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Project Prioritization for Nuclear Plant Investments

Lessons Learned from Other Industries

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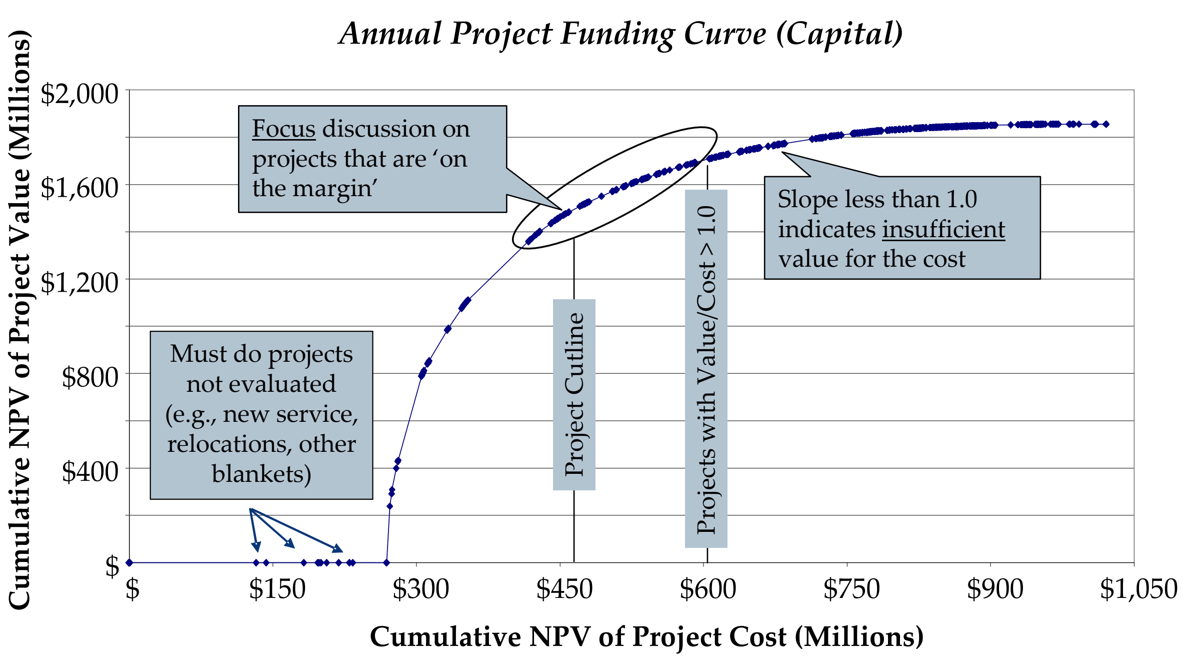

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Technical Update, December 2008

EPRI Project Manager

S. Hess

ELECTRIC POWER RESEARCH INSTITUTE
3420 Hillview Avenue, Palo Alto, California 94304-1338 ▪ PO Box 10412, Palo Alto, California 94303-0813 ▪ USA
800.313.3774 ▪ 650.855.2121 ▪ askepri@epri.com ▪ www.epri.com

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This document was prepared by

Woyshner Service Company, Incorporated
120 Country Club Drive
Moorestown, NJ 08057

Principal Investigator
W. Parkinson

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PRODUCT DESCRIPTION

Evaluating investments, sometimes called *project prioritization*, is a central business process in a plant's or fleet's management of their nuclear assets. To date, a variety of project prioritization approaches have been used in the nuclear industry. Many nuclear utilities use an approach that can be characterized as an engineering work grading process. Project prioritization is related closely to long-range planning. Long-range plans help to avoid surprises from increased expenditures and reduced levels of generation revenue resulting from unanticipated needs to refurbish or replace large assets. They also provide a repository for unfunded, lower priority projects that might be good investments in other years. Increasingly, nuclear utilities are developing and implementing long-range plans as well as integrating them with their capital investment requirements as identified from their equipment reliability programs. In addition, risk management is becoming an ever-increasing expectation, with utilities beginning to implement risk-management techniques in their investment process.

Background

Nuclear generation owners and operators are becoming aware of some of the limitations of conventional business approaches to achieving successful long-term operational excellence. Depending on circumstance and degree, these limitations often include the following:

- Year-over-year budgeting
- Overemphasis on costs rather than stakeholder values
- Focus on shorter term equipment issues rather than long-term global issues
- Inconsistent business case and cost benefit analyses
- Inadequate time horizons for long-term planning
- Insufficient attention to financial risk management techniques

Risk-informed and performance-focused asset management approaches have been successful when applied to financial investments and are increasingly being applied to physical assets in other industries such as aerospace and petrochemical and now to electric industry sectors such as transmission and distribution.

The Electric Power Research Institute (EPRI) has long been involved in research related to project prioritization of capital and O&M investments. In this technology area, EPRI has developed guidance and tools that have been applied in the transmission and distribution sector for prioritization techniques that use options analysis and evaluate market impacts of externalities such as environmental factors (for example, climate change). Within the nuclear sector, EPRI has long supported the development of methods to perform capital project prioritization and portfolio management, including various initiatives and tools for risk-informed asset management.

Approach

Long-term asset management objectives are accomplished through utility business planning. Integrating the technical requirements from the various plant and corporate organizations (including engineering) into business plans is a time-consuming and resource-intensive process. The Nuclear Asset Management (NAM) community sponsored EPRI to work with the

Equipment Reliability Working Group (ERWG) to identify possible improvements in this process.

This project began by developing an understanding of current nuclear plant project prioritization practices. The NAM community participated with the ERWG to produce project prioritization guidance that reflects that understanding. In this project, the key points were taken from that document as well as case studies from two nuclear fleet operators who were believed to have good practices in this area.

From this work and additional input from the nuclear community, a list of key topics for an investigation of techniques and insights that could be obtained by evaluation of practices used in other industries was developed. This investigation was accomplished through two principal means: 1) conducting a literature search of EPRI reports and web resources and 2) contacting experts familiar with—and who provide technical support to—other industries.

Objectives

This project was designed to ask four specific questions with respect to project prioritization:

1. What can be learned from outside of the nuclear industry?
2. How do we know if we are doing a good job?
3. How do we best evaluate disparate types of projects?
4. How does taking a long-term view influence the process?

Results

The result of this investigation is a series of case studies and reports containing lessons learned from the prioritization practices used in other industries. We completed the project by drawing these lessons learned into a concise summarized form for consideration by the NAM community.

EPRI Perspective

Much has been accomplished in asset management in the last five years in terms of improved equipment reliability, reductions in cost, and increases in business process productivity. The collective experience of the electric utility industry is substantial and can be augmented by selected insights from other non-electric industries. This report's examples provide tangible evidence of what can be accomplished with the maturing of a project prioritization capability. The report demonstrates that significant business benefits can be achieved by incorporating methods and processes that have proven to be useful and implementable in industries outside of nuclear power production.

Keywords

Asset management
Equipment reliability
Long-range planning
Performance monitoring
Project prioritization
Risk management

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CONTENTS

1 INTRODUCTION

Evaluating investments, sometimes called project prioritization, is a central business process in the management of any enterprise (including nuclear power plants). A variety of project prioritization approaches have been used in the nuclear industry. In their evaluation of projects for funding, many nuclear utilities use an approach which can be characterized as an engineering work grading process. In this approach, plants grade potential projects based on a number of attributes, obtaining a weighted score based on the "value" the project is perceived to provide to the organization. This assignment of value is then used to provide a rank ordered list of projects. This list is used to allocate funding, typically running down the ranked list by including the next highest value project until the budgeted funds are completely allocated.

Project prioritization is closely related to long range planning. Long range plans help avoid surprises from increased expenditures and reduced levels of generation revenue resulting from unanticipated needs to replace large assets. They also provide a repository for unfunded, lower priority projects which may be good investment candidates in future years. Nuclear utilities increasingly are developing and implementing long range plans as well as integrating them with their capital investment requirements. (We note: at nuclear utilities a majority of these are identified from and are directed at addressing plant equipment reliability.)

