillary benefit to a primary goal of improved generating performance. The value of this factor should be calculated using a net present value (NPV) analysis of future cash flows using accepted methods and assumptions. Note that this factor considers only project benefits; it does not include the costs associated with implementing the project, which are discussed under the following factor. (For example, for life cycle management projects, future costs of additional preventive maintenance activities should be viewed as a part of project costs.)

2.3.3 Project Cost

This factor includes the initial implementation cost[7] associated with each project that is being ranked and any future incremental operating or other costs that may be incurred as part of the project (for example, additional preventive maintenance costs). The cost of the project is an important factor for several reasons. Cost is the price or investment for obtaining the benefits generated by the project; projects with better relative benefit/investment ratios or higher total net benefits may be preferred. In some cases the absolute cost of a project may be a consideration - smaller cost projects may be preferred due to risk, budget or other considerations. Incurring the project cost is essentially a certainty and one that comes prior to any benefit in asset performance (timing of costs and benefits impact on NPV). In some cases, project costs have some degree of uncertainty. As was discussed in Section 1.3.5, often the best projects are those with the greatest certainty, in cost and benefit, not those with the largest expected benefit. The value of this factor

[6] Operating cost is taken to be cash cost that is subject to plant management control or influence on a going forward basis, generally taken to be O&M, capital, and fuel.

[7] Project costs may be categorized as O&M or capital. Financial techniques, such as NPV, are often more concerned with cash flows (including tax effects) than cost category, i.e., they tend to treat all cash flow dollars the same.

should be calculated using a net present value (NPV) analysis of initial and future costs using approved methods and assumptions.

2.3.4 Business Risk

Business risk stems from a variety of contributors that may randomly change the actual plant generation and/or operating cost and therefore contribute to variability and uncertainty of plant asset performance. In a statistical sense, risk may be reflected in the variance or standard deviation of the performance outcome distribution, or in the degree to which performance can be delivered with high levels of confidence. Many of the projects that deliver risk benefits will be directed at process improvements, organizational performance and assuring safety. The value of this factor will be determined based on three second level factors discussed below in Section 2.4.

2.3.5 Business Strategy

Strategic value can take on a variety of meanings at different plants but generally will include those initiatives and priorities that primarily yield benefits beyond the current performance period, or benefits that may not be directly measurable in terms of asset performance. The strategic value branch is inherently the most qualitative and has potentially the broadest impact. It should be understood that strategies to improve the operating performance of the plant are not the appropriate focus of this factor, since such strategies are implicitly accounted for in the other branches of the hierarchy. Rather, this factor accounts for activities that may contribute to the longer term viability or competitive position of the plant asset or of the enterprise business. For example, at the plant level, NRC license renewal and securing means for spent fuel storage contribute to the long term viability of the asset, but do little (and may reduce) current asset performance. At the enterprise level, developing increasingly standardized management and work processes across multiple plants may support a strategy to acquire and assimilate more plant assets, increasing enterprise value. The specific mechanisms of enabling and supporting such strategies will be generally plant and enterprise specific. The value of this factor should be determined based on an assessment of each project against an "anchored scale" for strategic impact. A sample scale for this factor is included in Appendix A.

2.4 Second Level Factors

The first level factors assure that the most important contributors, properly weighted, are used in the project ranking process. However the determination of how proposed projects may contribute to each of the factors requires further development of the structure below the first level for certain factors. The proposed assessment framework has second level factors for Business Risk.

The Business Risk branch of the hierarchy reflects primarily actions that improve and ensure performance of equipment, of the organization, of individuals and of key management and safety processes. While there are a variety of ways to organize this set of contributors, we have focused on three key areas: equipment reliability, organizational effectiveness and regulatory assurance. These are the pillars of consistent, safe and efficient nuclear operations. It is also clear that these factors are closely related; the fact that they reside within the same branch helps to assure that the contributions of projects will be captured without double counting or undue need to draw fine distinctions between specific factors. The second level factors for Business Risk are shown in Figure 2-2 and described below.

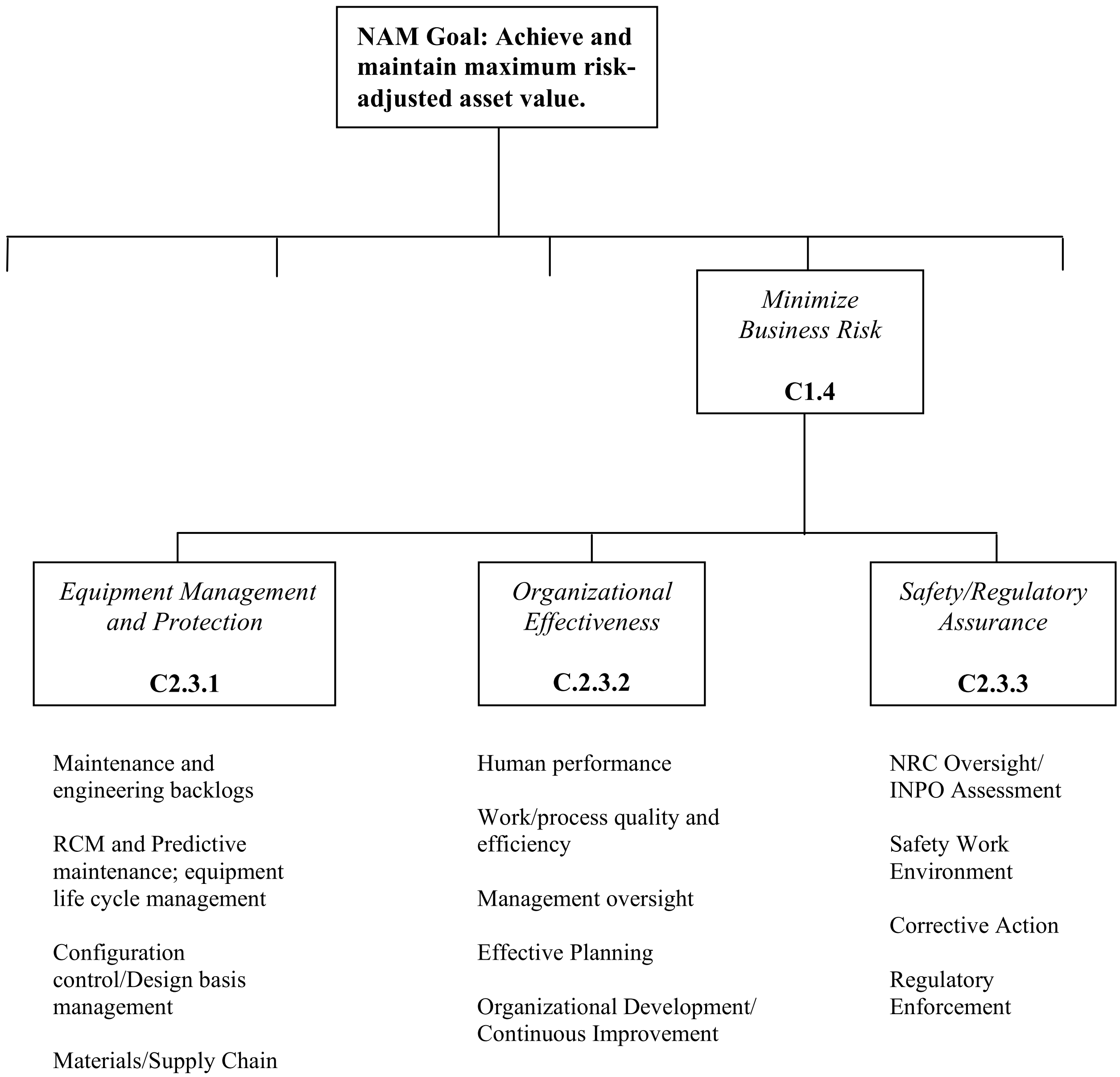


Figure 2-2
Second Level Ranking Factors

2.4.1 Equipment Management and Protection

The emphasis for this factor is on programs and processes that enhance equipment reliability including maintenance, engineering, and supply chain. It recognizes that equipment-related work backlogs create an environment where equipment performance could be degraded, leading to a higher likelihood of failure. Clearly there is some overlap between this factor and the Impact on Plant Generation factor discussed above. That factor emphasized specific plant equipment modifications that could address identified risks to generation. In contrast, the Equipment Reliability factor focuses on processes to track and document the condition of plant equipment, and the cumulative effect of how equipment is maintained and engineered on a current and contingent basis (e.g., the availability of spare parts in the event of degradation or failure).

The value of this factor should be determined based on an assessment of each project against an anchored scale. Four principal elements of equipment management are identified on Figure 2-2 and form the basis for developing the scale. A sample scale for this factor is included in Appendix A.

2.4.2 Organizational Effectiveness

This factor accounts for the importance of human performance and organizational processes in the overall asset management equation. At its most basic it includes the quality of individual performance, including minimization of errors. In a broader perspective it includes the quality of work processes and the efficiency of performing work activities. Often information technology (IT) projects are implemented with these goals in mind. Finally, this factor accounts for processes that sustain a high performance organization including accountability, planning at all levels, and organizational development including training, and knowledge/data management.

The value of this factor should be determined based on an assessment of each project against an anchored scale for organizational effectiveness. Five principal sources of organizational performance are identified on Figure 2-2 and form the basis for developing the anchored scale. A sample scale for this factor is included in Appendix A.

2.4.3 Safety/Regulatory Assurance

This factor recognizes the significance of safety and regulatory performance to preserving asset value by avoiding regulatory intervention, increased scrutiny, and penalties, as well as the ability to address regulatory issues smartly and efficiently. This factor includes some specific contributors, such as meeting requisite targets associated with the NRC oversight process and aggressive implementation of a corrective action program to identify and fix problems. More generally, establishing and maintaining a safety conscious work environment (SCWE) recognizes the impact of culture and assurance that the asset manager is effective in its primary responsibility for safety.

The value of this factor should be determined based on an assessment of each project against an anchored scale for regulatory assurance. Four principal sources of regulatory performance are identified on Figure 2-2. A sample scale for this factor is included in Appendix A.

2.5 Example of Applying an Anchored Scale

Following is an example of how a proposed project would be assessed using an anchored scale, in this case, the Regulatory Assurance scale. For a given project, an assessment would be made of its ability to contribute to Regulatory Assurance. This assessment would include consideration of the four vertical columns of Appendix A, Table A.3. It is possible that a project might contribute to performance in one or more columns or none. The type and extent of impact should be compared to the descriptors at various levels of the columns. In general, the highest level achieved in any one column would be the numerical score. For example, if there is no impact in any column the Regulatory Assurance factor score would be zero. If a project was assessed to provide "incremental improvement" in the corrective action program (CAP)(corresponding to a "5" in Column 3) and helps ensure "reliable implementation" of one or more regulatory commitments (corresponding to a "2" in Column 4), the Regulatory Assurance factor score would be 5.

3 APPLICATION OF THE PROJECT RANKING METHOD

This section describes how the framework is applied to rank proposed projects. Section 3.1 covers the pre-ranking screening that assures that required work is performed and projects that do not meet minimum criteria do not proceed to ranking. Section 3.2 describes the steps required to implement the ranking framework. Section 3.3 covers the mathematical method (the Analytic Hierarchy Procedure) used to rank projects. Section 3.4 provides a detailed ranking of ten sample projects. Sections 3.5 and 3.6 discuss how the ranking method can be extended to incorporate uncertainties about project data and perform sensitivity analyses. Section 3.7 provides an assessment of the ranking results and compares them with rankings obtained from techniques that consider only financial parameters.

3.1 Screening of Projects

The project ranking method needs to assure that certain projects are addressed by the ranking process, and that other projects are screened out of the process if they do not meet minimum criteria. In other words, projects at the top (must be done) and those at the bottom (should not be done) are segregated out. This will allow the ranking method to focus on those "marginal" projects that appear to have fundamental merit and where the key remaining question is: “Which ones offer the most in terms of asset value?”

For nuclear plant assets and enterprises, the screening for "must do" projects include those (relatively few) that are required to continue to operate the plant safely, or are required to meet a new or existing regulatory commitment. We note that many projects may offer safety benefits or enhancements, but are not required for safety. Safety benefits are relevant considerations and will be considered later in the proposed project ranking method. In addition to required-for-safety projects, management from time to time may dictate that certain projects or investments be made as a matter of policy. These projects also should be screened out up front.

An important question about proposed projects is whether the projects "make sense" based on certain absolute criteria, generally financial based. The ranking method will identify the relative merits of the projects but will not, in general, indicate if any particular project should be done (i.e. the method does not include a go/no-go criterion). There are a variety of financial tests that may be applied such as NPV of cash flows, ROI, IRR or payback period.[8] It is likely that each company will have preferred criteria for making such decisions. Projects should be screened on this basis prior to reaching the ranking system. This will ensure that all projects that are ranked already meet certain minimum criteria and will avoid unnecessary ranking analyses of projects

[8] See Appendix D for a discussion of these financial evaluation techniques, including a description of situations where these techniques can lead to conflicting results for the same proposed investment.

that will not be done. However, not all projects may be amenable to a financial screening analysis (e.g., those that offer significant organizational and process improvement value). Here, proceeding with the ranking process may be the best approach, as the ranking criteria are designed to account for non-financial value (as well as financial value if its estimation is possible). The general rule should be that proposed projects that offer only financial benefits should be screened out if they don't meet the minimum financial criteria while projects that offer non-financial benefits should be allowed to proceed.

The decision tree in Figure 3-1 illustrates the progression of project screening prior to entry into the ranking method.

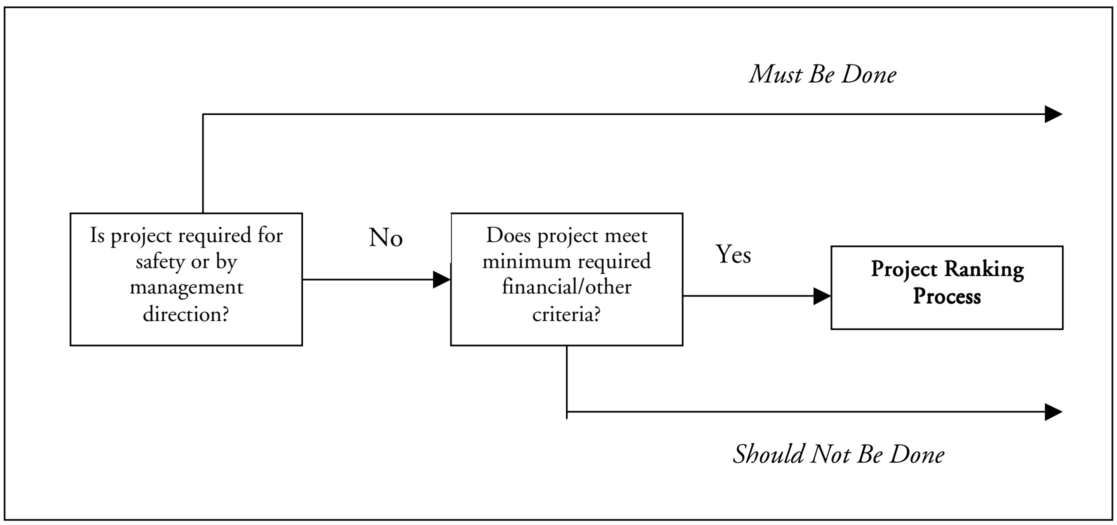


Figure 3-1
Decision Tree for Project Screening Prior to Ranking

3.2 Implementing the Assessment Framework

3.2.1 Overview

Implementing the assessment framework entails three sets of activities:

(1) The weights assigned to each first and second level factor must be developed, reviewed and adjusted as necessary. Two possible approaches for developing weights are discussed in Section 3.2.2.

(2) The "anchored scales" must be reviewed and adjusted as necessary. The use of an anchored scale is discussed in Section 2.5. Sample anchored scales are shown in Appendix A.

(3) The input data, such as NPV of operating cost reduction, for each project must be determined. Ten sample projects are described and evaluated later in this Section.

The first two activities (assignment of weights and formulation of scales) are expected to be done by, or under the direction of, plant management. These actions allow management to have direct input to the overall scheme for project ranking based on their priorities, assessment of plant situation, and the relative significance of different types of qualitative contributions. Expert panels or similar methods[9] may be employed to assist in finalizing the anchored scales. Importantly, once the framework is specified, the weights and scales should remain fixed for the cycle of project rankings. From time to time, and as the plant situation or environment changes, it is appropriate to revisit the framework specifications for any needed adjustment. Project sponsors would be expected to develop the input data for each of the factors, based on appropriate financial analyses and/or ratings based on the anchored scales.

This approach ensures that the framework specification process is transparent and separate from the ranking of individual projects. It helps to obtain management buy-in and endorsement through their participation in setting the framework, and establishes credibility in the ranking results. The framework also provides an explicit roadmap of what values management is looking for in proposed projects.