Additionally, risk management is becoming an ever increasing expectation. Stakeholders (including corporate shareholders, senior management and even regulatory authorities) want to know that needless risks are being avoided and that unavoidable risks are being mitigated. As a result, all nuclear utilities are implementing risk management techniques, to various degrees, in their investment evaluation and funding process.

Although project prioritization and allocation process have achieved a level of consistency and adequately address short term (e.g. 3 – 5 year) needs, nuclear generation owners and operators are becoming aware of some of the limitations of these conventional business approaches. Depending on circumstance and degree, these limitations often include year over year budgeting; overemphasis on costs rather than stakeholder values; focus on shorter-term equipment issues rather than long-term global issues; inconsistent business case and cost benefit analyses; inadequate time horizons for long-term planning; and insufficient attention to financial risk management techniques.

Risk-informed and performance-focused asset management approaches have been successful when applied to financial investments and are increasingly being applied to physical assets in other industries such as aerospace and petrochemical. This focus recently has migrated into some electric industry sectors, particularly transmission and distribution and application of information technology (IT). EPRI has long been involved in research related to project prioritization of capital and O&M investments. In this technology area, EPRI has developed both guidance and tools that have been applied in the transmission and distribution sector for prioritization techniques that employ options analysis and evaluate market impacts of externalities such as environmental factors (e.g. climate change). Within the nuclear sector, EPRI has long supported the development of methods to perform capital project prioritization and portfolio management, including various initiatives / tools for Risk Informed Asset Management.

Fundamental to this work have been recent EPRI research projects to (1) specify an integrated Nuclear Asset Management (NAM) process model and (2) conduct an industry survey of implementation tools that currently are employed to perform the analyses required to support an effective and efficient NAM program. To address the first issue, a detailed process mapping was developed to support detailed, consistent and repeatable analysis of asset management functions to support executive and senior management decision-making. This model is described in EPRI 1015091, "Nuclear Asset Management (NAM) Process Model" (published in December 2007). We note that one of insights from this model (from the perspective of both the Nuclear Asset Management and the Equipment Reliability communities) was a lack of consistency in the evaluation and prioritization of projects. This realization led to the work performed as part of this research effort and described in this report. To address the second issue, a number of US nuclear power plants were surveyed to identify the spectrum of methods and tools employed. The results of this survey were published in EPRI 1013576 "Nuclear Asset Management (NAM) Toolkit – Definition and Industry Survey" (published in November 2006).

Long-term asset management objectives are accomplished through utility business planning. Integrating the technical requirements from the various plant and corporate organizations (including engineering) into business plans continues to be a time-consuming and resource-intensive process. The Nuclear Asset Management community sponsored EPRI to work with the Equipment Reliability Working Group (ERWG) to identify possible improvements in this process.

This project began by developing an understanding of current nuclear plant project prioritization practices. The NAM community participated with the ERWG to produce project prioritization guidance which reflects that understanding. In this project, we took the key points from that document as well as case studies from two nuclear fleet operators who we believed had good practices in this area.

From this work and additional input from the nuclear community, we developed a list of key topics for an investigation of techniques and insights that could be obtained by evaluation of practices used in other industries. This investigation was accomplished through two principal means:

- A literature search of both EPRI reports and web resources
- Contacting experts familiar with and that provide technical support to other industries

This project was designed to ask four specific questions with respect to project prioritization.

1. What can be learned from organizations outside the nuclear industry?

2. How do we know if we are doing a good job?

3. How do we best evaluate disparate types of projects?

4. How does taking a long term view influence the process?

The result of this investigation is a series of case studies and reports containing lessons learned from other industries. These case studies indicate approaches that have been utilized by other industries that have added value to their prioritization approaches and have been adopted for use in them. In this report we document those that are believed to be relevant to application to commercial nuclear power production. We also provide recommendations for future research to permit their customization and application into plant and fleet business decision processes.

Much has been accomplished in asset management in the last five years in terms of improved equipment reliability, reductions in cost, and increases in business process productivity. The collective experience of the electric utility industry is substantial and can be augmented by selected insights from other non-electric industries. The report's examples provide tangible evidence of what can be accomplished with the maturing of plant / fleet capabilities to analyze and select investment opportunities. This report demonstrates that significant business benefits can be achieved by incorporating methods and processes that have proven to be useful and implementable in industries outside of nuclear power production.

The reader should also be aware that there is growing evidence that companies with industry leading project prioritization capabilities also have industry leading return on assets. In Ittner, Christopher D. and Larcker, David F., "*Coming Up Short on Nonfinancial Performance Measurement*", Harvard Business Review, November 2003, the authors describe the importance of developing and validating causal[1] value models. Based on surveys of 157 manufacturing and service companies, including more than 60 field studies, the authors found that significantly higher return on assets and return on equity were achieved by the twenty three percent of companies which did extensive causal value modeling and validation. We also report in Section 3 on similar results from surveys performed on Information Technology Portfolio Management programs. As an additional indication of the improvements that can be achieved in project prioritization and selection, Merkhofer[2] reports that "… organizations can typically increase value by 20-40% without increasing costs, or decrease costs by 20-40% without decreasing value, each budget cycle, by making better choices." Clearly, much is at stake from improving the effectiveness of project prioritization and long range planning.

In Section 2, this report delves into the current state of project prioritization in the nuclear generation industry. We excerpt relevant items from the recently released ERWG report "*Life Cycle Management Guidance Document for Implementation of the LCM Block of AP 913*" (and

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[1] A causal value model is a model in which a clear relationship is established between company value and performance indicators.
[2] *Addressing the Reasons Organizations Choose the Wrong Projects*, Lee Merkhofer, Priority Systems, 2003.

include the complete section on Project Prioritization Guide in Appendix A). We then describe two good practices from US utilities, delving into significant detail on their project prioritization and long range planning processes.

Section 3 describes a series of case studies from other industries. We provide three case studies from the electrical transmission and distribution industry and two case studies from the generation industry. We also include an EPRI generated example on the influence of climate change policy on the valuation of generation assets. We then discuss the use of project prioritization for information technology and for the transportation industry. An interesting case study from the Pharmaceuticals industry is then presented, followed by a short description of a relatively recent asset management standard promulgated and used for electric and gas utilities in the United Kingdom.

Section 4 describes insights on project prioritization from EPRI's Enterprise Asset Management Program. The insights come from two reports, both of which evaluated project prioritization techniques that can be used throughout an electric utility enterprise. One of the studies included development of a maturity model that utilities can use to assess their own asset management infrastructure, including both decision making processes and supporting information technology. The model contains twelve technical areas and five levels of maturity.

The other study describes project prioritization value models and their implementation at a corporate, strategic level. Together, these two studies have raised the bar for asset management, both in terms of value models and in terms of asset management processes and supporting information technology. The studies have also been validated through case studies with electric utilities and through surveys of executives.

We have drawn heavily from the insights from this program for this report for a few reasons. First, integration of nuclear plant prioritization processes with corporate strategies is an important topic for this report. Second, the case studies and executive interviews have borne out the importance of these insights. Third, the insights and best practices draw from throughout the electric industry and thus help answer the question of what can be learned from organizations outside the nuclear industry. Lastly, the self-assessment method helps answer the question of how do we know if we are doing a good job. Therefore, Section 4 includes guidance and insights on ten important topics regarding project prioritization that have been derived from the reports for the Enterprise Asset Management Program.

Section 5 draws upon all the above sources to generate a summarized form of the insights we have found. The section used the following six topics as a framework to summarize the insights we identified in Sections 3 and 4.

- Key Attributes of LCM Plans (as they relate to prioritization)
- The Project Prioritization and Long Range Planning Process
- Guidance for Selecting and Valuing Prioritization Attributes
- Integrating Project Ranking and Business Strategy

- Metrics to Evaluate Process Effectiveness
- Feedback Mechanisms for Continuous Process Improvement

Section 5 also discusses the implications of those insights to the NAM program members.