3.2.2 Weighting of Factors

The assessment framework uses multiple factors associated with the different ways projects contribute to increasing and maintaining nuclear asset value. Values for each factor for each project will be determined based on financial analyses or evaluations using anchored scales. To arrive at an overall "score" for each project, the factor values will be combined using "weights" for each factor. The factor weight expresses the relative importance of each factor for purposes of ranking projects. Thus factor value indicates "how much" a project contributes in a given area; factor weight indicates "how important" that type of contribution is in determining the rank of a project.

Management may specify weights based on a wide variety of considerations including the current plant situation and condition, operating and organizational performance, regulatory environment, and plant age. It is very important for management to recognize that factor weighting is different from calculating certain financial performance measures such as ROI, IRR or benefit/cost. Consider two projects, A and B. Both will cost $100 to implement. Project A will deliver $200 of increased generation revenue. Project B will deliver $200 in reduced operating expenses. From a financial measure perspective, both projects appear equal since a dollar of revenue and a dollar of operating expense are equal. However, for project ranking, the weight accorded these factors may not be equal. One plant may value an increase in generation more than a cost reduction - it may need more generation, may see benefits in overall plant reliability, and may be satisfied with some reduction in unit production cost. Another plant may value reduced operating cost more if it believes it needs to reduce production costs as a first priority to remain competitive in its markets. Thus either Project A or B could be ranked higher depending on the relative weights assigned to the generation revenue and operating cost factors. It is also clear from this example that factor weights will likely vary from plant to plant.

[9] The Delphi procedure and other approaches are commonly used for this purpose. Outside facilitators may be brought in to mediate discussions. It is important that managers and project sponsors understand the scales and accept them as fair and reasonable.

The approaches to arriving at factor weights appropriate to a particular plant can range from largely qualitative, such as consensus judgment by the management team, to highly quantitative, such as the use of performance indicators associated with each of the factors. Clearly project scores and rankings will change based on different factor weights. Since no project ranking outcome is "right" or "wrong," the primary objective should be to tailor the ranking method as closely as possible to the needs of each plant as perceived by its management, thus aligning resources with most value to its particular set of stakeholders.

This report illustrates the development of factor weights in two possible ways. These illustrations should help individual plants understand some of the issues and will also serve as the basis for creating an example assessment framework that will be used to rank a set of sample projects. The two ways are:

- Weights based on industry-standard or plant-specific performance indicators, and
- Weights based on industry quartile performance characteristics.

The two approaches are summarized below and described in detail in Appendix F.

3.2.2.1 Performance Indicator Approach

The approach described in this section will show how plant performance indicators (PIs) can be applied to weighting the assessment framework. Sources of performance indicators could be plant specific or industry-based, such as the Standard Nuclear Performance Model (SNPM) PIs developed under the Nuclear Energy Institute's auspices.[10] An advantage of the SNPM indicators is that they are consistent across the industry and industry-wide data should be available for benchmarking. Integration with the SNPM also provides the opportunity for creating a closed performance loop for nuclear assets as illustrated in Figure 3-2.

[10] NEI/EUCG Task Force Report, The Standard Nuclear Performance Model - A Process Management Approach - Revision 32003.

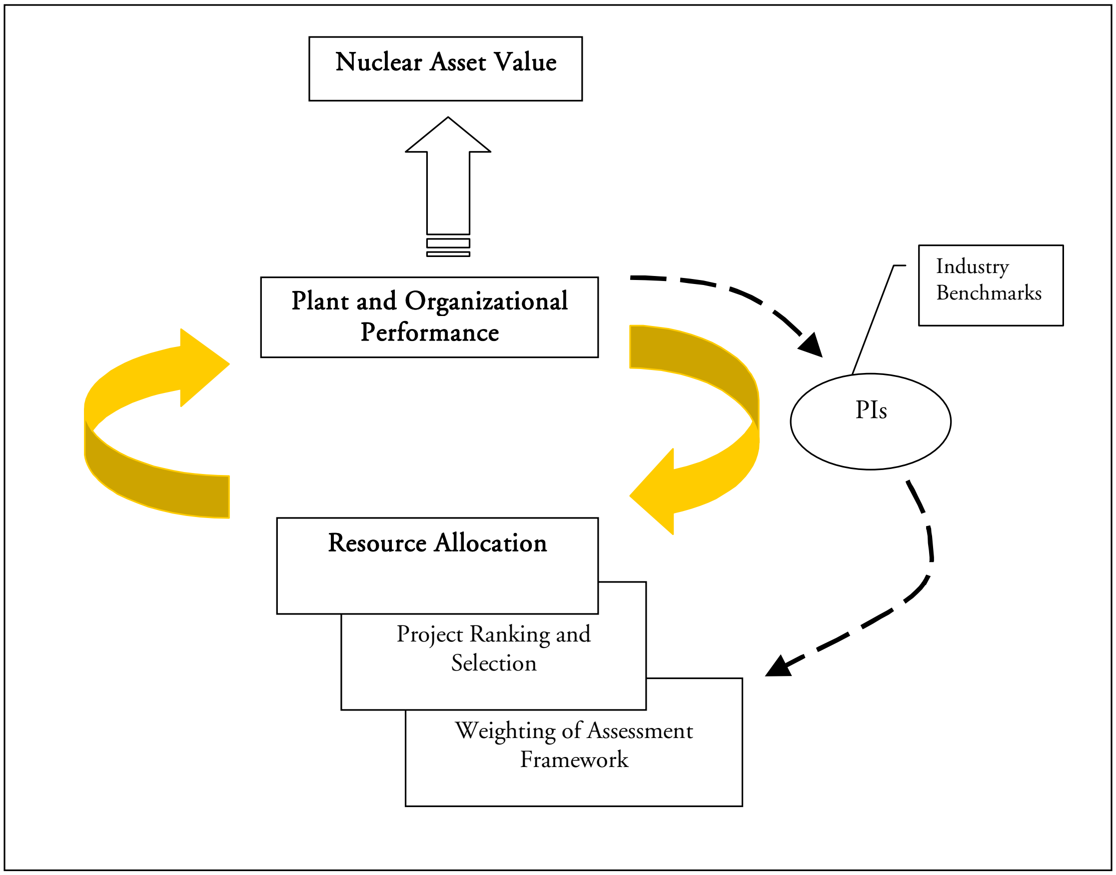
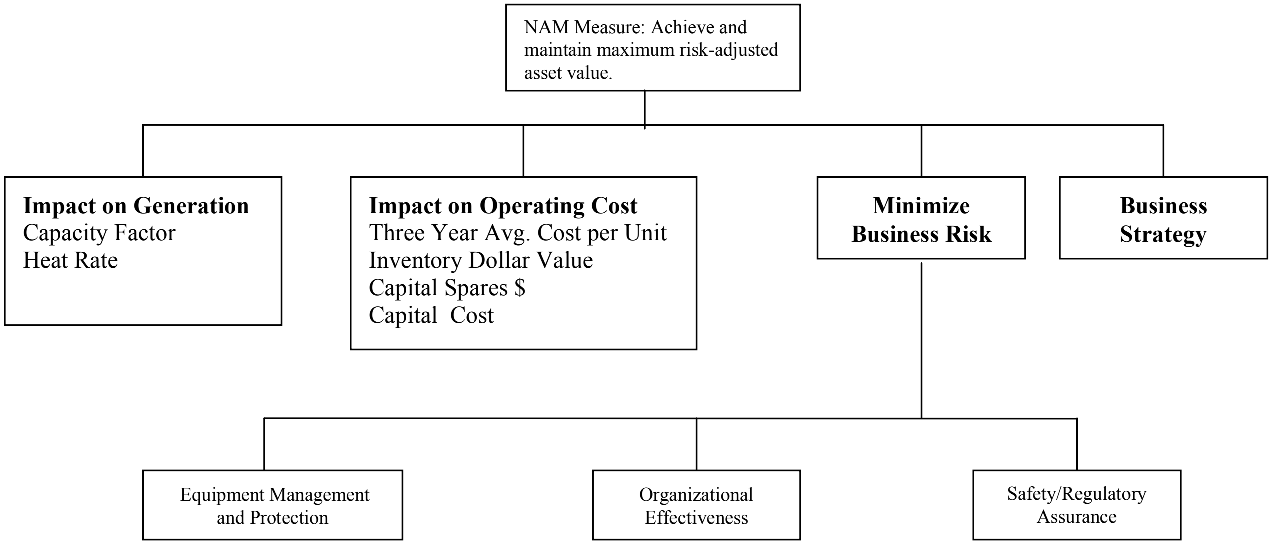


Figure 3-2
Nuclear Asset Management Closed Performance Loop

The process illustrated in Figure 3-2 is based on a fundamental performance dynamic where plant and organizational performance results drive resource allocation, which in turn feeds back into (changed) performance. We have added an outer loop where performance indicator results (using industry benchmarks to disclose performance gaps) are used to set the assessment framework weights, which in turn drive project ranking and selection, and ultimately resource allocation. The approach shown in Figure 3-2 recognizes that performance gaps are closed primarily by allocating resources to areas that are either deficient or where further improvement can yield highest asset value. The principal source of discretionary resource allocation is often project based, though closing performance gaps may also be considered during the process to allocate baseline budget resources to a plant (whether individual or part of a fleet).

The following approach was taken to align PI-based weighting with the ranking method. First, the assessment framework was reviewed against SNPM PIs and the first and second level factors were annotated with the PIs most applicable to each factor. This is illustrated in Figure 3-3 for the PIs currently available.



Forced Outage Rate
WANO Fuel Reliability Index

Maintenance and engineering backlogs
Number Open Engr Work Requests
FIN Average Effectiveness
Delinquent PMs
Deferred PMs
CM Backlog

RCM and Predictive maintenance; equipment life cycle management
Component Unavailability (WANO SSPI's)
Lost Generation Due to Maintenance
Number of systems identified as "(a)(1)" per the Maintenance Rule
PdM/CM Cost Ratio

Configuration Control/Design basis management
Number Engr Reworks

Materials/Supply Chain
Field Issue/Return Efficiency
Supplier Receive/Return Quality
Monthly Jobs on Materials Hold
Stockouts

Human performance
Lost Generation due to Personnel Error
Fire Brigade Drills
Fire Events
Fire Precursor Events
EFD Clock Resets
Clearance Problems
Operations Procedure Backlog
Overtime

Work/process quality and efficiency
Monthly Delayed/Deferred Jobs
3 Year Cost of Work Management
Business Services Customer Feedback
Productivity Factor

Management oversight
Chemistry Indicator
Open Fire Impairments
Control Room Deficiencies

Effective Planning
Forced Outage Readiness
Scope Stability
Emergent Work

Organizational Development/ Continuous Improvement
Training Hours per Employee
Turnover Rate

NRC Oversight/ INPO Assessment
NRC PIs
NEI's Regulatory Assessment Performance Indicator Guideline, NEI 99-02

Safety Work Environment
Number OSHA Recordable Events
WANO Indust Safety Accident Rate
Collective Rad Exposure
RPM Number

Corrective Action

Regulatory Enforcement

Figure 3-3
Assessment Framework Annotated with SNPM Performance Indicators

Figure 3-3 demonstrates that there is good alignment between the framework and PIs and there are sufficient PIs within each factor to support gap analysis. If necessary, additional plant-specific PIs can be added. In addition, when asset-management-specific PIs are available, they could be added to reflect more specifically the goal of maximizing asset value. In certain performance areas there may be more factors than necessary or optimal for understanding performance gaps. These situations may be handled by selecting one or more key indicators and/or creating a composite index of factors for these areas.

The second step is to use PI data associated with each of the hierarchy factors to establish factor weights. Using PIs may provide a detailed indication of performance gaps, but it will require some care to assure that they provide a sufficiently general indication of the importance of each hierarchy factor.

The approach for using the PI data to establish hierarchy factor weights is as follows:

(1) Select one or a subset of PIs that are representative of each hierarchy factor.

(2) Obtain industry-wide data for each of the PIs for a representative time period.

(3) For each set of PI data, apply a scaling process to the data to establish a common basis for comparing performance across PIs.[11]

(4) Identify the current performance value for each PI for the plant to which the hierarchy is being applied. Identify the appropriate performance goal for each PI, e.g. mean, first quartile or other specific value.

(5) Using scaled values, compute the relative change in magnitude of each PI necessary to move performance from its current value to the goal. The resulting values indicate the relative magnitudes of performance improvement required for each PI, and for its hierarchy factor.

(6) Establish the weight of each hierarchy factor based on the relative magnitudes computed in (5).

We will illustrate this for three PIs, one each to represent each of the three Business Risk factors:[12]

- Unplanned power changes (UPCs) per 7000 hours,
- Number of NRC inspection findings, and
- Forced outage (FO) rate.

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[11] Each PI will have different numerical magnitudes and ranges of data. In order to avoid introducing artificial differences among the PIs, the data must be placed on a common scale.

[12] One consideration was the availability of industry data sets. The data for Inspection Findings and Unplanned Power Changes could be obtained from the NRC website and so were convenient to use for this example. Data for forced outage rate was summarized from representative historical industry data. It is anticipated that SNPM PI data will be readily available across the industry in a similar manner or that individual plants could rely on their internally established performance benchmarks.

Unplanned power changes: This is one of the NRC's regulatory oversight program indicators under the "Initiating Events" Cornerstone. It is defined as the number of unplanned changes in reactor power of greater than 20% full-power per 7,000 hours of critical operation excluding manual and automatic scrams. In our example, we use data for a single quarter, the 3rd quarter of 2000, for all operating units. Because this parameter is used by the NRC it could be considered as an indicator of the Regulatory Assurance factor. However, it is also a good indicator of the Organizational Effectiveness factor since unplanned power changes are associated with personnel and supervisory actions and skills, administrative controls, procedure quality and adherence, etc.

NRC Inspection Findings: We have compiled numbers of findings by plant from NRC inspection results. Data are for a one year period, 3rd quarter 2000 through 2nd quarter 2001. NRC Inspection Findings will be used as an indicator of the Regulatory Assurance factor.

Forced Outage Rate: This is the amount of lost generation in a year due to forced outages, expressed as a capacity factor percentage. It will be used as the indicator for Equipment Management.

Data analysis for a hypothetical plant is summarized in table 3-1.[13] (Calculation details are shown in Appendix F.) The plant's current performance and goals are shown in the left columns, the performance gap in the middle column, and the relative weight of the three PIs in the right column. The relative importance of these PIs can be translated into weights for the factors in the ranking hierarchy. On a percentage basis the weights for the three factors would be Organizational Effectiveness (28%), Equipment Management (14%) and Regulatory Assurance (58%).

Table 3-1
Factor Weighting Based on Performance Indicators

PI	PI Data		Performance Gap (# of Std Dev)	Relative Importance	Factor and Weight
	Current	Goal			
UPC	2.1	0 (1stQ)[14]	1.27	2x	Org Effect – 28%
Findings	26	8 (1stQ)	2.52	4x	Reg Assur – 58%
FO rate	1.6%	1%	0.58	x	Eqpt Mgmt – 14%

The above example was based on a decision by the hypothetical plant's management to establish performance goals of 1st quartile for Organizational Effectiveness and Regulatory Assurance, and an incremental improvement in Equipment Management, but less than 1st quartile. One might

[13] Calculation details are shown in Appendix F. (move in parentheses into text)

[14] 1st quartile plants have a UPC indicator of zero.

have selected other performance goals in doing the gap analysis, e.g., industry average or internally set goals.[15]

It should be noted that the relative magnitudes of the performance gaps, e.g., 2x, 4x, etc. are only suggestive of the relative importance of the performance areas and associated hierarchy factors. Management might agree that there is a clear difference in gaps for certain areas but still choose to limit the weighting difference for the factors to a smaller value. For example, management might want to define a more even balance across all performance areas.

In order to extrapolate the approach developed in the above example to completely specify factor weights, selected PIs across all the framework factors would need to be assessed, scaled and gaps analyzed. Where multiple PIs are selected to represent certain factors, scores for each PI would need to be combined (e.g., averaged) to arrive at a single proxy value.[16]

A significant benefit of using PIs to set factor weights is the feedback loop that is created and the self-adjusting nature of the process. PI results and performance goals are used to identify gaps, and to then assign framework weights. This, in turn, impacts which projects are funded and implemented. Monitoring future PI results then provides indications of how effective the selected projects were in changing performance and achieving goals. Changed performance leads to changes in the gap analysis (and to the extent industry benchmarks are changing, this is constantly fed back into the process as well) and adjustment of the framework weighting factors for the next project budgeting cycle. Management always retains the option of adjusting performance goals and fine tuning the factor weights to best meet its competitive environment, availability of capital, business strategy and other relevant considerations.