Appendix A provides the Project Prioritization Guidance from the ERWG report and Appendix B provides a bibliography of EPRI reports with insights on project prioritization and long range planning.

2
CURRENT NUCLEAR PRACTICES AND KEY TOPICS FOR INVESTIGATION

The initial task for this project was to develop an understanding of current nuclear practices. EPRI's Nuclear Asset Management (NAM) advisory group had sponsored a number of such studies over the past decade. The issue of effective project prioritization independently was identified by the Equipment Reliability (ER) community through the Equipment Reliability Working Group (ERWG). Consequently, EPRI participated with an ERWG effort to produce guidance in the specification of equipment long-term reliability plans and project prioritization decision-making which reflects current industry best practices. The relevant portions of that document are discussed below. Section 2 of the document that provides guidance in project prioritization is provided in Appendix A. In this section, we present a synopsis of the most relevant portion of the document, namely Section 2, entitled Project Prioritization Guidance.

This section of the report then continues with case studies from two nuclear fleet operators who we believe employ robust and comprehensive practices in project prioritization. The case studies were developed based on the governing procedures used by these fleet operators, observations of the information technology used to implement the procedures and selective interviews with responsible individuals from these utilities. The combination of ERWG project prioritization guidance and results from the nuclear utility case studies are intended to provide a comprehensive overview of the current state of project prioritization employed in nuclear power plant decision-making.

From this work and input from the nuclear community, including the abovementioned objectives, we developed a list of key topics for investigation of techniques and insights currently employed in other industries. These topics were used to guide, but not limit, our analysis of other industries.

2.1 Equipment Reliability Working Group Project Prioritization Guidance

The ERWG developed guidance entitled "Life Cycle Management Guidance Document for Implementation of the LCM Block of AP 913" (abbreviated as ERWG LCM Guidance in this report). In this section, we draw heavily from that document to describe what the ERWG believes to be the state of the industry and the requirements for guidance for Equipment Reliability related plans and projects. We focus specifically on Section 2, entitled Project Prioritization Guidance, but also draw the intended use of the document from the Forward.

2.1.1 Use of the ERWG Document

The Equipment Reliability Working Group determined, through the results of the Equipment Reliability Index (ERI) and other trends, that the implementation of effective life cycle planning is a gap within the industry in meeting reliability targets. One purpose of the ERWG LCM Guidance is to provide some specific implementation guidance, including guidance on attributes to be included in Life Cycle Management Plans and criteria that should be used to rank and prioritize LCM equipment-related projects. A key objective of the ERWG LCM Guidance is to ensure alignment of the LCMP's with the process used by executive decision-makers to evaluate and approve the integrated long range plan and allocate resources and budget for its execution.

A second objective of the ERWG LCM Guidance is to provide a standard set of criteria and attributes to benchmark against and make adjustments to current nuclear plan prioritization programs. To achieve the objectives of this guidance, the ERWG recommended that Equipment Reliability and Business Operation organizations conduct a joint self-assessment of their programs against the information presented in the ERWG LCM Guidance document.

Figure 2-1 provides a high level overview of LCMP business plan integration from the perspective of equipment reliability. Greater detail, including interfaces and task sequencing, is provided in the NAM process model (EPRI Report 1015091).

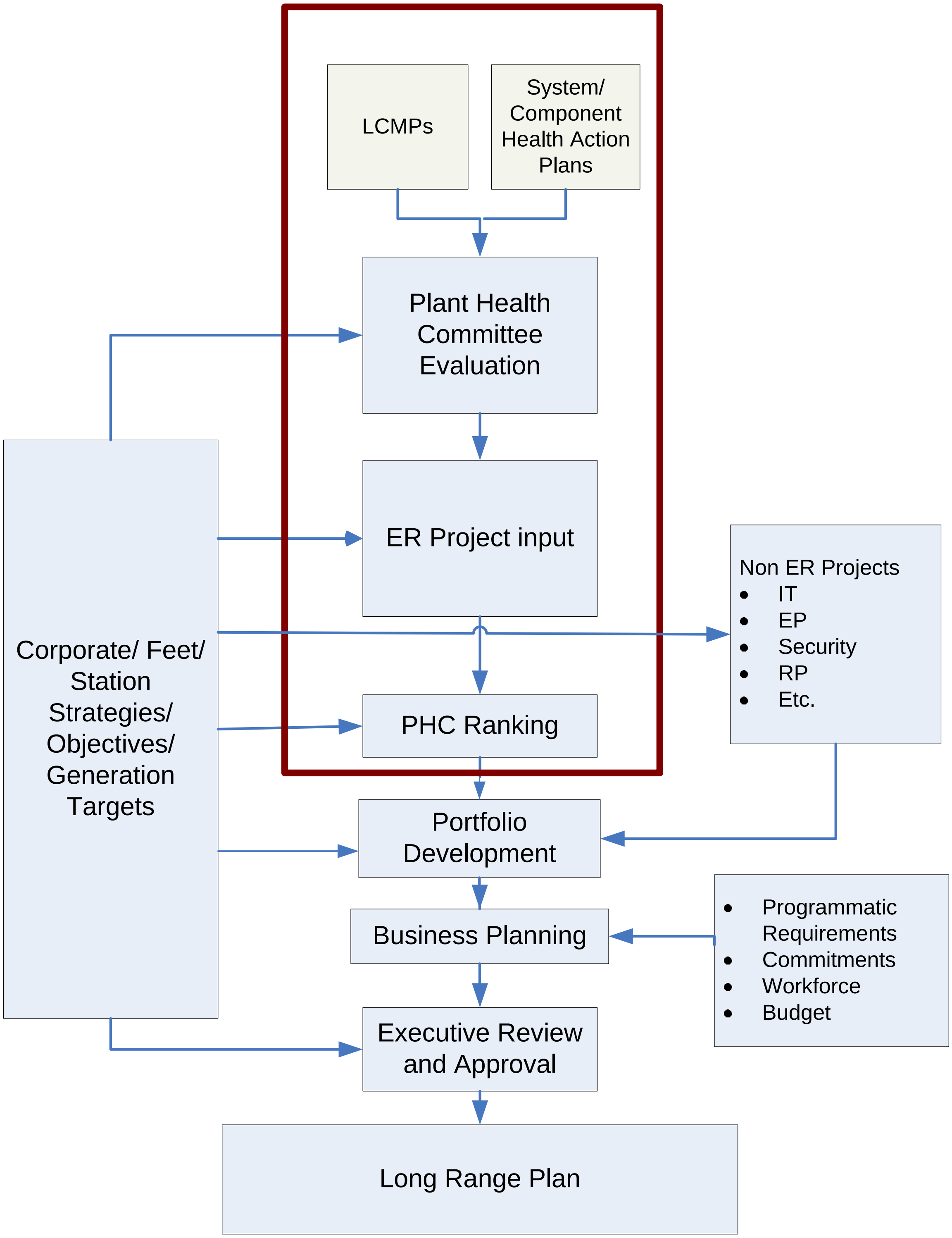

Figure 2-1 - LCMP Business Plan Integration

2.1.2 ERWG Prioritization Guidance

Prioritization processes are intended to allocate resources in a manner that provides maximum benefits to the NPP stakeholders. To achieve this objective, prioritization processes need to allocate available resources (financial, physical and human) to projects across the entire spectrum of activities necessary to ensure long-term safe and economic operation of the NPP. Thus, in addition to projects which address equipment reliability issues, projects that address security, emergency preparedness, information technology and other issues also must be evaluated and prioritized. Hence, the attributes that are considered in the prioritization need to reflect this broad scope and be sufficiently comprehensive to support effective integrated decision-making.

The intent of the ERWG LCM Guidance is to provide a set of attributes that support evaluating equipment reliability projects within this broad perspective so that executive decision-makers are presented with complete and accurate information from which effective resource allocations can be made.

Prioritization activities are conducted on a set of candidate “projects”. In the ERWG LCM Guidance, the use of the term projects is intended to be interpreted broadly. Here, the term project is defined as follows: a discrete working objective requiring budget and business planning support to track costs and ensure completion.

The ERWG LCM Guidance points out the following:

- long-term operational strategies are developed as part of the corporate business planning and executive decision-making process.
- the weighting and scoring applied to the individual attributes are critical elements in the evaluation process.
- the key success criteria is to have a set of attributes that is clear, easy to interpret and can be applied consistently at the plant or fleet level

The ERWG LCM Guidance then presents a list of attributes, currently in use at one or more plants. These attributes were identified by a group of expert industry reviewers as being important considerations in the prioritizing of projects that impact long-term equipment reliability. To facilitate the evaluation and ranking process, the attributes are grouped into the following categories.

A. Nuclear / Industrial / Radiological Safety
B. Plant Operation Impact
    i. Plant Generation
    ii. Plant Condition / SSC Health
    iii. Operational Flexibility
    iv. Operational Risk
C. Regulatory Impact
D. Human Performance
E. Financial (Costs / Savings) Impact

F. Other Business Impacts
   i. Strategic Value
   ii. Uncertainties
   iii. Dependencies
   iv. Risk / Consequences

The guidance recognizes that individual nuclear power plants may use alternative groupings (as can be seen in the subsequent case study).

The specific scoring and weighting associated with each category and attribute are specific to each organization's values and business objectives. However, the ERWG guidance presents the attributes within each category in a rank ordered priority as determined by the previously mentioned group of industry equipment reliability experts. Thus, the attributes represent a rank ordered list by which individual plant operators can calibrate their weighting and scoring systems. See Appendix A for this rank ordered list as well as additional secondary attributes that have been used at some operating nuclear power plants.

The ERWG LCM Guidance also mentions two areas that the survey of NPPs found to be the least represented in existing NPP processes:

1. The degree to which a project will contribute to or achieve strategic objectives.
2. The need to evaluate project dependencies and risks, including timing and continuity dependencies for projects executed in multiple stages or over multiple budget cycles, and synergies between two projects.

Both of these items typically often are addressed outside the prioritization by direct management evaluation. But, this lack of a structured approach offers opportunities to circumvent the prioritization process and inhibits transparency to those outside the process.

The ERWG LCM Guidance also notes that many plant issues are complex and solutions may be evaluated and implemented in phases and over multiple budget cycles. This challenge warrants a phased approach to prioritization that includes criteria for both initial screening and full project evaluation. The screening process should evaluate the same core attributes described to ensure that outcomes of the screening process are compatible with the full prioritization process.

The ERWG LCM Guidance on project prioritization closes by advising NPP decision-makers to evaluate the benefit – cost tradeoffs against a wide variety of different criteria to provide maximal value to all stakeholders. Corporate strategic goals and objectives should be used to develop the attribute weightings and scorings used to characterize the candidate projects. While not recommending any particular method to develop applicable attribute weightings, the ERWG LCM Guidance describes some aspects for the ranking method used to be effective and achieve broad acceptance by all stakeholders. These include:

- demonstrable alignment with corporate values and strategic objectives,
- clear and concise guidance on input data required,

- straightforward execution of analysis so that outcomes are repeatable and understandable,
- flexibility to account for changing conditions (e.g. changes in regulatory requirements, corporate strategies, etc.).

The ERWG guidance closes by mentioning two applicable EPRI reports that document application of project prioritization methods at electric utilities with operating nuclear power plants:

- 1007385, "Project Ranking Method for Nuclear Power Plants: Prioritizing Proposed Capital and O&M Projects", (2003),
- 1012954, "Pilot Application of Enterprise Project Prioritization Process at Nebraska Public Power District", (2006)

Appendix B of this report provides a more complete list of EPRI reports from all EPRI business units that speak to the topic of project prioritization.

2.2 Good Practice Case Studies from US Nuclear Utilities

This subsection identifies two good practice case studies from US nuclear fleet operators. The first good practice case study emphasizes the long term planning aspect of project prioritization. This good practice illustrates the use, flow and availability of information throughout the process as well as how the results integrate into a prioritized long range plan.

The second good practice case study emphasizes the prioritization and evaluation aspect of project prioritization. This good practice describes the overall process and the role of various site organizations as they work together to create their prioritized long range plan. The case study also includes a representative scoring system for the issue prioritization process for equipment reliability.

Together these two case studies represent a rather complete snapshot of good practice for a nuclear plant project prioritization and long range planning process. The reader will note that the following discussion does not include many details on the prioritization scoring system. There are three reasons for this. First, the ERWG guidance and other EPRI reports (see list in Appendix B) include discussions of criteria for scoring. Second, our insights in subsequent chapters discuss in some detail techniques used to create and apply prioritization scoring systems. Third and most important is the fact that the actual scoring technique employed is much less important than the use, flow and availability of information used in the evaluations and the overall process and roles of organizations participating in the decision-making process.

Of paramount importance is a transparent decision-making process that uses readily available information as input to an evaluation that has clearly defined objectives. In the decision-making process, the decision criteria are consistently applied over the full spectrum of proposed projects with effective communications describing the decisions reached and the basis for them. Finally, the decision-making process is consistently applied with appropriate checks and balances to ensure outcomes are aligned with the organization's strategic and tactical objectives.

2.2.1 The First Good Practice Case Study

The nuclear fleet operator that represents this case study has taken the view that not only should assets be managed over the long term, but they should be managed on a fleet level. Managing assets over the long term includes understanding the failure mechanisms unique to this (long-term) time period as well as the corresponding investments that must be made to ensure company goals are met. Using the fleet perspective allows the long term view to benefit from allocating the full resources of the corporation to provide flexibility and to ensure the evaluations comprehensiveness in the evaluations.

For this utility, Long Term Planning objectives include:

- Ensuring comprehensive identification of issues requiring incremental investment
  - Short term (0 to 4 years)
  - Long term (5 years to end-of-plant life)
- Ensuring optimal project selection over a 10-year rolling period.

Long term planning helps the nuclear generation organization to align with the corporation's long range plan of 5-year financial commitments as well as to meet its budget and power generating commitments to the corporation. Thinking long term also helps make a number of the company's initiatives work more effectively, including optimizing the use of site and corporate resources[3] and leveraging supply management strategies.

With regard to the assets themselves, the long term view is intended to identify and solve problems well before they would be anticipated to impact plant operation. This focus of long term planning is intended to have the following benefits:

- minimize emergent / crisis projects by executing steps before the plant is impacted, and
- provide sufficient time for alternate approaches or contingency actions to be developed (if necessary).

At this utility, overall long term planning is viewed to improve equipment reliability, optimize outage durations, and positively impact the value of the plant (as measured in the annual net present value (NPV) analysis).

Long term planning involves integrating and maintaining important information developed by technical experts both inside and outside the company. Strategies for over two dozen major equipment types are managed across the fleet and integrated into Long Term Asset Management plans for each of major system at each power plant. We note

[3] These resources include both internal and external resources available to the corporation.

that resources and constraints at the plant sites and across the corporation are considered and documented in the plans.

To accomplish this business process in a transparent way, this nuclear fleet operator utilizes a central information repository along with formal procedures which clearly lay out the process and responsibilities for developing and maintaining the long term plans. In the following discussion, we will discuss the information sources that are the key inputs, the processes which guide decision making, and the central information repository which helps make the process work and its results accessible and understood.

2.2.1.1 Integrated Equipment Reliability Long Term Planning

The heart of the long range planning process at this utility is their Integrated Equipment Reliability Long Term Planning process. This process covers the Life Cycle Planning and Life Cycle Management elements of equipment reliability. The process coordinates the activities of engineering, operations, maintenance, work management and business operations. Responsibilities are distributed from the Vice President of Engineering to various decision making committees to subject matter experts for critical assets. Of critical importance is the integration of the long term planning process with the shorter term processes of normal maintenance, testing and operation.