3.2.2.2 Industry Quartile Approach

This approach establishes factor weights based on a blend of analytical treatment of nuclear plant performance and management judgment. From the principles developed in Section 1.3, we expect that the current operating performance, or performance "regime," of a plant will influence the opportunities for improving and sustaining asset value, and therefore, the relative importance of each factor in the ranking hierarchy. Thus the relative importance of the factors will likely differ for each plant based on its specific operating characteristics and strategic business situation. In this section, we will illustrate how to address these differences by considering how

[15] Note that for Unplanned Power Changes, there is an NRC limit of 6 to maintain a green indicator color. This would not normally provide a useful target since it is a threshold that is to be avoided and almost always is - only three units exceeded this level for the 3rd Q 2000.

[16] This brief example is not meant to imply that using PIs for setting weights is a simple, mechanical task. As previously noted, the set of currently available PIs may not provide adequate coverage for some ranking factors. Reasonable people may disagree on the significance of a specific PI for plant performance or the relative importance of different PIs. However, the existence of the powerful feedback loop described in this section should foster increased interest in identifying a complete, coherent set of NAM PIs.

plants in each industry "quartile" of performance may present different asset management priorities and thus different weighting factors.[17]

Conventionally, U.S. nuclear plant performance is categorized into four quartiles. The first quartile represents the top 25% of plants for a given metric and so on for each succeeding 25%. The mean performance of the plants within each quartile is used to characterize the particular regime, but the range of performance within a quartile is not often explicitly noted. To add this dimension, we analyzed the capacity factor (CF) performance of plants for 1999-2001 and developed CF performance distributions for each quartile. These results indicate that in going from lower to higher quartiles, standard deviation (variability) becomes progressively smaller, supporting increases in mean CF. Experience confirms that top plants are very consistent performers and lower plants are not (in fact it is difficult to find individual plants in the 3rd or 4th quartiles that have high consistency, i.e., low variability). A more refined perspective is provided by the 90th percentile values of CF (the value of CF which 90% of the quartile plants exceed). This performance data is shown in table 3-2.

Table 3-2
U.S. Nuclear Plant Capacity Factor Performance Quartiles

1999-2001	1stQ	2ndQ	3rdQ	4thQ
Mean	95.82%	92.24%	88.77%	78.91%
Standard Deviation	4.79%	5.83%	7.65%	21.35%
90th Percentile	89.79%	85.05%	78.88%	59.38%
Mean-90th Percentile	6.03%	7.19%	9.89%	19.53%

The difference between the mean and 90th percentile values may be thought of as the discount associated with performance variability. The discount is small in the first quartile (about 6 percentage points) but enlarges to severely impair performance in the 4th quartile (almost 20 percentage points).

For asset management purposes, the change in performance variability compared to change in mean performance may be one way to view the relative importance of each. One approach to do this is to evaluate the needed performance improvement for plants in each quartile to move up in rank to the next quartile. Table 3-3 illustrates what is required to move CF performance between quartiles. For example, to move from the 3rd to 2nd quartile, mean CF performance would need to increase 3.47% and 90th percentile performance 6.17%. The ratio of these values, 1.78, indicates the relative significance, or importance, of improvement in performance variability

[17] Refer to Appendix F for details on this approach. We do not suggest that every plant in a quartile shares entirely similar performance characteristics; in fact the range of plant performance becomes fairly widely differentiated in the lower quartiles. Thus asset managers will want to assess the specific performance of their plants in adapting and applying these ranking methods. The suggested weightings by quartile provide a guide and framework within which to do this.

compared to mean performance. The ratios for the other quartile changes indicate that this multiplier ranges from about 2 to about 1.33, decreasing as plants move up in quartiles.

Table 3-3
Performance Improvement Necessary to Move to Next Higher Quartile

	2ndQ to 1stQ	3rdQ to 2ndQ	4thQ to 3rdQ
Change in Mean CF	3.58%	3.47%	9.86%
Change in 90th Percent CF	4.74%	6.17%	19.50%
Ratio Change 90th/Mean	1.32	1.78	1.98

Using these analyses of the distributions for each quartile and the performance improvement required to move up from quartile to quartile, we developed a method for inferring the relative importance of the hierarchy factors. The results are summarized in table 3-4, which suggests a set of weighting percentages for each factor based on quartile group. (Calculation details are shown in Appendix F.)

Table 3-4
Factor Weights for Plants in Different Performance Quartiles

	Factor Weights				
Quartile	**Generation**	**Operating Cost**	**Project Cost**	**Business Risk**	**Strategic**
Q1	0.20	0.20	0.20	0.20	0.20
Q2	0.20	0.15	0.15	0.30	0.20
Q3	0.20	0.15	0.15	0.35	0.15
Q4	0.25	0.1	0.10	0.50	0.05
			Eqpmt Rel	**Org Effect**	**Reg Assur**
Q1			0.25	0.50	0.25
Q2			0.33	0.33	0.33
Q3			0.33	0.33	0.33
Q4			0.40	0.20	0.40

Note that the weights have been apportioned to make sense based on the fundamental dynamics of nuclear asset performance. These dynamics include the importance of management as a key driver, the need to focus on performance reliability as the means to raise overall (mean) performance, and the view that cost is primarily a dependent variable, i.e., cost is primarily a consequence of how the plant performs rather than an independent variable that is directly managed. The weights also make intuitive sense based on a general assessment of the plant situations in each quartile, as discussed below.

4th Quartile: These plants may focus on improving plant generation and reducing risk as the first priority. Reducing cost or supporting strategic initiatives are of less importance, and unit costs will improve anyway with higher generation.

3rd Quartile: These plants still must focus on reliability to continue gaining in overall performance, even though variability is significantly better in this quartile.

2nd Quartile: These plants are performing well but are looking to rise to the top tier of performance. Operating Cost and strategy take on added value as improved operating performance enables other priorities to be pursued. Project Cost becomes an increasing consideration as the opportunities to increase generation performance become incrementally smaller.

1st Quartile: These are top tier plants and are performing at or close to the maximum levels possible. Their priority is to sustain performance leading to a balanced weighting of all top-level factors. They are in the best position to support strategic initiatives at the plant or enterprise levels.

The quartile approach focuses on one of the most important PIs: capacity factor. In contrast, the performance indicator approach applies a more detailed analysis to multiple PIs and is therefore more complicated to apply. Other approaches for specifying weighting factors are possible - ranging from using management expert judgment to more detailed analytical approaches. Considerations that may apply in selecting an approach for determining weights include: (1) is a single plant involved or multiple plants across an enterprise; and (2) how important is it to use objective data as a basis? If more than one plant is involved, and depending on the enterprise-level methods to be employed for project selection and resource allocation, use of objective data may be preferred. It balances a common approach that can be applied to all nuclear enterprise plants but preserves the ability to tailor the framework based on the unique performance situation for each plant. Objective data also may be preferred if there is oversight or review of costs and investment decisions by economic regulators or other affected parties, such as minority owners. In all cases, a balance between soundness and the burden of specifying weighting factors needs to be maintained.

3.3 The Analytic Hierarchy Procedure (AHP)

Before proceeding with the example ranking, we explain why the Analytic Hierarchy Procedure (AHP) was selected as the mathematical method for performing the actual project rankings.[18] There are numerous project ranking methods described in the Operations Research and the Project Management literatures. The method selected for ranking proposed intermediate-size nuclear projects needs to meet the following criteria:

[18] Refer to Appendix E for a more complete discussion of the material covered in this section.

- The method should be simple enough that it does not impose a significant burden on the managers and staff who use it.
- The method should require only data that can be collected readily by the project sponsors and the managers responsible for making project selections.
- The method must allow input from the most appropriate sources for each data type. For instance, policy issues may involve input from top management, while cost data may involve input from personnel directly involved, and payoff data may involve input from corporate finance personnel.
- Non-financial factors may play an important role in project selection.
- The method should support the hierarchy of factors described in Section 2. The hierarchy allows higher level factors to be decomposed into their contributors, thus allowing greater insight into the specific value contributions of a proposed project.

Given these criteria, the large number of possible ranking methods can be reduced to one: the Analytic Hierarchy Procedure (AHP). AHP allows disaggregation of relevant factors to several levels. Moreover, it permits management at several levels to specify the weights for factors at appropriate levels of disaggregation. Most importantly, the supporting calculations can be easily set up in a spreadsheet program, such as Microsoft Excel™, or a user can purchase a dedicated AHP software program, such as Expert Choice (available from Expert Choice Inc.)

3.4 Project Ranking Example

Thus far we have described the structure and elements of an assessment framework for ranking nuclear projects. In this section we complete the description of this approach by using the framework to rank a series of ten hypothetical projects. This example illustrates the mechanics of the computation of project scores using the analytic hierarchy procedure (AHP) and discusses the results in light of the framework specifications. (The AHP procedure is described in Appendix E.)

For our example we will take ten proposed projects covering a spectrum of equipment, process, human performance and strategic initiatives. We will specify factor weights based on the industry quartile approach, described previously, and compare project rankings for different sets of factor weights (corresponding to plants in different performance regimes). The project set and input data are presented in Appendix B. Note that some of the project values may not be entirely representative of actual plants and in some cases have been structured to ensure that all ranking factors are exercised. Thus, interpretation of ranking results should be directed primarily at understanding of the rankings based on the input data and framework specifications - not as an independent view of the value of certain types of projects.

3.4.1 Second Level (Business Risk) Factor Analysis

Due to the two level structure of the framework, analysis begins with the second level factors that contribute to Business Risk. As shown in Appendix B, only five of the ten sample projects contribute value to reducing Business Risk based on the project sponsors' assessments. Of these projects, two contribute to each of the three second-level factors (Equipment Reliability, Organizational Effectiveness and Regulatory Assurance) and the other three contribute to one or two of the factors.

In applying AHP, comparison matrices are constructed for each of the three Business Risk Factors. Each matrix shows pairwise comparisons of the factor for each of the projects. The comparison procedure is followed for each of the three Business Risk Factors and the resulting project preference values are shown in the summary table 3-5 below. At the bottom of this table are entries for the weights associated with each of the three factors. Three sets of weights are entered based on the development of factor weights using industry quartile performance characteristics described in Section 3.2.2.2. The weights for a 4th Quartile plant are listed in the top row indicating that both Equipment Reliability and Regulatory Assurance would be weighted twice Organizational Effectiveness. The weights are used to compute an overall Business Risk Score for each project. The scores for a 4th Quartile plant are shown to the right of the table of preference values in the left-most column under Project Scores for Business Risk Factors. Keep in mind that the absolute values of the scores are not significant, it is the relative values across projects that are important. Looking at this set of data indicates that Project 4 is the highest rated project for Business Risk Reduction for a 4th Quartile plant. While the scoring for an individual plant would be based on a single set of factor weights, we have shown weights for 1st Quartile and 3rd/4th Quartile to illustrate the effect on project scoring. The results are shown in the adjacent columns in the table.

Table 3-5
Summary of AHP Results for Business Risk Factors

	Eqpt Rel	Org Eff	Reg Assur	Project Scores for Business Risk Factors: Q4	Q1	Q2/Q3
P1	0	0	0	0.0000	0.0000	0.0000
P2	0	0	0	0.0000	0.0000	0.0000
P3	0	0	0	0.0000	0.0000	0.0000
P4	0.1125	0.126316	0.055556	0.0925	0.1052	0.0971
P5	0	0	0.111111	0.0444	0.0278	0.0367
P6	0.09375	0.094737	0.074074	0.0861	0.0893	0.0866
P7	0	0	0	0.0000	0.0000	0.0000
P8	0.09375	0	0.12963	0.0894	0.0558	0.0737
P9	0	0	0	0.0000	0.0000	0.0000
P10	0	0.078947	0.12963	0.0676	0.0719	0.0688

		Eqpt Rel	Org Eff	Reg Assur
Weights	**Q4**	0.40	0.20	0.40
	Q1	0.25	0.50	0.25
	Q2/Q3	0.33	0.33	0.33

Taking the project scores at the Business Risk level, we have rank ordered the projects by score for each quartile, shown in table 3-6 below. Examination of the table indicates the project rankings do not differ dramatically. This is due in part to the characteristics of the projects themselves and also due to the lack of consideration at this level of other project factors, notably project cost. Projects 4 (CMMS Software) and 6 (Root Cause Training) rank high since they both contribute value across all three Business Risk factors. Similarly, Project 5 (Safety Culture Survey) ranks low as it has contributes only in the Regulatory Assurance area at a moderate level.[19] The ranking for Project 10 changes with quartile since its contribution to Organizational Effectiveness is subject to significantly different weighting based on quartile.

[19] While Project 5 ranks lowest, this ranking is just among those projects that contribute at all to Business Risk reduction, and only considering Business Risk factors.

Table 3-6
Project Ranking for Business Risk Factors, by Plant Performance Quartile

Project Rank	Q4	Q1	Q2/Q3
Highest	P4	P4	P4
	P8	P6	P6
	P6	P10	P8
	P10	P8	P10
Lowest	P5	P5	P5

3.4.2 First Level Factor Analysis

After computing project scores at the Business Risk level, the next step is to proceed with analysis of the first level factors. The analysis is done in an analogous manner as for the Business Risk factors, with the development of pairwise matrices for each of the first level factors, comparing each project to all other projects.

Table 3-7 summarizes the output data for each of the first level factors and computes project scores for a 4th Quartile plant. Note that the weights at the bottom of the table correspond to those specified for a 4th Quartile plant. Scores for each project are computed by multiplying the factor values by the weights and summing. The column to the right of the scores shows the projects in rank order.

Table 3-7
Summary of AHP Results for Business Risk Factors

		Gen	Operating Cost	Project Cost	Business Risk	Strategy	Score Q4	Rank Q4
	P1	0.0613	0.0000	0.0417	0.0000	0.0000	0.0195	**P4**
	P2	0.2512	0.0000	0.0209	0.0000	0.0000	0.0649	**P6**
	P3	0.0123	0.0086	0.0834	0.0000	0.0000	0.0123	**P2**
	P4	0.1562	0.4310	0.0042	0.0925	0.1143	0.1345	**P8**
	P5	0.0000	0.0000	0.1113	0.0444	0.0857	0.0376	**P9**
	P6	0.0000	0.0172	0.3338	0.0861	0.0000	0.0781	**P10**
	P7	0.0107	0.0000	0.1669	0.0000	0.0000	0.0194	**P5**
	P8	0.0245	0.0000	0.1001	0.0894	0.0000	0.0608	**P1**
	P9	0.1838	0.0345	0.0125	0.0000	0.0000	0.0507	**P7**
	P10	0.0000	0.0086	0.1252	0.0676	0.0000	0.0472	**P3**
Weights	**Q4**	0.25	0.10	0.10	0.50	0.05		

Similar calculations can be performed to yield results for 3rd, 2nd and 1st Quartile plants. Table 3-8 summarizes the project rankings by performance quartile. Note that the three top-ranked projects are the same and the rankings do not change across quartiles. This indicates that these projects have overriding contributions to asset value for any plant. Similarly, the three bottom-ranked projects are the same across quartiles, though the relative rankings vary somewhat. Thus, the top and bottom projects are consistently ranked notwithstanding the factor weights that vary by plant performance quartile.

Table 3-8
Summary Rankings for Each Quartile

Project Rank	Q4	Q3	Q2	Q1
Highest	P4	P4	P4	P4
	P6	P6	P6	P6
	P2	P2	P2	P2
	P8	P8	P5	P9
	P9	P10	P9	P5
	P10	P9	P8	P10
	P5	P5	P10	P8
	P1	P7	P7	P7
	P7	P1	P1	P3
Lowest	P3	P3	P3	P1

Examination of the four middle-ranked projects (P5, P8, P9, and P10) shows considerable relative movement among the projects across quartiles. This suggests that projects with "marginal" business risk contribution may be valued differently depending on the operating situation of the plant. For example, P8 (RHR maintenance backlog and white PI) is ranked highest (in the mid-range) for a 4th quartile plant, but lowest (in the mid-range) for a 1st quartile plant. This seems to make sense - addressing safety system performance and clearing a white NRC PI would be very high priority for a plant that is performing at the bottom of the industry. The same project for a plant at the top of the industry might have lower priority since it has an excellent performance record and more margin with regulators.

3.5 Incorporating Uncertainty About Project Performance

The preceding example of the proposed project ranking method was based on inputs that were single-point best estimates. It is also possible to perform the ranking using probability distributions for input data. A user might want to do this to reflect an input that is believed to be probabilistically distributed or to check the robustness of the relative rankings created using point estimates. Following is an example of how probabilistic project performance data can be incorporated. The earlier example showed four projects (P5, P8, P9, and P10) that were clustered in the middle of the rankings with about the same relative ranking score. Rerunning the ranking evaluation using probabilistic inputs for these projects can provide additional insight into the robustness of the original rankings. Probabilistic inputs can be entered in Microsoft Excel™ spreadsheets using Palisades Corporation’s @Risk or Decisioneering’s Crystal Ball add-on.