The Long Term Planning process employs six major steps:

1. Development of corporate level strategies and deliverables that leverage fleet economies of scale.

2. Identification and use of available industry information.

3. Corporate project initiation and prioritization.

4. Site specific system and component long term planning.

5. Site specific long term issue prioritization.

6. Feedback into corporate strategies and deliverables from site long term planning results.

Figure 2-2 illustrates how these steps integrate.

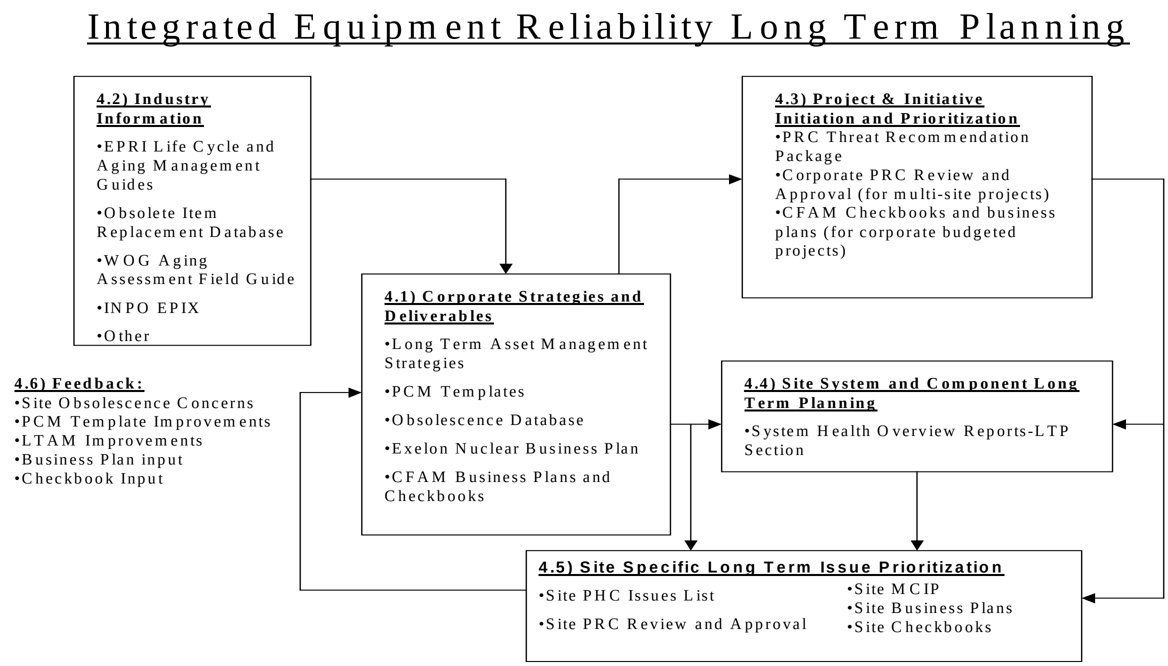

Figure 2-2 - Integrated Equipment Reliability Long Term Planning

It can be seen from the figure that the process involves a substantial amount of information, a number of information integration and feedback steps, and a number of approvals. As a result, information technology can play an important role in the process by improving efficiency of the process, by ensuring a degree of consistency and conformance among process participants, and by enabling good process documentation.

Important information sources in the process include:

- Long Term Asset Management (LTAM) Strategies – These strategies are described in more detail below. They identify major maintenance and replacement requirements across the fleet.

- Performance Centered Maintenance Templates (PCM) – These templates identify standard / best practices for time and condition based maintenance tasks. They also identify the condition monitoring or functional testing tasks. These tasks characterize equipment condition that would indicate potential need for early or unplanned refurbishment, or could be used to adjust the frequency of refurbishments.

- Obsolescence Program Database – This database identifies the systems and components that could cause equipment reliability concerns due to obsolescence.

- Business Plans and Checkbooks – There are business plans and checkbooks for individual plant sites as well as rollups for the nuclear generation organization and the corporation. They identify the initiatives and projects that will be pursued over the next three years.

- System Health Overview Reports (SHOR) – These reports identify the issues that currently are affecting the overall health of the system; the SHOR is managed using a web based system health application. The reports include the action steps necessary to improve the systems in the short term (0 to 4 years); they also include a long term improvement plan (5 years to end-of-plant life). The reports are specific to each plant site and include corporate sponsored long term issues.

After discussing the Long Term Asset Management Strategies in more detail, we will return to this process and these databases and examine how information technology helps the company perform these important asset management activities.

2.2.1.2 Long Term Asset Management Strategies

LTAM Strategies focus on the fleet's critical assets. For the purposes of requiring the development of a LTAM strategy, a critical asset is one whose repair or replacement requires either or both of the following:

- capital or expenses that would exceed typical site project budgets
- impact the ability to perform a standard refueling outage

As mentioned earlier, more than two dozen assets meet these criteria at this utility.

For each of these assets, the process illustrated below in Figure 2-3 is followed. Below we describe key elements of that process.

Long Term Asset Management Strategy Process

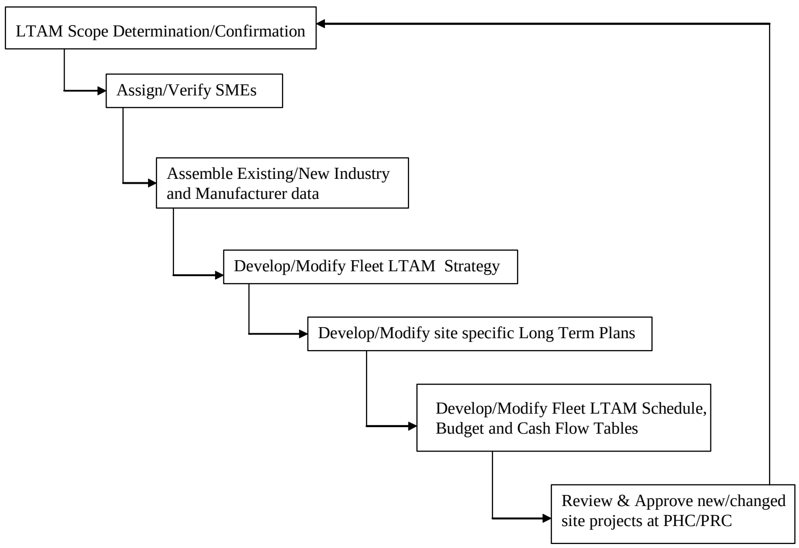

Figure 2-3 - Long Term Asset Management Strategy Process

Each critical asset is assigned a Subject Matter Expert (SME)[4]. The SME assembles relevant information on existing and new manufacturers as well as industry and fleet data.

Using this comprehensive review of information, the SME develops a LTAM strategy. The strategy includes:

- a description of the scope of the asset, e.g., it includes necessary related auxiliary systems,
- the failure mechanisms and obsolescence issues and the expected prognosis for the life of the component, and
- mitigation strategies to address the failure mechanisms.

Additionally, the strategy includes a specific list of degradation issues that apply to selected assets in the fleet. Each issue is described together with risk mitigation strategies and long term recommendations. LTAM Strategies also describe fleet priorities, providing much of the same information, but from a fleet perspective.

The LTAM Strategy for the asset provides a description of applicable degradation issues. This description includes a discussion of detection, development (including degeneration

[4] SMEs also prepare the normal maintenance and testing strategies as represented in the preventive maintenance templates, helping to ensure good integration between short term and long term activities.

rate and life expectancy), and remedy / mitigation actions. Risk mitigation strategies describe the current risk to the component and the plant and a list of actions to minimize the list until final repair or replacement, e.g., additional spare parts to be maintained, inspections and condition monitoring to be performed as well as implementation of applicable manufacturers recommendations and additional monitoring if required. Long term recommendations describe options for maintenance or replacement along with their pros and cons, bases for the recommended approach and business case evaluations as necessary.

Site system managers and component owners develop system long term plans, for which the LTAM Strategies provide a major input. Together with the corporate SMEs, site system managers and component owners come to agreement on which, if any, variations from the LTAM Strategy are acceptable.