Tables 3-9 and 3-10 show the revised inputs for the four projects. The cost data were input using @Risk's Trigen distribution, a type of triangular distribution where the lower number represents the 10th percentile, the middle number is the most likely value, and the higher number represents the 90th percentile. The quantitative data from the qualitative scales were entered using uniform distributions, where any value from the specified range is equally likely. Input data ranges were chosen so that mean values would be close to the point values specified for the original example, thus preserving the original rank order of projects. The data ranges were selected to illustrate adding probabilistic values; they do not necessarily represent realistic ranges for any parameter. The input data for the other six projects remained as specified in Appendix B.

Table 3-9
Revised Input Data for Sample Projects Incorporating Uncertainty in Top Level Factors

Project	Description	Generation	Op Cost	Proj Cost	Bus Risk	Strategic
5	Periodic safety culture survey	0	0	200,225,250	See table 3-10	1,5
8	Maint backlog for RHR system; address white PI	400,800,1200	0	200,250,300		0
9	LP turbine rotor replacement	4000,6000,8000	150,200,250	1500,2000,2500		0
10	Improved inspection access for RPV head	0	25,50,75	175,200,225		0

Table 3-10
Revised Input Data for Sample Projects Incorporating Uncertainty in Second Level Factors

Project	Description	Equipment Reliability	Organizational Effectiveness	Regulatory Assurance
5	Periodic safety culture survey	0	0	4,8
8	Maint backlog for RHR system; address white PI	4,6	0	6,8
9	LP turbine rotor replacement	0	0	0
10	Improved inspection access for RPV head	0	3,7	6,8

The comparison matrices were recalculated using the revised input functions and the output is summarized in Figure 3-4. In this Figure, projects are displayed in descending order according to their average ranking score. This order is the same as shown in the original example for a plant in the second quartile. In addition, a ranking score range is shown for several projects, indicating the 10th and 90th percentiles for the ranking scores. Consistent with the original analysis, the projects in the middle of the rankings (P5, P8, P9, and P10) have approximately the same average relative ranking score. Three of the four projects also have similar ranges, indicating that the uncertainty about their possible performance, as reflected in the data inputs specified, is about the same. However, one project (P9) shows a larger range, indicating that its relative ranking score is subject to greater variability, again based on the input data specified. The output for P9 appears reasonable given that it is by the far the largest of the four projects in terms of costs and potential financial benefits, so variations in those factors would more dramatically affect this project's relative desirability. In this sense, P9 represents a riskier project.[20]

[20] No precise statement can be made about a project's quantitative risk based on the method described in this section; it simply demonstrates how ranking can change based on probabilistically varying inputs

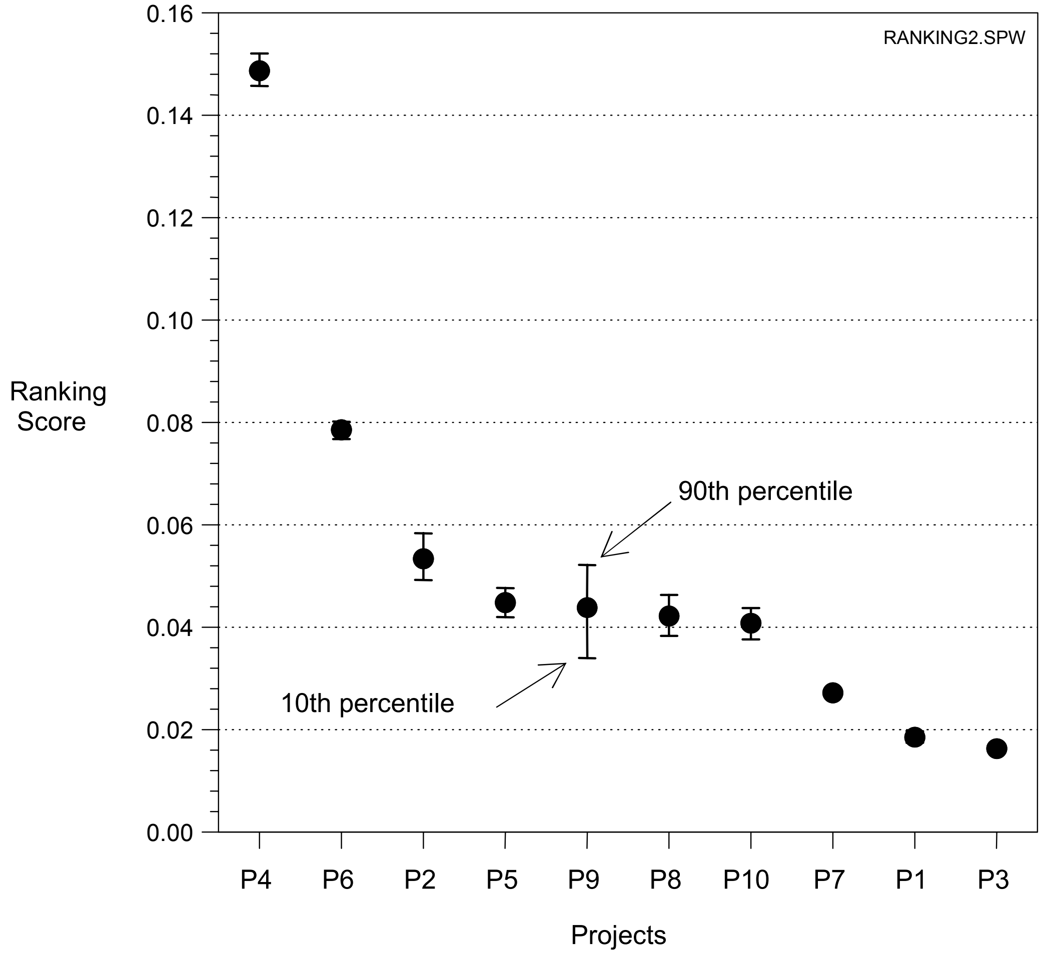

Figure 3-4
Project Rankings Incorporating Uncertainty

Note that ranges also appear for projects where the data inputs were not changed, i.e., they remained single point best value estimates. This is due to the underlying mathematics of the AHP technique. Because all projects are compared pairwise with all other projects for each ranking factor, if one project has a variable (probabilistic) value for a given factor, then the values in the resultant matrices will also vary for all projects with which it is compared. Thus, ranges can result for projects that have only single point input data. This makes sense since the proposed method creates relative rankings, so if one project's inputs vary in a way that makes it relatively (un)attractive, then some other project's relative ranking may increase (or decrease) in response.

3.6 Sensitivity Analysis

Sensitivity analysis is used to determine how much data inputs have to change before the outputs (results) are significantly affected. Commercial AHP software, such as Expert Choice (available from Expert Choice Inc.), support multiple methods for determining sensitivity. For example, the top level factor weights in the assessment framework could be adjusted to see how such changes would affect the relative rankings of the proposed projects.

If a user is concerned whether a factor might be more or less important than originally indicated, then the user could increase or decrease the factor's weight and see the impact on alternatives. In the case of the Expert Choice program, as the weight of one factor increases, the weights of the remaining factors decrease in proportion to their original priorities, so that the sum of the weights remains constant, and the relative rankings of the proposed projects are then recalculated.

3.7 Assessment of Ranking Results

Some assessment of ranking results achieved with the use of the assessment framework is possible based on the ten-project example. First it should be recognized that there is no "right" or "wrong" answer with the results of any ranking method. Rankings are expected to, and do, vary across different methods. The ranking results can provide insights that may not be otherwise available and serve as a complement to traditional financial evaluation techniques. In addition, the ranking method should provide an objective, transparent and agreed upon process. This provides a useful "signal" to the organization as to the types of projects that are valued by management and leads to acceptance of the decisions reached.

The results obtained from the ranking method can be compared to results obtained from methods that consider only the financial parameters associated with projects. Table 3-11 shows the rankings for the ten sample projects using two popular methods: project NPV and Benefit/Cost (B/C) ratio. For example, project P2, the Power Uprate of 2%, has the highest NPV and the most favorable B/C ratio and is ranked number 1 for each method. In contrast, project P5, the Periodic Safety Culture Survey, has the lowest NPV and least favorable B/C ratio and is ranked number 10 for each method. Note that some projects have different rankings for NPV and B/C, e.g., project P1, RCP Motor Replacement, is ranked number 4 according to NPV but number 2 using B/C. This is because the methods apply different calculations to the same financial data, as discussed in Appendix D. The left column in table 3-11 shows the rankings obtained using the assessment hierarchy (for a 2nd Quartile plant, without consideration of uncertainties).

Table 3-11
Comparison of Ranking Methods Results for Ten Example Projects

	Ranking Hierarchy	NPV	B/C	Project	
Project Rank	9	4	2	P1	RCP Motor Replacement
	3	1	1	P2	Power uprate of 2%
	10	7	6	P3	Intake bar rake replacement
	1	3	8	P4	New CMMS software
	4	10	10	P5	Periodic safety culture survey
	2	8	7	P6	Root cause analysis training
	8	6	5	P7	Repair steam leaks
	6	5	3	P8	Maint backlog for RHR system; address white PI
	5	2	4	P9	LP turbine rotor replacement
	7	9	9	P10	Improved inspection access for RPV head

The differences are highlighted in the following discussion of each of the projects.

P1: This project ranks relatively high using traditional NPV and Benefit/Cost methods because of its financial parameters. The hierarchy ranks P1 quite low because there is only one type of benefit, generation revenues, and the project is fairly costly.

P2: This project ranks highly across all methods. P2 has similar characteristics as P1 but the generation value is very high, boosting its performance under the framework method.

P3: This project is ranked relatively low by all methods due to marginal financial parameters.

P4: This project generates conflicting signals from the NPV and B/C methods due to high project cost. The hierarchy ranks the project very high since it values the additional contributions to business risk and strategy.

P5: This project would not make the cut using traditional methods due to a lack of financial benefits. The hierarchy incorporates business risk and strategic value to yield a moderate ranking.

P6: This project ranks low under traditional methods since its financial parameters are marginal. It ranks high under the hierarchy due to its business risk value where it contributes to all three second-level factors.

P7: This project receives moderate to low rankings across all methods. It offers a plant efficiency benefit, but one where the financials are not compelling, and no other value contributions.

P8: This project receives moderate to high rankings across all methods. It has reasonable financial parameters and contributes to equipment reliability and regulatory assurance under business risk. Note that P8 ranks at 4 for 4th and 3rd quartile plants reflecting the higher value placed on these factors for plants in these regimes. This brings out some of the subtlety of the hierarchy method to generate rankings based on situational information as well as project parameters.

P9: This ranks relatively high in all methods due to good fundamental financials. Note that the hierarchy ranking is somewhat less positive due to the lack of non-financial contributions. When uncertainty with respect to financial benefits and costs was incorporated, this project's ranking score showed relatively high variability because the project is relatively large in financial terms.

P10: As with P5, this project would not make the cut using traditional methods due to a lack of financial benefits. The hierarchy does not give the project a significantly higher ranking but does provide the opportunity to bring in the organizational and regulatory values for the project. This added visibility might result in greater scrutiny of the project merits and demonstrates that projects can be very marginal even when there are specific regulatory benefits.

4
ENTERPRISE LEVEL CONSIDERATIONS

An "enterprise" can be any organizational level above the individual plant.[21] In some organizations, e.g., a nuclear operating company, the enterprise may be the nuclear fleet. A generating company enterprise may hold both nuclear and non-nuclear generating assets. A large, integrated energy enterprise may have a portfolio of regulated and non-regulated assets, including, for example, generating plants, trading operations and foreign investments. This section describes how the ranking method can incorporate enterprise-level considerations.

4.1 The Nuclear Fleet is the Enterprise

At the fleet level, the most straightforward approach is to simply combine the project rankings from the individual plants into a single master list, sorted by the scores each project received at the plant level. The advantage of this approach is that it preserves the key contributions of the plant-level ranking method: recognizing and comparing multiple sources of quantitative and non-quantitative value. In addition, this approach would preserve the impact of the weights assigned to each factor and subfactor at the plant level. To ensure ranking consistency, all plants in the fleet would need to use the same ranking model, i.e., the same set of factors and subfactors, and the same set of anchored scales for qualitative inputs. However, factor weights could be different for each plant in accordance with its needs, performance and circumstances.

A variant on the approach described above is the use the plant rankings but applying a different enterprise weighting factor to each plant as appropriate. This "plant weight" would be based on the relative overall value of each plant's contribution to the fleet (or corporate asset portfolio) or some other management policy, e.g., a policy that favored large plants over small ones, or plants serving favorable markets to plants that serve less favorable markets.[22] These plant weights would bias the relative position of each plant's projects in the overall fleet ranking based on the underlying fleet or corporate policy.

Because the factor or plant weights may differ, the above approach may result in what may appear to be a non-level playing field. However, this is an actually an advantage of this approach as it tends to force plant-level decision makers to articulate what is important to them and enterprise-level decision makers to define policy biases that may exist informally. This

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[21] A single merchant plant might also be considered an enterprise. In such a case, project ranking can be applied as for any other individual plant.

[22] Plant weights based on market considerations such as predicted price levels and volatility might be based on plant values calculated using a real options methodology. See Appendix C for a discussion of the use of options techniques, including real options, in evaluating nuclear projects.

approach is recommended because it incorporates the maximum amount of information from decision makers at all levels.

An alternative approach at the fleet level is to compare all projects using a common set of factor weights. The advantage to this approach is that it would create what appears to be a level playing field for comparing projects among plants. The primary disadvantage is that it would ignore and negate the value associated with developing factor weights that are customized for each plant and reflect its needs, performance and circumstances. Because of this shortcoming, this approach is not recommended.

A potential problem with any of the above approaches is that a significant number of Plant A's projects may rank higher (or lower) than the projects proposed at Plant B. This may result because Plant A's projects actually have higher (lower) value than Plant's B's or because of some systematic bias in the application of the ranking scheme. One policy that would overcome this sort of problem is to guarantee that each plant will receive some minimum amount of resources for projects, independent of the overall rankings, essentially applying a constraint to the ranking results. Such a policy may lead to a suboptimum allocation of fleet resources but is more likely to lead to an answer that is more acceptable to the overall organization.

The approaches described above can be easily implemented. There is no theoretical limit to the number of projects that can be compared and ranked using the proposed method. A practical limit may be the total number of projects the organization is willing to consider. To accommodate such a practical limit, fleet management might limit each plant's input to, say 50 projects. After the first set of projects is ranked, and resource allocations provisionally made, the next set of projects could be ranked, assuming resources were still available, assigned provisional resources, and so forth.

In any case, the output of fleet-level project ranking will need to be integrated with enterprise level financial analysis rules and resource allocation methods.

Resource allocation and strategy implementation decisions are complicated and not straightforward. As an example, consider two different strategies for managing a fleet of plants with differing material condition (MC). One strategy seeks to maintain the current MC of each plant, the other aims to improve it so that all plants have the same MC as the best plant in the fleet. The strategies can be thought of as different approaches to project rankings across the fleet; in effect, another way to set the factor weights or other aspects of the project assessment framework. These two strategies can be compared and evaluated using a fleet simulation model.[23] Such a model can incorporate key performance drivers such as management performance, the regulatory environment, and technical and safety issues. It can also accommodate multiple sources of risk – both internal and external to the firm – such as risks associated with cost or capacity factor performance or future electricity prices.

The plot shown in Figure 4-1 below compares the results for the two different MC strategies. The "Maintain MC" strategy is shown as circles, with the large circle showing the average of the

[23] This analysis was performed using the POWERGEN nuclear power plant fleet simulation model. See Appendix G for a more detailed discussion of simulation and the POWERGEN model, including its commercial availability.

simulation results. The "Improve MC" strategy is shown as squares, with the large square showing the average of the simulation results. The average value of the fleet capacity factor increases with the MC improvement strategy, which is to be expected since higher MC means fewer forced outages. If the fleet asset management focus was on raising CF (which may be the case at some enterprises), then this strategy might be viewed as improving performance. However, the fleet five-year NPV of income (revenue less all costs) is essentially the same with either strategy; the additional immediate investment required to upgrade some plants offsets the additional revenue they create. The improvement strategy adds CF but not value. This latter result may not be intuitive or revealed through other evaluation approaches. Simulation allows the integration of many contributing variables to compute a top level measure, such as the NPV of fleet income, as the basis for judging alternative strategy (project ranking) approaches.