The next part of the LTAM process includes prioritizing projects as well as scheduling work to optimize outage durations and cash flows for the site. Plant Health Committees (PHCs) and Project Review Committees (PRCs) prioritize, integrate and authorize LTAM Strategy items and Long Term Plan issues, including all items that need action over the life of the plant. Prioritization is accomplished using the following project metrics:

- PHC Plant Health Issue Priority Ranking Score
- Project Prioritization Ranking Score
- LTAM Consequence of Failure Rating
- LTAM Probability of Failure Rating

The list of projects is represented for each site in the Material Condition Improvement Plan (MCIP) matrix. MCIP shows when LTAM Strategy items and Long Term Plan issues will be funded for both outage and non-outage periods. The process is illustrated in Figure 2-4 below.

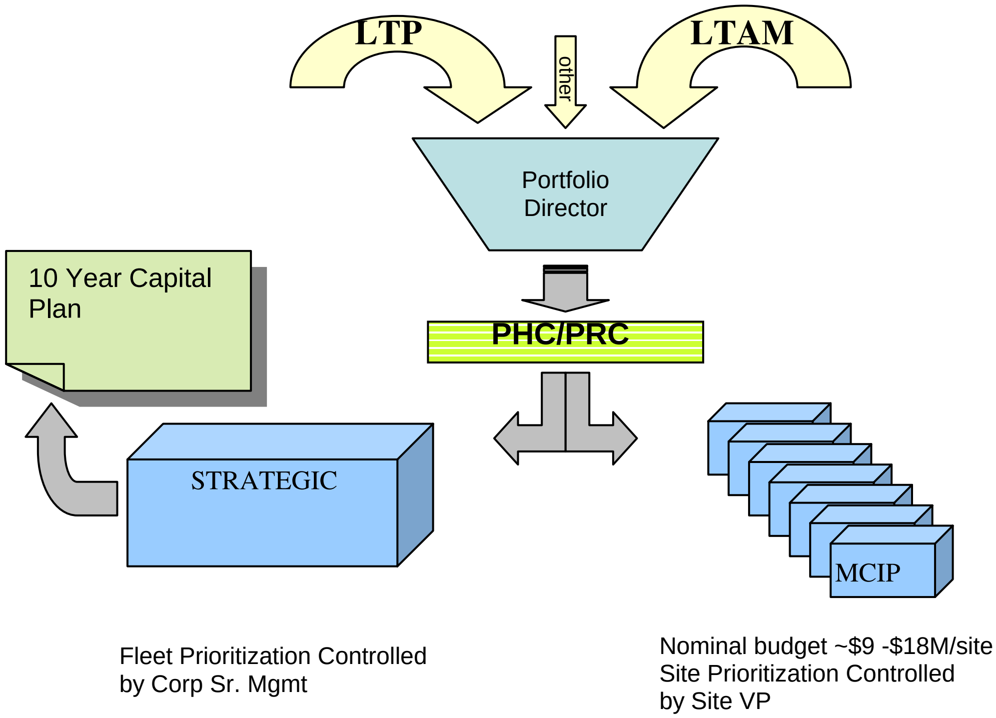

Figure 2-4 - Prioritization of Items in Long Term Plans and LTAMs

2.2.1.3 Information Technology Support for Long Term Planning and LTAM

Three important information technology systems support the Integrated Equipment Reliability Long Term Planning process.

- A web based application accessible from the company's Equipment Reliability Website, maintains the Long Term Plans.
- The company's Equipment Reliability Website stores and provides access to the LTAM Strategies
- A commercial application is used to set project priorities and create the list of approved projects (the MCIP) together with the schedule, budget and cash flow associated with each.

The system health application contains system health information for the entire fleet. It offers easy access to anyone who wants to view information about system condition. For the purposes of this discussion, the system health application provides access to both short and long term plans for the system.

The long term plan describes issues that need to be addressed in future years. To develop these plans, System Managers access various inputs, including the LTAM Strategies, preventive maintenance plans, and other information, through the company's Equipment Reliability Website. PHC and PRC members may view these plans on the system health application, as well as view plans for other sites.

LTAM Strategies also are stored on the company's Equipment Reliability Website. These strategies contain information stored in documents with a variety of tables containing the critical information needed in subsequent process steps. Examples of some of these tables are provided below, including:

- the budget status for each asset and corresponding vulnerability by power station in the fleet (Table 2-1),
- year by year cash flows for each power station and corresponding issue (Table 2-2), and
- year by year issue resolution schedule for each power station (Table 2-3).

Table 2-1 - LTAM Strategy Budget Table Example

Asset	Vulnerability	Station							
		1	2	3	4	5	6	7	8
		G	G	G	G	G	G	G	R
		Y	G	Y	G	G	G	G	G
		G	G	G	G	G	G	G	G

Green - Budgeted per recommendations, No current issues or not applicable

Yellow - Budgeted late or below the line but no current issues or Budgeted correctly but has experienced problems

Red - Budgeted late and has experienced problems

Notes explain bases for red and yellow windows

Table 2-2 - LTAM Cash Flow Table Example

Station & Unit	Issue	Year n	Year n+1	…………	…………	Year n+ 25
Station X Unit 1	• Issue 1 • Issue 2	• $$ • $$$				
Station X Unit 2	• Issue 1 • Issue 2 • Issue 3		• $ • $$		• $$$	
Station Y Unit 1	• Issue 1					• $$$$

Table 2-3 - LTAM Strategy Schedule Example

Station & Unit	Year n	Year n+1	……	…………	……	Year n+ 25
Station X Unit 1	• Issue 1 • Issue 2					
Station X Unit 2		• Issue 1 • Issue 3		• Issue 2		
Station Y Unit 1						• Issue 1

Information from the LTAM Strategy tables and from the system health application is manually loaded into the (commercially obtained) asset management application. The commercial application helps manage the project prioritization process and also maintains the current status of authorized and funded items which are displayed with budget schedules. Both outage and non-outage periods are authorized and funded. Figure 2-3 (above) illustrates the overall process.

As can be seen from the above discussion, the company has used information technology to facilitate the rather complex process of identifying issues, creating projects and alternatives to resolve them, prioritizing those projects, and funding and scheduling them.

This application of technology helps to overcome two sometimes difficult data / information management situations that are particular importance for the project prioritization processes:

- maintaining a hierarchical view of assets, e.g., component, system, unit, site, business unit and corporation, as well as
- representing results by year over year for both short and long term time frames.

The overall solution also enables a multi-tiered, multi-organization approval process by making the required information accessible to all decision-makers and information providers within the organization. Those levels range from the asset owner / manager who must manage the asset's reliability and performance to the executive who must oversee the process and ensure the business unit meets the goals and expectations of the corporation.

Even with the success of its process and associated information technology, the company continues to look at ways the process can be improved. One such example is the transparency of the process. Transparency improvements include possible increased integration of data and the associated the IT solutions, as well as increasing the availability of status information and knowledge added to the process by decision-making groups like the PHC and PRC.

The business process and associated information which supports the company's project prioritization and long term planning processes demonstrate many of the characteristics of more mature asset management applications[5]. These include the following.

- Success in managing data and information collection has been achieved in multi-organizational asset management initiatives. The process involves engineering, operations, maintenance, work management and business operations, with individuals ranging from the Vice President of Engineering, to various decision-making committees, to subject matter experts for critical assets.
- Asset managers are aware of the variety of available condition information and tap that information for high valued assets and critical business processes. System health information helps drive the asset management process and is available for viewing by all decision makers. This condition information also is available across the fleet, allowing comparisons across similar assets.
- Performance monitoring is accepted across the entire organization and supported by portals. The system health application database is a good example for this asset management business process.
- Performance goals are set based on value and their relationship to stakeholder goals is clearly specified, explicitly modeled, and measurable. In this example, the stakeholder is the corporate organization and the performance goals are the station's budget and power generation commitments over the short and long term.
- Decision support tools for asset replacement and maintenance planning use condition information and degradation models. System health and anticipation of end of asset life play a particularly important role in the system long range plans and in the LTAM Strategies.
- Decision support tools are used and managers and executives understand the bases for their operation and how results are obtained. The above mentioned health information, prioritization and various bases are accessible to management through the intranet and through MCIP reports.

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[5] See Table 2-1, Maturity Index Table in *Information Technology for Enterprise Asset Management, An Assessment Guide,* 1012527, EPRI, Palo Alto, CA: 2007.

- Data collection for ranking applications increasingly is being automated. Additionally, management has increasing levels of confidence in the results. Health measures are applied both for assets and budgets and are available in the electronic system health application and LTAM Strategies. Prioritization information is available in the commercial asset management application.
- Staff skill and experience is incorporated in models and decision-making as a matter of established process. SMEs at both the corporate and plant level play a critical and well defined role in the long term planning process.
- Project cost and performance are measured and compared against original estimates. Budget health is tracked and maintained.
- Long range plans for capital investments are developed and comprised of individual projects. In particular, the project level planning addresses a variety of planning windows from the short term to end of asset life and end of plant life.
- Alternatives are considered throughout the decision process. Contingencies and condition monitoring options are identified early in the planning process and are available if needed.
- The strategic planning, project prioritization, and budgeting processes are integrated, and decision support tools are used throughout the process. This example shows a particularly strong relationship from business unit commitments to the corporation to projects and required budgets.
- O&M budgets are increasingly flexible in responding to changes in investment strategies. Advanced planning allows management to pursue opportunities and to act before goals are affected. Contingencies are developed in case situations change.
- Risks are estimated qualitatively and / or quantitatively for business critical projects. These estimates include both threats to system and plant reliability and availability as well as risks associated with completing projects within budget and on schedule.
- Business processes are documented in procedures or equivalent documents. More than a half dozen procedures define the roles of equipment reliability, maintenance, supply and business operations. Those procedures specify what information is input to and obtained from the various information technologies.
- The company has executive sponsorship for asset management which ensures it is an essential part of the corporate culture and that it is integrated into the appropriate business processes.

Of equal importance as an insight for asset management program development, the company's project prioritization and long term planning process and supporting information technology are an example of how business goals have been extended from the corporate level to merge with equipment based asset management processes, people and tools at the business unit level, e.g., LTAM plans, SMEs and web-based System Health Monitoring.

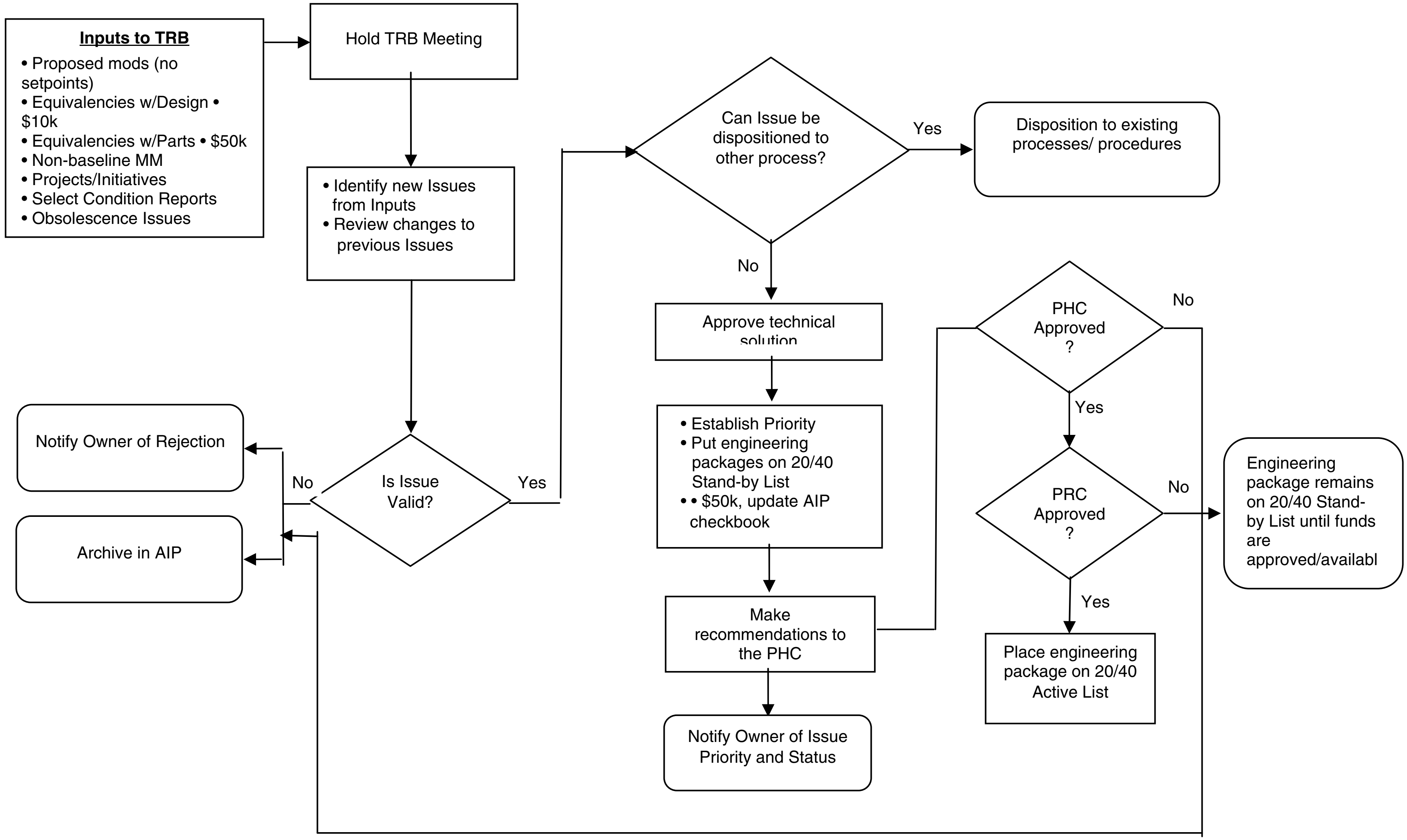
2.2.2 The Second Good Practice Case Study

In the previous good practice case study, we examined the role of information provided by long term asset management and fleet subject matter experts in the project prioritization process. In this example, we focus on the role of the various plant committees responsible for executing the process, how an issue is managed, and what information is required and reviewed to evolve the issue into a solution and to prioritize it, including the prioritization criteria employed to make decisions.

The fleet operator highlighted in this case study uses a similar approach and similar information as the previous nuclear generating company. In this example, we focus on the groups which determine the final priority of investments and how they implement the corresponding processes.

The evaluation process begins with an issue. An issue is a problem that could impact the station, corporate or business processes in an unacceptable manner (per the Corrective Action Program) or an opportunity to improve equipment, processes or facilities. Issues are maintained in an issue list. To evolve the issue into a solution and to prioritize its implementation, the Technical Review Board (TRB), the Plant Health Committee (PHC) and the Project Review Committee (PRC) execute the process depicted in Figure 2-5.

Figure 2-5 - Technical Review Board Issue Evaluation Process



At this utility, the TRB consists of eight supervisory level members who review issues and disposition them either to other plant processes or as engineering packages for future consideration. Any item estimated to cost more than $50,000 also must be approved by the PHC and PRC. The TRB also can reject the proposed solution to the issue. If so, the TRB provides the originator with the basis for the rejection.

The PHC is a station management team that assures important asset improvement issues are identified and proposed solutions are reviewed for their technical merit. The PHC monitors the completed issues list. It also is involved with the plant's life-cycle management plans by reviewing system, component and program health reports and long-term plans.