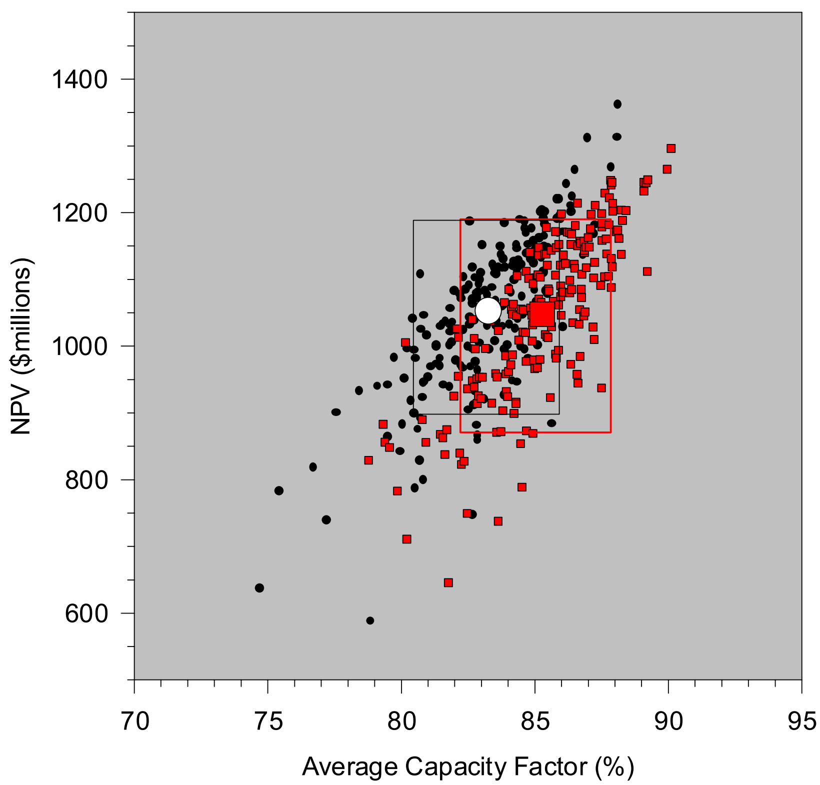

Figure 4-1
Simulation Results for Different Asset Management Strategies

In addition, simulation results can be analyzed and displayed to reveal strategy risks. Referring to Figure 4-1, the boxes around the simulation results are formed by identifying the 10th and 90th percentiles for the results for each MC strategy. While the boxes are similar, the improvement strategy (right) box extends somewhat lower than the box for the status quo strategy, indicating somewhat greater downside risk for the improvement strategy.

The specific application of fleet simulation to project ranking lies in the ability to test fleet level strategies to determine which strategies or combinations of strategies yield the best fleet value. That understanding then can be translated into the project ranking methods applicable to individual plants - through adjustments to factor weights and anchored scales in the assessment framework, and project screening criteria. For example, if the "Maintain MC" strategy discussed above was deemed best for some or all plants, the weight for Equipment Reliability might be increased and the weight for Improve Generation reduced or held at a nominal level. This approach makes it possible to extend enterprise level strategic direction directly into the resource allocation process at the plant level in a manner that is expected to optimize fleet value while retaining each plant's ability to identify its most beneficial projects.

4.2 The Enterprise Above the Fleet

At organizational levels above the nuclear fleet, project/investment ranking can be inextricably entwined with other asset management processes, especially portfolio management and resource allocation. Key questions at these levels address the role of each generating plant in the asset portfolio and how scarce resources should be apportioned among competing investment proposals. These enterprises need to consider project ranking in the context of resource allocation across their plants and other management strategies to maximize the value of their asset portfolio.[24]

Portfolio management addresses the mix of asset types held by the enterprise. It considers such issues as asset interdependencies, where asset risks are correlated with each other, versus true diversification, and where each asset's risks are independent. Portfolio management is concerned with asset disposition (the set of decisions to acquire certain assets and divest others) and the level of strategic and operational flexibility the enterprise wishes to maintain. For a generation portfolio, these enterprise decisions reflect policy toward spreading risk through diversification of markets, fuel types and plant operating characteristics. A more diverse generation portfolio allows the enterprise to implement various trading strategies and related activities such as fuel trading. The optionality value of a single plant is enhanced by its inclusion in a portfolio because it allows such trading to occur.[25]

Resource allocation refers to the methods used to implement portfolio management decisions. It is concerned with who gets how many resources, for what purpose, and when (investment timing). Different methods are available to help decision makers allocate resources among competing investment proposals, including traditional financial analysis methods (payback, NPV, internal rate of return, benefit/cost),[26] custom economic evaluation models, decision analysis based on risk preferences, simulation models and methods that consider the options

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[24] At higher organizational levels (above the fleet level), it may not be necessary to perform a detailed ranking of intermediate size nuclear projects as compared to all the other investment opportunities available to the enterprise.

[25] Roger D. Feldman, "Equity Investment in the U.S. Power Market: What Will be the New 'New Thing'?," Journal of Project Finance, 6 (3) : 5-8, Fall 2000.

[26] See Appendix D for a brief description of these financial methods, their advantages and limitations, and their use in ranking proposed investments.

value of investments.[27] All of these decision support methods organize and process proposed investment information according to specified policies and rules; their outputs are a set of recommendations, not the final answer. It must remembered that insights into value and strategy come from the people who know the business, use the recommendations to organize their own analysis and participate in the process.

[27] See Appendix C for a discussion of the use of options techniques, including real options, in evaluating nuclear projects. EPRI has developed tools for applying real options methods to generation asset decisions. For more information, refer to EPRI's Generation Asset & Project Evaluators, which are modules in the EPRI Energy Book System. The Energy Book System was originally developed for fossil assets. Information on the Energy Book System is available on the EPRI website (http://www.epri.com/).

A
SAMPLE ANCHORED SCALES

A.1 Anchored Scale for Equipment Management and Protection

	Maintenance/Equip Reliability Mgmt	Engineering Management	Materials/Supply Chain Mgmt
10	Comprehensive implementation of life cycle management		
9			
8	Improved performance against maintenance rule system performance goals Significantly increased use/effectiveness of predictive maintenance and RCM	Implementation/significantly enhanced aging management program Significant improvement in engineering solutions including correction of design deficiencies	Optimization of spare parts availability
7			
6	Significant reduction in maintenance backlogs Significant reduction in maintenance preventable functional failures (MPFFs)	Significant reduction in engineering backlogs	Improved spare parts availability with potential plant reliability impact Improved assurance of correct spare parts
5	Improved effectiveness of maintenance resources allocation Improved quality of maintenance Improved performance of testing/calibration	Improved quality of engineering work products Improved engineering tools, analytical methods, and risk analyses Enhanced inspection assessments	Ability to purchase parts via internet Ability to share spare parts with other plants
4	Increased use/effectiveness of predictive maintenance and RCM Reduced work arounds and temp mods		Improved quality of replacement parts including parts evaluations and qualification of commercial grade parts

	Maintenance/Equip Reliability Mgmt	Engineering Management	Materials/Supply Chain Mgmt
3	Incremental reduction in maintenance backlogs Improved work controls such as foreign material exclusion areas Improved instructions and procedures for performance of maintenance	Incremental reduction in engineering backlogs Improved testing procedures Improved systems health reports	
2	Sustains current levels of maintenance performance	Sustains current levels of engineering performance	Sustains current levels of materials/supply chain performance
1			
0	No impact on maintenance and equipment reliability management	No impact on engineering management	No impact on materials/supply chain management

A.2 Anchored Scale for Organizational Effectiveness

	Human Performance	Process Efficiency/Quality	Continuous Improvement
10			Provides new skills necessary to expand the business or acquire new assets
9	Significantly contributes to resolution of a red or yellow finding re licensed operator requalification		
8			
7	Significantly contributes to resolution of a white finding re licensed operator requalification Significant improvement in human error probability (HEP) in response to events	Provides ability to access significant economies of scale	Improved tracking and analysis of operating and test data to identify common causal factors and trends Improved performance against self-assessment findings
6	Significant improvement in human performance causing/contributing to equipment failures Significant improvement in the ability to detect incipient equipment failures	Provides incremental improvement to efficiency/quality of several key processes Significant increase in worker productivity	Significant improvement in staff skills and knowledge and/or managers capabilities Significant improvement in addressing industry issues, trends, notices ,etc.
5	Improved data available to operators and plant staff Improved quality of procedures and instructions Improved adherence to procedures		Provides improved structured methods for communicating information

	Human Performance	Process Efficiency/Quality	Continuous Improvement
4		Identify and address program deficiencies in a timely manner Reduced cycle times for significant processes	Improved self-assessment performance including ability to identify human performance issues
3	Provides increased assurance that performance is maintained re licensed operator requalification Provides equipment or instrument displays with improved HFE	Provides incremental improvement to efficiency/quality of a key process Minor increase in worker productivity Improved planning/scheduling of work activities	Provides increased ability to share skills/resources across departments or plants Increased ability to meet and maintain proficiency standards
2	Sustains current level of human performance including FFD	Sustains current level of process performance	Maintains/reinforces current skills and knowledge.
1			
0	No impact on human performance	No impact on process efficiency/quality	No impact on continuous improvement

A.3 Anchored Scale for Safety/Regulatory Assurance

	NRC/INPO Oversight	Safety Work Environment	Corrective Action Program	Regulatory Enforcement
10	Significantly contributes to resolution of multiple/ repetitive degraded cornerstones; multiple yellow or a red input			Level 1, 2 or 3 violation or higher NRC enforcement action
9	Significantly contributes to resolution of a Degraded Cornerstone; two or more white or a yellow input			
8		Addresses a Substantive Cross-Cutting Issue; corrects sig deficiency in SCWE, improves level of SCWE	Addresses a Substantive Cross-Cutting Issue; provides significant improvement to CAP program	Deviations, Level 4 violation; CAL commitments, NONs
7	Significantly contributes to resolution of a Safety-Significant Inspection Finding/Performance Indicator (white input)	Provides reduction in worker radiation exposure; removal of a workplace hazard		
6		Resolves safety allegation; improves response to safety concerns; provides estimate of current level of SCWE		NCVs; Reg commitment or issue that affects future operating cycle; flexibility on timing/scope of required actions
5	Provides increased assurance that performance is maintained in the "Licensee Response Column"	Provides improved integration of safety in business processes and practices.	Provides incremental improvement to CAP program including backlog reduction, improved timeliness.	

	NRC/INPO Oversight	Safety Work Environment	Corrective Action Program	Regulatory Enforcement
4		Sustains current level of SCWE		Mgmt-regulatory issue that does not require immediate action or compliance; minor violations
3		Provides improved tracking of rad exposures, hazardous materials, etc.		
2	Sustains current level of regulatory performance		Sustains current level of CAP performance	Ensures reliable implementation of regulatory commitments.
1				
0	No impact on regulatory performance	No impact on work environment	No impact on CAP	No impact on regulatory commitments

A.4 Anchored Scale for Strategic Value

	Strategic Value
10	Enables or is integral to enterprise level strategic initiative success Positions enterprise to enter new business area
9	
8	Enables or is integral to specific plant level strategic initiative success Results in dominant competitive position in current business area
7	
6	Contributes significantly to specific enterprise level strategic initiatives
5	Contributes significantly to specific plant level strategic initiatives Strengthens competitive position in current business area
4	
3	Generally supports or is consistent with specific enterprise level strategic initiatives
2	Generally supports or is consistent with specific plant level strategic initiatives
1	
0	No impact on specific strategic initiatives

Note: The adaptation of this scale for a specific plant will likely involve the integration of specific plant and enterprise strategic initiatives into various levels of the scale. This will help assure that strategic value is assigned only when there is a specific nexus of a proposed project to a specific strategic initiative. In addition, not all strategic initiatives would be necessarily accorded the same scale value - so that a project that is assessed as contributing significantly to Strategic Initiative 1 might correspond to a "4" on the scale and another project that is assessed as contributing significantly to Strategic Initiative 2 might correspond to a "5" or "6" on the scale.

B
EXAMPLE PROJECT DESCRIPTIONS AND DATA

B.1 Example Project Data for First Level Hierarchy Factors

Project	Description	Generation	Op Cost	Proj Cost	Bus Risk	Strategic	Comments
1	RCP Motor Replacement	$2000	$0	$600		0	Reduced forced outages.
2	Power uprate of 2%	8200	0	1200		0	
3	Intake bar rake replacement	400	50	300		0	Reduced forced outages; reduced maintenance
4	New CMMS software	5100	2500	6000		4	Shortened refuel outages; reduced staff and spare parts
5	Periodic safety culture survey	0	0	225		3	
6	Root cause analysis training	0	100	75		0	Reduced recurrence of problems
7	Repair steam leaks	350	0	150		0	Improve thermal efficiency
8	Maint backlog for RHR system; address white PI	800	0	250		0	Reduced forces outages; improved regulatory performance
9	LP turbine rotor replacement	6000	200	2000		0	Risk avoidance of failure; reduced maintenance
10	Improved inspection access for RPV head	0	50	200		0	Reduced inspection costs

Note: All dollar amounts are $000 based on NPV of cash flows. Strategic and Business Risk data are based on 0 - 10 scale.

B.2 Example Project Data for Second Level (Business Risk) Hierarchy Factors

Project	Description	Equipment Reliability	Organizational Effectiveness	Regulatory Assurance
1	RCP Motor Replacement	0	0	0
2	Power uprate of 2%	0	0	0
3	Intake bar rake replacement	0	0	0
4	New CMMS software	6	8	3
5	Periodic safety culture survey	0	0	6
6	Root cause analysis training	5	6	4
7	Repair steam leaks	0	0	0
8	Maint backlog for RHR system; address white PI	5	0	7
9	LP turbine rotor replacement	0	0	0
10	Improved inspection access for RPV head	0	5	7

C
USE OF OPTIONS IN PROJECT EVALUATION

C.1 Introduction

As nuclear generating plants have been exposed to more competitive electricity markets, interest has risen in applying decision support techniques that consider the uncertainty and volatility inherent in such markets. One specific approach that has been proposed is "real options." This approach takes techniques that have been developed for valuing financial options and applies them to real assets, e.g., a nuclear generating plant. A second, more general approach is to consider different project options that may be available as part of the process to formulate, propose, evaluate, and approve specific projects. Either approach has the potential to add value to nuclear project decision making; the general approach is discussed following and the real options approach is discussed later in this appendix.

An options approach appeals to managers and other decision makers because it directly confronts two key dimensions an investment decision: uncertainty and flexibility. Uncertainty refers to the unknown component of the future; as the future becomes the present, uncertainty becomes certainty. Flexibility is the ability to change the way assets are managed as uncertainty is resolved. Different approaches to incorporating options may be appropriate at the plant level, which is project-focused, and the enterprise level, which must consider large projects and other major corporate issues. However, managers at all levels face the same basic decisions with respect to a proposed project (investment): do a project now, don't do it at all, or perhaps do it or something else later (the options decision). Options increase in value as outcomes increase in uncertainty or the timing of final decisions can be deferred.[28]

C.2 Options at the Plant Level

At the plant level, options focus on ways to hedge, manage or transfer project risk. Specific methods available are analogous to financial options known as puts and calls.[29] A "put" is an option to sell a financial security at a specified price during a specified period of time. Put options are used to reduce downside risk. A "call" is an option to buy a financial security at a specified price during a specified period of time. Call options are used to secure an opportunity to make a further investment if the original investment turns out to be profitable.

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[28] Bain and Company, "Real Options Analysis," http://www.bain.com/bainweb/expertise/tools/mtt/real_options.asp.

[29] The discussion on project options at the plant level has been adapted from Dragan Milosevic (ed.), Project Management Toolbox, John Wiley, forthcoming, ch. 2.

A proposed nuclear project faces many potential risks. Some of these risks are internal to the project, e.g., the risk that the proposed project will not be effective, or that there will be cost or schedule overruns. There is the risk that the plant will not have the technical skills or other resources needed to implement the project. Some risks are external, e.g., the risk of regulatory changes, or emergence of a cheaper or substitute technology for implementing the project. Many of these risks may be offset by put or call options.

A put is a way of limiting losses from downside risk. Some measures that are analogous to puts are:

- Defer: postpone the project to gather additional information about risks and benefits, or to conserve resources.
- Multi-stage: a project that can be done in stages can be stopped if things look bad, and resumed if new information justifies resumption.
- Outsource: contract with a third party to carry out the project; include a negotiated termination clause if things go sour.
- Explore: start with a pilot or prototype project and expand it if it looks favorable.
- Abandon: choose facilities or other equipment that have a high salvage value, so that something can be recouped if the project must be terminated.
- Flexible scale: design the project so that it can be limited in scope if conditions turn out to be less favorable than anticipated, but not so bad the project should be terminated.

Each of these measures costs something (just as do options in the stock market), but each either reduces risk or transfers that risk to someone else.

Some nuclear projects may turn out better than expected. The call is a way of gaining benefit from upside performance or positioning the plant to take advantage of other successful projects. Some measures that are analogous to calls are:

- Flexible scale: design the project so that it can be expanded if conditions turn out to be more favorable than anticipated. An example of this is a process improvement that is successful at one plant, then adopted across the fleet.
- Strategic growth: this is a project that is a link in a chain of projects, or is a prerequisite to other projects.

While plant-level projects have to satisfy financial and other criteria established at higher organizational levels, options at the plant level should appropriately focus on variables and alternatives that plant personnel can take advantage of, understand and manage.

C.3 Options at the Enterprise Level

The enterprise level may be the nuclear business unit, responsible for a fleet of nuclear generating plants; a generation business, which has to consider both nuclear and non-nuclear resource requests; or the corporate level of an integrated energy company. Regardless of the level of the enterprise (plant, fleet, or corporation), decision makers need to appropriately consider options in their investment ranking, resource allocation, and portfolio management decisions. However, the decision context and top-level goals may vary with organizational level. For the nuclear business unit, the overarching goal may be to maximize the performance and value of the nuclear fleet. For the generation business unit, the goal may be to maximize performance of the generation portfolio. Corporate management is trying to maximize the value of the overall enterprise. The methods for considering options may vary at each level.

Lower organizational levels, e.g., the nuclear business unit, will generally be "takers" of corporate rules and polices that guide investment choice and resource allocation. The options component of most decisions will probably center on project options and risk management. Quantitative (financial) and qualitative factors, such as maintaining favorable regulatory relationships, must be balanced. Performance risk on the plant side (e.g., capacity factor) is still the dominant concern and responsibility of management.

At the corporate level, options focus on ways to calculate the optionality value of assets, both currently owned and prospective.[30] The greater the uncertainty in the markets for products produced by assets, the greater the optionality value. Decisions at this level may not be concerned with the options available for specific projects of all but the greatest in cost or investment.

Real options are appropriate at any level (plant, fleet, generation, corporate) where the decision involves changing the shutdown date for the plant. Such decisions include early retirement, license renewal, or "life and death" major equipment decisions like steam generator or reactor vessel replacement. Another appropriate application is consideration of the option value of the plant site, e.g., the option to expand generating capacity at the site.

C.4 Considerations When Applying Real Options to Plant Investments

Real options analysis can add value to nuclear investment decisions. However, the decision maker needs to understand the strengths and weaknesses of this approach in order to apply it to the class of decisions for which it is most appropriate.

To begin, one source of optionality value, the flexibility to run when electricity prices are high and not running when prices are low, does not apply to nuclear plants. This specific optionality value is a function of the plant's ability to follow electricity prices, running when prices are high and not running when prices are low. Gas peaking plants have the best options value in this respect, while baseload nuclear and coal plants have the least because of their inflexible operating characteristics. For any plant, realizing the value of operating options requires that the owner have corresponding trading expertise otherwise the potential value of options cannot be realized.[31]

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[30] EPRI has developed tools for calculating options value. Nuclear Asset and Project Evaluator (NAPE) or Fossil Asset and Project Evaluator (FAPE) can be applied at the plant or fleet level. The Energy Book System can be applied at the corporation level.

[31] Julia Frayer and Nazli Z. Uludere, "What is it worth? Application of real options theory to the valuation of generation assets," briefing note from London Economics International LLC.

However, nuclear plants do exhibit two major types of flexibility, both involving the end date of service: early retirement and license renewal.[32] In this case, option value is the "increment in net present value due to the right – not the obligation – to retire a plant before expiration of the original licensed term or to operate during a license renewal term; option value is always positive because an option will be exercised only if future conditions are favorable."[33]

A second consideration is that applications of the Black-Scholes option-pricing model may focus on electricity price volatility and tend to ignore risk in other value contributors, primarily plant capacity factor and operating costs. These applications may overestimate the importance of price volatility if the nuclear plant has a more predictable price stream because of contracts, or if the specific application ignores the tendency of electricity prices to revert to the mean in the long run. In addition, reliable forward electricity price data may not be available for the market in which a plant or fleet operates.[34]

An appropriate application of real options is setting minimum financial performance standards (hurdle rates) for proposed projects or other investments. In such an application, real options focused on electricity prices effectively means that the NPV or Benefit/Cost hurdle rate may be increased as electricity price volatility increases. However, for plants under regulation or with firm long-term contracts, volatility is zero and traditional discounted cash flow NPV (or similar financial technique) is sufficient.[35] Investment under the traditional NPV rule will be higher than that under the option value. Price uncertainty and the usual irreversibility of a nuclear project investment leads to a reduction in the amounts invested. It should be noted there is a greater distance between the optimal entry threshold and the optimal exit threshold under the option value approach than under traditional NPV. When the firm takes into account the uncertainty over future electricity prices, it is more reluctant to invest in generation projects. On the other hand, for an existing plant, the firm is more reluctant to abandon the investment due to the option value of keeping the plant viable. Establishing financial methods, criteria and hurdle rates is usually a corporate responsibility.

One consulting firm that practices in the area of decision analysis[36] has observed that real options are not particularly relevant if the firm doesn't have significant resolution of uncertainty over time or flexibility, initial moves do not affect the future options or preserving flexibility is too

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[32] Art Altman, "Overview of Nuclear Asset & Project Evaluator (NAPE)," Proceeding: 2001 Nuclear Asset Management Workshop, EPRI, Palo Alto, CA: 2002, p. 4-4. For more information on EPRI's work in applying real options to generation asset decisions, refer to EPRI Nuclear Asset and Project Evaluators: Motivation, Concepts and Way Forward, EPRI, Palo Alto, CA: 2000. 1000636. EPRI's Generation Asset & Project Evaluators are modules in the EPRI Energy Book System. The Energy Book System was originally developed for fossil assets.

[33] Nuclear Power Financial Indicators for a Competitive Market, EPRI, Palo Alto, CA: 2001, 1003050, p. C-5.

[34] Frayer and Uludere, "What is it worth?"

[35] Marie-Laure Guillerminet, "The choice of the regulated organization according to the investment in a marginal nuclear equipment," 25th Annual IAEE International Conference, Aberdeen, 26-29 June 2002.

[36] Strategic Decisions Group, "Real Options Results Are In: Executives, Beware the Hype," Executive eBriefing™, 14 Feb 2001, pp. 36-37, 53.

costly. High option value is about both uncertainty and the ability to attractively defer resource commitments until aspects of that uncertainty are resolved. Option value needs both, not just one. Managers must decide which types of nuclear project decisions qualify for real options consideration.

Real options are not the only way to incorporate uncertainty and flexibility in decision making. For example, simulation[37] can accommodate multiple sources of risk – both internal and external to the firm. Simulation methods can include risks for costs, electricity prices, capacity factor and others; simulation outputs can show statistical confidence intervals for results. A fleet simulation model can incorporate key performance drivers such as management performance, the regulatory environment, plant material condition, and technical and safety issues. Such a model can be used to evaluate alternative fleet management strategies. Simulation allows the integration of many contributing variables to compute a top level measure, such as the NPV of fleet income, as the basis for judging alternative strategy approaches.

One key value contributor of real options is that it requires managers to evaluate decisions, including proposed projects, in terms of risk and flexibility. It helps managers identify risk components and decide which ones to retain, hedge or transfer. Real options can force managers to look for opportunities to increase flexibility, including options to defer a project or abandon it if benefits are not being realized.[38]

C.5 Conclusion

Options can be considered at the plant and enterprise level of the organization. At the plant level, the focus is on identifying options associated with individual proposed projects. Expensive projects may warrant the real options approach. Real options is one financial decision support tool available to the manager. It complements but does not replace other financial techniques such as NPV, IRR, ROI and Benefit/Cost analysis. The most appropriate use for real options is for decisions that inherently have great uncertainty and flexibility, e.g., the decision to retire a nuclear plant before the end of its licensed life or the decision to pursue license extension for a nuclear plant. Real options can be used to set minimum financial performance criteria (hurdle rates) for proposed projects; in a competitive electricity market, such criteria will be more stringent than in an environment where future prices for plant output are known or assured. Real options, which is primarily a financial technique, is not well-suited to handle qualitative factors. In general, the more a generating plant is actually exposed to the consequences of changing electricity prices, the more real options should be a factor in decision making. Of course, all options are worthless if resources and budgets are not allocated to hold and execute the options.

[37] Simulation uses mathematical equations to represent complex real world systems and the interaction of components of those systems. See Appendix G for an example of how simulation can be used to represent a fleet of nuclear power plants.

[38] Bain & Company, "Real Options Analysis."

D
PROJECT FINANCIAL EVALUATION AND RANKING TECHNIQUES[39]

Most utilities screen projects through a variety of financial techniques to evaluate their viability and contribution to the company's future value. The primary techniques include payback period, net present value, internal rate of return, and benefit/cost ratio. This appendix describes these techniques and their use in evaluating and ranking proposed projects.

Payback Period - The payback period of a project is the time it takes to recover the initial investment. It is the duration needed for returns from the project to equal the project cost or investment. Usually the time value of money is not taken into account, but it can by applying net present value to both the returns and investment stream. Many companies specify a payback period of just one or a few years for small to intermediate projects to be accepted.

The payback period screen offers a quick analysis method, but also may shortchange good projects because it may not accept those with delayed revenues or cost savings. It says nothing about a project's total cumulative benefits.

Net Present Value (NPV) – The NPV is the present value of a project's future net cash flows, discounted to the present, less the present value of the investment stream. The discount rate is either the company's cost of capital, its required rate of return for new investments, or a risk-adjusted rate of return to account for project risk. If the NPV is positive, the project is acceptable.

Internal Rate of Return (IRR) – The internal rate of return method for a project is the discount rate that equates the present value of the expected cash flows with the initial investment (cost). The project investment is set equal to the sum of the discounted annual cash flows and solved for the discount rate. Many companies set a minimum rate of return required of projects commonly referred to as the "hurdle" rate. If the IRR is greater than the hurdle rate, it is accepted.

Benefit/Cost or Benefit/Investment Ratio (B/C or B/I Ratio) – This parameter is the ratio of the net present value of future cash flows (not including investment cost) to the investment cost discounted to the present. If the B/C Ratio is greater than 1, the project is acceptable.

Corporate financial academics (such as Brealey/Myers and Van Home/Wachowicz) maintain that the NPV approach to screening is the preferred method. Any project with a positive NPV is

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[39] This appendix is based on material developed by Gary M. Doughty of Janus Management Associates, Inc. based on materials from James C. Van Horne and John M. Wachowicz, Jr., Fundamentals of Financial Management, 10th ed. (Prentice Hall), ch. 8.

acceptable because it will increase the value of the firm; and the NPV method quantifies the dollar contribution to shareholder wealth. Thus, to rank projects using the NPVs is essentially to choose all those with a positive value. If there were limits to the capital budget, then one would choose all the projects that can be funded in descending NPV order.

Companies frequently use other methods of screening projects. For instance, the prospect of returning the investment quickly makes the Payback Period attractive. The B/C Ratio and IRR seem to identify those projects with the biggest "bang" for the but they do not specify how many dollars a project will contribute to the company.

However, when choosing between projects that are mutually exclusive, some of the financial screening techniques may give contradictory results. The size or scale of the project, the timing of the future cash flows (savings or revenues), and the lives of the projects can affect the decision.

With regard to project scale, a small project may have a very high IRR compared to a large project, but the NPV for the large project is much higher. Likewise, the B/C Ratio of a small project may be very large because of the low investment requirement compared to a large project, but the large project NPV is orders of magnitude higher.

The timing of the future cash flows resulting from the project can affect ranking decisions. Obviously, the Payback Period screen will eliminate projects with revenue / savings that are further out in time. If future cash flows grow in value with project life, some very beneficial projects will not be undertaken if the primary decision criterion is Payback Period. Timing of cash flows can also affect the IRR calculation and an IRR investment decision can conflict with the NPV approach depending on the discount rate.

Comparing projects with different lives can lead to problems with NPV if the projects need to be replaced at the end of their respective useful lives. In this case, the NPV comparison needs to be made over some common investment horizon. For example, if project A has a useful life of 5 years and project B's useful life is 10 years, then the comparison needs to be made over 10 years for both. For project A, this means replacing the original A with an identical replacement A at the end of year 5, then computing the overall 10-year NPV. The resultant value can be directly compared to project B's NPV, which was calculated on a 10-year basis.

As shown above, evaluating proposed projects using only financial techniques can lead to rankings of projects that are not the same from one technique to another. The project ranking method described in this report can provide additional insight into the different types of value proposed projects can contribute to the asset, and identify which projects are preferred based on their overall value contribution.

E
OVERVIEW OF PROJECT RANKING AND SELECTION METHODS[40]

This appendix reviews possible project selection methods, compares advantages and disadvantages, and suggests a preferred method as being most suitable for nuclear power plants.

E.1 Some Assumptions

The following assumptions are made regarding the need for and requirements placed on project selection methods.

- There are more projects in the project menu than available resources to carry out, since otherwise there is no need for project selection.
- Projects related to nuclear safety, and projects required by regulatory agencies, will be not be part of the project selection process but will be put at the head of the list. Remaining resources will then be allocated to projects selected from the project menu.
- The major selection criterion will be retained or added value to the plant or fleet.
- Additional selection criteria not easily convertible to financial payoff may also be required, such as workplace safety (non-nuclear) or reduced (non-nuclear) emissions.
- Company policy may require that specific types of projects must be included in the list of selected projects (e.g., at least one project at each of a fleet of plants; at least one project aimed at a specific aspect of the business).
- There may be interactions among projects, such as:
  - Demand for the same resources
  - Similar set-up requirements for different projects, making it convenient to do both (or all) simultaneously
  - Some projects may appear in the menu in different forms (e.g., do a project on a crash basis, or do the same project on a routine basis).

E.2 Review of the Most Common Ranking and Selection Methods

The most common methods used in various industries are described here, with the most important advantages and disadvantages of each.

[40] Prepared by Joseph Martino, author of Research and Development Project Selection, John Wiley & Sons, 1995.

- **Economic methods**: These consider only the economic costs and returns of the project. They do not consider non-financial factors that may also be important. However, economic methods do permit direct comparison with the costs and returns of other capital investments. This may be their primary advantage. There are three economic methods widely used in industry.
  - **Payback Time**. This is simply the time until the returns equal the previous costs and the cumulative cash flow is no longer negative. This method hedges against uncertainty because it does not require estimates of future interest rates, or of revenues beyond the end of the payback time. Moreover, it is easy to use. However, it does not consider magnitude of the project, nor potential returns once payback has been reached. It also does not consider time value of money.
  - **Net Present Value**. This is the sum of returns less costs, each discounted by the appropriate rate. It allows comparison of different cash flows over time, and properly represents project magnitude. However, it is not robust against uncertainty in discount rates.
  - **Internal Rate of Return**. This is simply the interest rate at which the project's Net Present Value is zero. It establishes a "hurdle rate" for projects, allowing direct comparison among different projects. It does take account of the time value of money. However, although cash flow is used in IRR computations, the final result says nothing about the magnitude of the project. It may favor a small project with immediate returns over a more profitable project with more remote returns.

  Economic methods are discussed further in Appendix D.
- **Scoring Models**. These are mathematical formulas that take into account any factors that are considered important, and produce a numerical score for a project. In general, the scoring model will include factors with coefficients or weights. The coefficients or weights are chosen to represent the relative importance of the various factors; they are usually determined by management. The values of the factors are usually provided by those persons responsible for the project. Scoring models can include both inherently quantitative factors such as costs or financial returns and qualitative factors such as degree of complexity of a project. The major advantages of scoring models are their ability to combine various factors into a single score, and their transparency. Their major disadvantage is the amount of information usually required to compute a score and the judgments needed to assign weights and formulate scales for each factor.
- **Analytic Hierarchy Procedure**. The Analytic Hierarchy Procedure, like the scoring model, allows the user to combine several factors into a single score. It utilizes coefficients or weights, usually supplied by management, and the values of the individual factors, usually supplied by those responsible for the project. Also like the scoring model, the AHP can utilize both quantitative and qualitative factors. Unlike the scoring model, which is a "one level" model, the AHP allows factors to be broken down into a hierarchy of sub-factors. This disaggregation can be continued to as many levels as needed. This is one of the major advantages of the AHP, since different levels of management can supply weights for the appropriate levels of disaggregation.
- **Portfolio Optimization**. This method is used when there are interactions among projects, such as use of common resources. The idea is to assure that the set of projects selected does

not exceed the available amounts of the constraining resources. For small project sets, a Microsoft Excel™ spreadsheet can be used. For larger project sets, specialized programs must be used. Whether done using Excel or a specialized program, the process involves a "search" through the set of candidate projects to find the unique subset that stays within the constraints while maximizing some measure of payoff.

- **Network Analysis**. This method is used when there are timing requirements among several projects, such as the need to complete one before another can be started, or the need to carry out two or more projects during some kind of time window.
- **Monte Carlo Simulation**. This method requires that probability distributions for uncertain variables be estimated. Computer simulation can then be used to establish that, with a specified probability, the budget or other constraints will not be exceeded. The major disadvantages of this method are the need to obtain probability estimates, and the need to conduct extensive computer simulations.

E.3 Recommended Method

The nuclear power industry is "data rich," for a variety of historical reasons. Given this fact, there is no need to choose a project selection method that does not require much data. Since non-financial factors may play an important role in project selection, the economic methods are probably not adequate for most selection situations. Information provided by EPRI indicates that resource constraints, other than budget, will usually not be a problem. That is, non-financial resources such as computer time or particular skills can usually be purchased or outsourced. Therefore resource-related interactions among projects can usually be ignored. Finally, from the criteria listed in Section 3.3, the methods should be simple enough that they do not impose a significant burden on the managers and staff who must use.

Given these considerations, the choice of project selection method narrows down to Scoring Models or the Analytic Hierarchy Procedure. The latter seems more appropriate, since it allows disaggregation of relevant factors to several levels. Moreover, it permits management at several levels to specify the weights for factors at appropriate levels of disaggregation. Therefore, AHP is recommended as the most appropriate method for ranking nuclear power plant projects.

Since AHP can utilize qualitative factors, a discussion and example of how these factors can be quantified is provided below.

E.4 Scaling of Qualitative Factors

Qualitative factors must be put on a numerical rating scale in order to be combined with quantitative factors in a scoring model or with the Analytic Hierarchy Procedure. This is done by using "anchored scales." These are numerical scales with verbal "anchor points" at various numbers. These anchor points are intended to allow different people to reach similar ratings on a given project, and to allow people rating different projects to reach consistent ratings.

The following scale is intended as an illustrative example of a rating of technological maturity for a project. It is to illustrate the approach only. In an actual application, the scale might be revised to fit local circumstances. However, all projects must be rated on the same scale.

Note that not all scale values need verbal descriptors. It is possible to interpolate between anchor points. However, the more anchor points there are, the less ambiguity will exist in using the rating scale. The following is a scale that might be used to rate or score technological maturity in selecting components to purchase for a project.

1. All components are experimental only
2.
3. All components available only as pre-production samples from potential vendors
4.
5. Most components available only from single sources
6.
7. Over half of components are commercially available from multiple sources
8.
9. All critical components are commercially available from multiple sources; other components have single sources only
10. All components are commercially available from multiple sources

E.5 An Example of the Analytic Hierarchy Procedure[41]

The AHP is a procedure for ranking entities such as projects, when there are multiple factors to be taken into account, and when some or all factors can be disaggregated into subfactors. It is not necessary that all branches have the same number of levels.

This example consists of five projects, P1 through P5. Each project is evaluated on four factors, F1 through F4. Factors F1, F2 and F3 have one level only. Factor F4 has three subfactors, F41, F42, F43. Each of the four factors has a weight indicating its relative importance, and the three subfactors of Factor F4 likewise have weights indicating their relative importance. The projects, factors, weights and numbers in this example are purely hypothetical. They are not intended to be realistic representations of anything, but are intended solely to illustrate the AHP procedure. The factor "tree" is shown below in Figure E-1.

[41] For a real world example of the application of AHP, see Prasanta Kumar Dey, "Quantitative risk management aids refinery construction: Combining the Analytic Hierarchy Process and decision tree analysis provides an effective means for controlling a complex project," Hydrocarbon Processing, 81 (3) : 85 (7), Mar 2002.

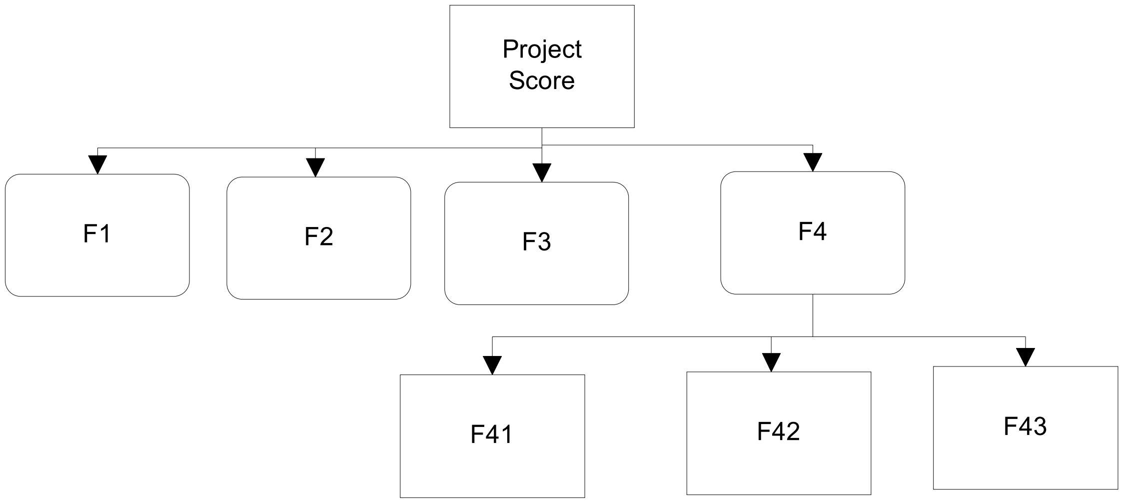

Figure E-1
Illustrative Hierarchy for Analytic Hierarchy Procedure

The four factors are given relative weights. However, these weights must be normalized so that the "gain" at each level of the hierarchy is equal to 1.0. This is to assure that branches are given equal weight, regardless of their length. (The calculations described here can be performed using a spreadsheet program or specialized AHP software.)

Since F4 is disaggregated into three subfactors, the weights for the three subfactors must next be normalized. This is done in the same manner as was done for the top four factors.

Next the subfactors must be aggregated to get F4. Project values on each subfactor are normalized in the same manner as for the factor weights. The result is a set of project scores on F4. Project scores on F1, F2 and F3 are computed in the same manner as subfactor scores were computed.

Finally, the total scores for each project are computed. For each project, multiply its score on each factor by the normalized weight for that factor. The project scores can then be sorted in descending order. In practice, the projects would be funded in order of decreasing score, until the budget is exhausted.

F
APPROACHES FOR ASSIGNING WEIGHTING FACTORS

This appendix develops factor weights, in greater detail than shown in the body of the report, in two possible ways. The two ways are:

- Factor weights based on SNPM performance indicators
- Factor weights based on industry quartile performance characteristics

F.1 Performance Indicator Approach

The approach described in this section will show how plant performance indicators (PIs) can be applied to weighting the assessment framework. Sources of performance indicators could be plant specific or industry-based, such as the Standard Nuclear Performance Model (SNPM) PIs developed under NEI's auspices. An advantage of the SNPM indicators is that they are consistent across the industry and industry-wide data should be available for benchmarking. Integration with the SNPM also provides the opportunity for creating a closed performance loop for nuclear assets as shown in Figure 3-2.

The process illustrated in Figure 3-2 is based on a fundamental performance dynamic where plant and organizational performance results drive resource allocation, which in turn feeds back into (changed) performance. We have added an outer loop where performance indicator results (using industry benchmarks to disclose performance gaps) are used to set the assessment framework weights, which in turn drive project ranking and selection, and ultimately resource allocation. The approach shown in Figure 3-2 recognizes that performance gaps are closed primarily by allocating resources to areas that are either deficient or where further improvement can yield highest asset value. The principal source of discretionary resource allocation is (should be) project based, though closing performance gaps may also be considered during the process to allocate baseline budget resources.

The following approach to implement PI-based weighting is suggested. First, the assessment framework was reviewed against the SNPM PIs and the first and second level factors were annotated with the PIs most applicable to each factor. This is illustrated in Figure 3-3 for the PIs currently available.[42] Figure 3-3 demonstrates that there is good alignment between the framework and PIs and there are sufficient PIs within each factor to support gap analysis. If necessary additional plant specific PIs can be added. In certain areas there may be more factors

[42] PIs were selected from NEI/EUCG Task Force Report Draft Rev A, The Standard Nuclear Performance Model - A Process Management Approach - Revision 2, Dec 2001.

than necessary or optimal for understanding performance gaps. These situations may be handled by selecting one or more key indicators and/or creating a composite index of factors for these performance areas.

The second step is to use PI data associated with each of the hierarchy factors to establish factor weights. Using PIs may provide a detailed indication of performance gaps, but it will require some care to assure that they provide a sufficiently general indication of the importance of each hierarchy factor.

The approach for using the PI data to establish hierarchy factor weights is as follows:

1. Select one or a subset of PIs that are representative of each hierarchy factor.
2. Obtain industry wide data for each of the PIs for a representative time period.
3. For each set of PI data, apply a scaling process to the data to establish a common basis for comparing performance across PIs.[43]
4. Identify the current performance value for each PI for the plant to which the hierarchy is being applied. Identify the appropriate performance goal for each PI; e.g. mean, first quartile or other specific value.
5. Using scaled values, compute the relative change in magnitude of each PI necessary to move performance from its current value to the goal. The resulting values indicate the relative magnitudes of performance improvement required for each PI, and for its hierarchy factor.
6. Establish the weight of each hierarchy factor based on the relative magnitudes computed in (5).

We will illustrate this for three PIs, one each to represent each of the three Business Risk factors:[44]

- Unplanned power changes per 7000 hours
- Number of NRC inspection findings
- Forced outage rate

Unplanned power changes: This is one of the NRC's regulatory oversight program indicators under the "Initiating Events" Cornerstone. It is defined as the number of unplanned changes in

[43] Each PI will have different numerical magnitudes and ranges of data. In order to avoid introducing artificial differences among the PIs, the data must be placed on a common scale.

[44] One consideration is the availability of industry data sets. The data for Inspection Findings and Unplanned Power Changes could be obtained from the NRC website and so were convenient to use for this example. Data for forced outage rate was summarized from representative historical industry data. It is anticipated that SNPM PI data will be readily available across the industry in a similar manner or that individual plants could rely on their internally established performance benchmarks.

reactor power of greater than 20% full-power, per 7,000 hours of critical operation excluding manual and automatic scrams. In our example, we use data for a single quarter, the 3rd quarter of 2000, for all operating units. Since this parameter is used by the NRC it could be considered as an indicator of the Regulatory Assurance factor. However it is also a good indicator of the Organizational Effectiveness factor since unplanned power changes are associated with personnel and supervisory actions and skills, administrative controls, procedure quality and adherence, etc.

NRC Inspection Findings: We have compiled numbers of findings by plant from NRC inspection results. Data are for a one year period, 3rd quarter 2000 through 2nd quarter 2001. NRC Inspection Findings will be used as an indicator of the Regulatory Assurance factor.

Forced Outage Rate: This is the amount of lost generation in a year due to forced outages, expressed as a capacity factor percentage. It will be used as the indicator for Equipment Management.

Figure F-1 summarizes the raw data for each PI. For each PI there are 103 data points corresponding to the total number of operating units. The horizontal lines represent the range of the data, e.g., for Inspection Findings plants had from 4 to 65 findings during the period. Values for the mean of the data set are shown in **bold**, and for the boundary of 1st quartile performance, values are shown in *italics*. For example, the mean of the UPC indicator is "1.4" and the 1st quartile is "0". For this indicator "0" is also the lower limit of the data range. The " ⥣" symbols indicate the current performance values for our hypothetical plant. For example, current performance for Inspection Findings is 26 findings. Note that for Inspection Findings and UPC, current performance is above the industry mean, while for FO Rate performance is below the mean.

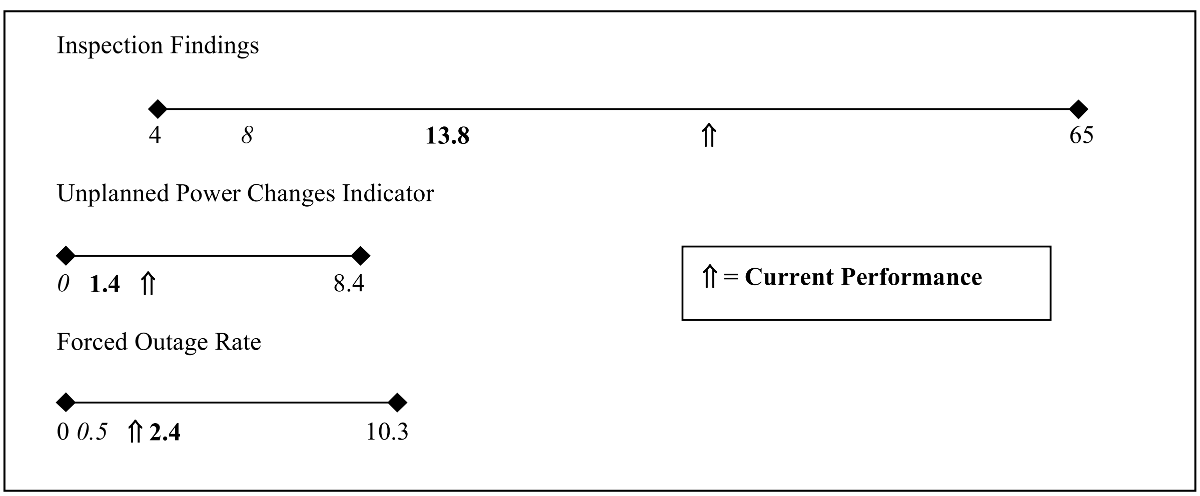

Figure F-1
Industry Performance for Selected Performance Indicators

In order to establish a valid comparison of these indicators, the raw data must be scaled.[45] The scaled data for the three indicators are presented Figure F-2. Note that the scaled values for all indicators have a mean value of zero (in **bold**), and the values along the axis represent multiples of standard deviation. For example, the lower range of Inspection Findings is "-1.38", indicating that this point is 1.38 standard deviations below the mean. The values for upper quartile are again shown in *italics*, and current performance values are indicated by " ⇑" with values scaled accordingly. See that for the UPC data, the 1st quartile point is "0" (raw data) and "-0.87" (scaled data set). The scaled value indicates that the 1st quartile point is a little less than one standard deviation below the mean. For the Inspection Findings data, the 1st quartile point is "8" (raw data) and "-0.82". Thus the 1st quartile for Findings is also a little less than one standard deviation below the mean.

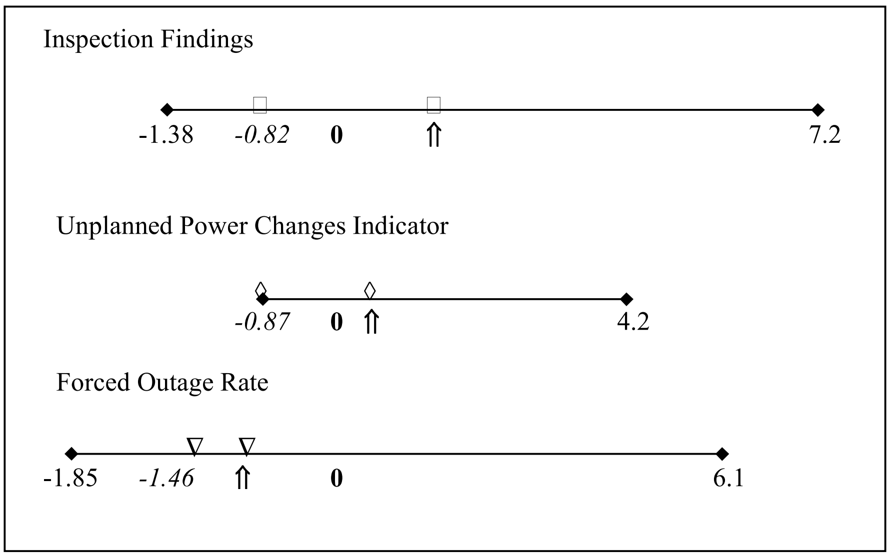

Figure F-2
Scaled Industry Performance Indicators

The next step in establishing hierarchy factor weights is to quantify the performance goals in each of the areas covered by the three PIs. We have done this for each PI as follows:

Inspection Findings:	8 (corresponds to 1st quartile)
UPC Indicator:	0 (corresponds to 1st quartile)
Forced Outage Rate:	1% (incremental improvement)

On Figure F-2 the current and target performance values are indicated by different symbols: Findings (□), UPC Indicator (◊), and Forced Outage Rate (∇). It is readily apparent from

[45] For each PI, scaling is accomplished by taking each data value, subtracting the mean and dividing by the standard deviation of the set of data. The result is a data set with mean of zero and data values corresponding to increments of standard deviation from the mean. Thus, very different sets of original data can be converted to comparable scales.

examination of the scales that the magnitude of improvement is greatest for Findings, less for UPC, and smallest for FO Rate.

To quantify the relative magnitudes of change for each PI, the scaled value of the goal is subtracted from the scaled value of current performance. The results are summarized in Table F-1. For the UPC indicator, current performance of "2.1", scales to "0.40", or a little less than one half a standard deviation above the mean, and "1.27" standard deviations above the 1st quartile level. The Findings indicator current performance of "26", scales to "1.70", or 1.7 standard deviations above the mean and 2.52 standard deviations above 1st quartile. The second column from the right in the table summarizes the relative changes for each PI in units of standard deviation. The last column translates this to an approximate relative multiplier, showing that the UPC change is 2x, and the Findings change is 4x the FO Rate change. Since these indicators were proxies for our hierarchy factors, it suggests that the relative weights that should be applied to the hierarchy factors represented by each of the indicators.

Table F-1
Factor Weights Based on Goals for Performance Indicators

PI	Raw Data		Scaled Data		Gap to 1st Q	Relative Weight
	Current	Goal	Current	Goal	(Std Devs)	
UPC	2.1	0 (1stQ)[46]	0.4	-0.87	1.27	2x
Findings	26	8 (1stQ)	1.7	-0.82	2.52	4x
FO rate	1.6%	1%	-0.62	-1.1	0.58	x

On a normalized percentage basis the weights for the three factors would be Organizational Effectiveness (28%), Equipment Management (14%) and Regulatory Assurance (58%).

The above example was based on a decision by the hypothetical plant's management to establish performance goals of 1st quartile for Organizational Effectiveness and Regulatory Assurance, and an incremental improvement in Equipment Management, but less than 1st quartile. One might have selected other performance goals in doing the gap analysis; e.g., industry average or internally set goals.[47] To illustrate the effects of a different set of goal assumptions, we selected the following alternate goals:

Inspection Findings:	13.8 (corresponds to mean)
UPC Indicator:	1.4 (corresponds to mean)
Forced Outage Rate:	0.5% (corresponds to 1st quartile)

---

[46] 1st quartile plants have a UPC indicator of zero.

[47] It can be noted that for Unplanned Power Changes, there is an NRC limit of 6 (normalized 4.3) to maintain a green indicator color. This would not normally provide a useful target since it is a threshold that is to be avoided and almost always is - only three units exceeded this level for the 3rd Q 2000.

The results are summarized in Table F-2.

Table F-2
Factor Weights Based on Different Goals for Performance Indicators

PI	Raw Data		Scaled Data		Gap to 1st Q	Relative Weight
	Current	Goal	Current	Goal	(Std Devs)	
UPC	2.1	1.4 (mean)	0.4	0	0.4	x
Findings	26	13.8 (mean)	1.70	0	1.7	4x
FO rate	1.6%	0.5% (1stQ)	-0.62	-1.46	0.84	2x

Now the relative gaps have shifted such that UPC is the smallest, FO Rate next and Findings remains the largest. (The fact that the relative weight factors are once again x, 2x and 4x are coincidental.) For this set of assumptions, the factor weights on a normalized percentage basis would be: Organizational Effectiveness (14%), Equipment Management (28%) and Regulatory Assurance (58%).

It should be noted that the relative magnitudes of the performance gaps, e.g., 2x, 4x, etc., are only suggestive of the relative importance of the performance areas and associated hierarchy factors. Management might agree that there is a clear difference in gap for certain areas but still choose to limit the weighting difference for the factors to a smaller value. This might be necessary to ensure better balance across all performance areas and to account for the variability with time in the PIs themselves.

In order to extrapolate the approach developed in the above example to completely specify factor weights, selected PIs across all the framework factors would need to be assessed, scaled and gaps analyzed. Where multiple PIs are selected to represent certain factors, scores for each PI would need to be combined (e.g., averaged) to arrive at a single proxy value.[48]

A significant benefit of using PIs to set factor weights is the feedback loop that is created and the self-adjusting nature of the process. PI results and performance goals are used to identify gaps, and to then assign framework weights. This, in turn, impacts which projects are funded and implemented. Monitoring of future PI results then provide indications of how effective the selected projects were in changing performance and achieving goals. Changed performance leads to changes in the gap analysis (and to the extent industry benchmarks are changing, this is constantly fed back into the process as well) and adjustment of the framework weighting factors for the next project budgeting cycle. Management always retains the option of adjusting performance goals and fine tuning the hierarchy weights to best meet its competitive environment, availability of capital, business strategy and other relevant considerations.

[48] This brief example is not meant to imply that using PIs for setting weights is a simple, mechanical task. As previously noted, the set of currently available PIs may not provide adequate coverage for some ranking factors. Reasonable people may disagree on the significance of a specific PI for plant performance or the relative importance of different PIs. However, the existence of the powerful feedback loop described above should foster increased interest in identifying a complete, coherent set of NAM PIs.

F.2 Industry Quartile Approach

This approach is based on a blend of analytical treatment of nuclear plant performance and judgment as to the priorities and practical considerations associated with nuclear asset management. From our principles, we expect that the current operating performance, or performance “regime”, of a plant will influence the opportunities for improving and sustaining asset value, and therefore, the relative importance of each factor in our hierarchy. Thus the importance of the factors will likely differ for each plant based on its specific operating characteristics and strategic business situation. For purposes of this project, we will illustrate how to address these differences by considering how plants in each industry "quartile" may present different asset management priorities and thus different weighting factors.[49]

Often U.S. nuclear plant performance is categorized into four quartiles. The first, or top quartile represents the top 25% plants for a given metric and so on for each succeeding 25%. The mean performance of the plants within each quartile is used to characterize the particular regime, but the range of performance within a quartile is not often explicitly noted.[50] To add this dimension, we analyzed the performance of plants for 1999 - 2001, and developed CF performance distributions for each quartile. These results are shown in table F-3 and indicate that in going from lower to higher quartiles, variability becomes progressively smaller, supporting increases in mean CF. Experience confirms that top plants are very consistent performers and lower plants are not (in fact it is difficult to find individual plants in the 3rd or 4th quartiles that have high consistency).

Table F-3
U.S. Nuclear Plant Performance Quartiles, including Standard Deviation

1999-2001	1stQ	2ndQ	3rdQ	4thQ
Mean	95.82%	92.24%	88.77%	78.91%
Standard Deviation	4.79%	5.83%	7.65%	21.35%

A more refined perspective is provided by the 90th percentile values of CF (the value of CF which 90% of the quartile plants exceed) as shown in table F-4. The difference between the mean and 90th percentile values may be thought of as the discount associated with performance

[49] We do not suggest that every plant in a quartile shares entirely similar performance characteristics; in fact the range of plant performance becomes fairly widely differentiated in the lower quartiles. Thus asset managers will want to assess the specific performance of their plants in adapting and applying these ranking methods. The suggested weightings by quartile provide a roadmap and framework within which to do this.

[50] We are not suggesting that the range of performance values among a group of plants is congruent with the variability in performance of an individual plant. Ideally the detailed performance characteristics, including variability, of an individual plant would be analyzed as the basis for assessing where to direct project investments. However for purposes of this paper, it is more practical to address performance on a more generic basis and we are using performance range within an industry quartile as a proxy for plant variability. Based on our detailed analyses of individual plants this is a reasonable approximation and serves the purpose of illustrating a method for assigning assessment factor weights.

variability. The discount is small in the first quartile (about 6 percentage points) but enlarges to severely impair performance in the 4th quartile (almost 20 percentage points).

Table F-4
U.S. Nuclear Plant Performance Quartiles, including 90th Percentile

1999-2001	1stQ	2ndQ	3rdQ	4thQ
Mean	95.82%	92.24%	88.77%	78.91%
90th Percentile	89.79%	85.05%	78.88%	59.38%
Mean-90th Percentile	6.03%	7.19%	9.89%	19.53%

For asset management purposes the change in performance variability compared to change in mean performance may be one way to view the relative importance of each. One approach to do this is to evaluate the needed performance improvement for plants in each quartile to move up in rank to the next quartile. For plants already in the 1st quartile, preserving rank and perhaps improving position within the quartile would be the objective. Table F-5 illustrates what is required to move CF performance between quartiles, again using the 1999 - 2001 data. For example, to move from 3rd to 2nd quartile, mean CF performance would need to increase 3.47% and 90th percentile performance 6.17%. The ratio of these values, 1.78, indicates the relative significance, or importance, of improvement in performance variability compared to mean performance. The ratios for the other quartile changes indicate that this multiplier ranges from about 2 to about 1.33, decreasing as plants move up in quartiles.

Table F-5
Performance Improvement Necessary to Move to Next Higher Quartile

	2ndQ to 1stQ	3rdQ to 2ndQ	4thQ to 3rdQ
Change in Mean CF	3.58%	3.47%	9.86%
Change in 90th Percent CF	4.74%	6.17%	19.50%
Ratio Change 90th/Mean	1.32	1.78	1.98

Using these analyses of the distributions for each quartile and the performance improvement required to move up from quartile to quartile, we have developed a method for inferring the relative importance of the hierarchy factors. The results are summarized in table F-6, which suggests a set of weighting percentages for each factor based on quartile group.

Table F-6
Factor Weights for Plants in Different Performance Quartiles

	Factor Weights				
Quartile	Generation	Operating Cost	Project Cost	Business Risk	Strategic
Q1	0.2	0.2	0.2	0.2	0.2
Q2	0.2	0.15	0.15	0.3	0.2
Q3	0.2	0.15	0.15	0.35	0.15
Q4	0.25	0.1	0.1	0.5	0.05
			Eqpt Rel	Org Effect	Reg Assur
Q1			0.25	0.5	0.25
Q2			0.33	0.33	0.33
Q3			0.33	0.33	0.33
Q4			0.4	0.2	0.4

The weights appear to make sense based on the fundamental dynamics of nuclear asset performance. These dynamics include the importance of management as a key driver, the need to focus on reliability as the means to raise overall (mean) performance, and the view that cost is primarily a dependent variable; i.e., cost is primarily a consequence of how the plant performs rather than an independent variable that is directly managed. The weights also make intuitive sense based on a general assessment of the plant situations in each quartile, as discussed below.

4th Quartile: These plants may focus on improving plant generation and reducing risk as the first priority. Reducing cost or supporting strategic initiatives are of less importance, and unit costs will improve anyway with higher generation. Note that the importance of Business Risk reduction (C1.3) is specified as two times that of improving Generation (C1.1) performance based on the ratios of Δ90th/Δmean developed above for the 4th to 3rd quartile. Within the Business Risk branch, the weights of Equipment Reliability (C2.3.1) and Regulatory Assurance (C.2.3.3) are twice that of Organizational Effectiveness.

3rd Quartile: These plants still must focus on reliability to continue gaining in overall performance, even though variability is significantly better in this quartile. The ratio of importance of Business Risk reduction to Generation is reduced to about 1.75. Within Business Risk, the second level factors carry equal weight reflecting the balanced approach needed in this regime. Operating Cost and Strategy factors remain at relatively low weights.

2nd Quartile: These plants are performing quite well but are looking to rise to the top tier of performance. Here the balance between Business Risk reduction and further improvement in expected Generation is reduced to about 1.5 (rounding up from 1.33). Operating Cost and strategy take on added value as improved operating performance enables other priorities to be pursued. In addition, Project Cost becomes an increasing consideration as the opportunities to increase generation performance become incrementally smaller.

1st Quartile: These are top tier plants and are performing at or close to the maximum levels possible. Their priority is to sustain performance leading to a balanced weighting of all top level factors. They are in the best position to support strategic initiatives at the plant or enterprise levels. Within Business Risk, Organizational Effectiveness (C.2.3.2) is now weighted at a higher importance in view of the fact that other areas are already at relatively high performance levels.

F.3 Conclusion

Approaches for specifying weighting factors other than the quartile approach described above are possible - ranging from using management expert judgment to more detailed analytical approaches. Considerations that may apply in selecting an approach for determining weights include: (1) is a single plant involved or multiple plants across an enterprise; and (2) how important is it to use objective data as a basis? If more than one plant is involved, and depending on the enterprise-level methods to be employed for project selection and resource allocation, use of objective data may be preferred. It balances a common approach that can be applied to all nuclear enterprise plants but preserves the ability to tailor the framework based on the unique performance situation for each plant. Objective data also may be preferred if there is oversight or review of costs and investment decisions by economic regulators or other affected parties, such as minority owners.

G
SIMULATION AND NUCLEAR POWER PLANT PERFORMANCE ANALYSIS

G.1 Overview of Simulation and POWERGEN

Simulation uses mathematical equations to represent complex real world systems and the interaction of components of those systems. POWERGEN is PowerShift LLC's proprietary simulation model of nuclear generation.[51] It can model a single unit or the entire fleet of a nuclear enterprise. POWERGEN is used to develop consistent visions of potential generating and business performance under a range of conditions. It is based upon the actual process states of an electric generating plant, with specific capabilities to address the unique aspects of nuclear power plants. POWERGEN uses dynamic simulation methods and Monte Carlo sampling techniques.

POWERGEN is used to support strategic planning, plant valuation and performance improvement projects. POWERGEN addresses weaknesses inherent in traditional utility planning approaches by (1) creating explicit linkages between major performance drivers and performance results and (2) incorporating the essentially probabilistic nature of the processes, events, and external factors that determine actual plant performance,[52] and (3) integrating significant industry and plant historical data.

POWERGEN recognizes that overall business performance is determined by the combined effects of a number of operational, cost and regulatory components. It embodies a systems view of these essential performance variables. While traditional plant performance analysis often treats these variables as independent, POWERGEN incorporates their functional interdependence to determine how future performance might look.

POWERGEN is a multi-state, probability-based stochastic simulation model. Stochastic systems evolve through time in a manner that is not completely predictable, much like the normal operation of a power plant that is occasionally, and unpredictably, forced to shut down by a major equipment failure. For stochastic systems, one uses probability concepts to capture this inherent variability. Simulation is used to duplicate the dynamic interactions that occur among system components and computerized simulation models allow for thousands of possibilities to be considered.

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[51] POWERGEN is used to support PowerShift LLC's strategic consulting projects; it is not currently available for sale or for use by other parties. For additional information on POWERGEN, contact PowerShift LLC.

[52] Traditional utility planning can ignore the linkages between drivers and results, and rely too heavily on point estimates of future performance.

The POWERGEN model simulates power plant operation one day at a time over a specified time frame, usually several years. On any day, the plant can be in one of several defined states, such as Normal Operations, Refueling or Forced Outage. The time spent in each state and the transitions between states are determined by probability distributions, time-based conditional statements and necessary logical relationships in the power generation process. An example of a logical condition is that an outage is followed by power ascension. A time-based condition would be the start of refueling outages, which are established at the beginning of a run in the system calendar. A probabilistic condition would be the probability associated with a forced outage occurring on any given day.

G.2 Application of POWERGEN

In a client application, plant-specific experience and industry data are combined to produce a customized model of the plant(s) being reviewed. Historical plant performance data provides the starting point for analysis. This approach allows future performance to be linked to past performance.

Repeated runs of the customized POWERGEN model produce representative distributions of important performance parameters, such as yearly capacity factor, generation lost for various reasons and O&M costs. These performance parameter distributions show a likely range of performance and, more importantly, provide insight into the nature and size of risks that can detract from maximum potential plant performance. POWERGEN thus provides both data and context for calculating plant valuation and setting goals for plant performance.

A nuclear fleet can be modeled by specifying each of its member units. Each unit is configured to reflect its unique performance characteristics. For example, each unit can be programmed to reflect its own experience with forced outages or derates. Cross-unit interdependencies can also be specified, e.g., a regulatory shutdown at one unit at a two-unit site can be programmed to lead to shutdown of the mating unit.

Each unit can be managed with different policy guidelines. For example, one unit might have a high target material condition (which will require additional O&M costs to attain) while another may be in a restricted O&M situation (and its material condition may deteriorate over time, leading to more forced outages).

A portfolio can be constructed by combining the individual unit models into a single overall model. The overall model can be run under different sets of assumptions to determine the impact of various top-level management approaches and decisions. For example, a POWERGEN portfolio model can be used to evaluate the impact of different resource allocation policies on unit performance and fleet ROI. With its day-by-day, year-by-year approach to performance simulation, POWERGEN can highlight the relative ROI of different policy assumptions, i.e., highlight the time value of performance improvement. POWERGEN results can show senior managers the likely performance consequences of various policies and quantify the associated performance risks. Such analyses can help senior managers make informed, risk-adjusted decisions with regard to optimizing the design of their nuclear portfolio.

Program:
Nuclear Power

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