The PHC dispositions (i.e., approves, prioritizes, or disapproves) the TRB's recommendations using the 20/40 Active and Stand-by Lists. The 20/40 Active List contains approved projects comprised of no more than twenty active, outage-related modifications per refueling outage and no more than forty active, non-outage-related modifications. The 20/40 Stand-by List contains approved modifications with lower priority than the Active List and serves as a secondary list of projects that can be implemented should conditions warrant (e.g. additional funds and time become available).

The PRC reviews projects with an estimated cost greater than $50,000 and makes the final disposition for funding and prioritization in the Asset Improvement Portfolio (AIP) checkbook. We note that there are other increasing levels of management review for projects with estimated costs greater than $500,000; however for this case study we restrict our attention to application of the basic process.

The AIP checkbook is a document input to the nuclear station business plan. It contains major (≥ $50,000) asset improvement projects that either are being evaluated or have been approved for execution through the end of the plant life. The AIP checkbook documents projected and forecasted O&M and Capital expenses as well as priorities of approved projects, including both funded projects as well as approved but unfunded projects.

A key element to managing the disposition of issues is the issue prioritization process (IPP). The IPP initially is performed by the TRB; however, the IPP results are reviewed and possibly adjusted by the PHC and the PRC. The IPP provides a means to determine the relative order that projects should be funded. A prioritization is performed for each project to assess its value across the fleet.

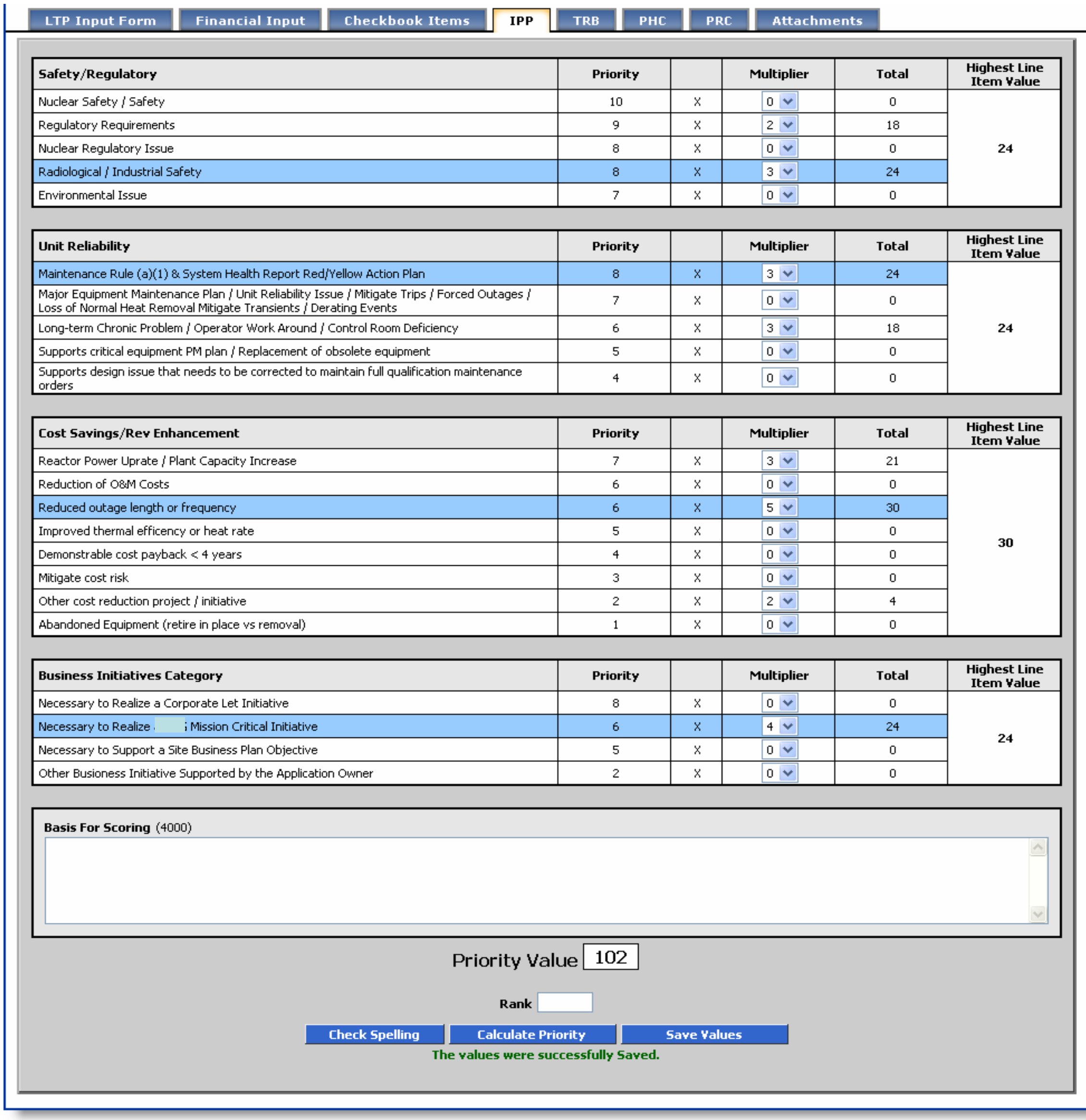
The IPP employs four categories (safety / regulatory, unit reliability, cost savings / revenue enhancement, and business initiatives), each with sub-criteria line items. The business initiatives category includes a sub-criterion for both corporate led business initiatives as well as initiatives led by the entire generation fleet, including fossil.

Each sub-criteria line item has a predefined *priority*[6]. The analysis determines which line items are applicable and then assesses a *priority multiplier* for each line item. The priority multiplier accounts for the relative impact the project has in preventing a negative consequence or in addressing a situation. The product of the sub-criteria line item's predefined priority and the assessed multiplier produces an overall *priority value* for that category's line items. These

[6] The terms used by the utility are italicized to help clarify the four different measures used in prioritization for Equipment Reliability.

priority values are summed to obtain a priority for each category.   The four category priorities are summed to obtain a *total IPP score*.

The IPP can be implemented manually using a form, however its typical application is automated using software. Figure 2-6 illustrates the automated form for the IPP.



LTP Input Form | Financial Input | Checkbook Items | IPP | TRB | PHC | PRC | Attachments

Safety/Regulatory	Priority		Multiplier	Total	Highest Line Item Value
Nuclear Safety / Safety	10	X	0	0	
Regulatory Requirements	9	X	2	18	
Nuclear Regulatory Issue	8	X	0	0	24
Radiological / Industrial Safety	8	X	3	24	
Environmental Issue	7	X	0	0	

Unit Reliability	Priority		Multiplier	Total	Highest Line Item Value
Maintenance Rule (a)(1) & System Health Report Red/Yellow Action Plan	8	X	3	24	
Major Equipment Maintenance Plan / Unit Reliability Issue / Mitigate Trips / Forced Outages / Loss of Normal Heat Removal Mitigate Transients / Derating Events	7	X	0	0	
Long-term Chronic Problem / Operator Work Around / Control Room Deficiency	6	X	3	18	24
Supports critical equipment PM plan / Replacement of obsolete equipment	5	X	0	0	
Supports design issue that needs to be corrected to maintain full qualification maintenance orders	4	X	0	0	

Cost Savings/Rev Enhancement	Priority		Multiplier	Total	Highest Line Item Value
Reactor Power Uprate / Plant Capacity Increase	7	X	3	21	
Reduction of O&M Costs	6	X	0	0	
Reduced outage length or frequency	6	X	5	30	
Improved thermal efficency or heat rate	5	X	0	0	30
Demonstrable cost payback < 4 years	4	X	0	0	
Mitigate cost risk	3	X	0	0	
Other cost reduction project / initiative	2	X	2	4	
Abandoned Equipment (retire in place vs removal)	1	X	0	0	

Business Initiatives Category	Priority		Multiplier	Total	Highest Line Item Value
Necessary to Realize a Corporate Let Initiative	8	X	0	0	
Necessary to Realize [illegible] Mission Critical Initiative	6	X	4	24	24
Necessary to Support a Site Business Plan Objective	5	X	0	0	
Other Busioness Initiative Supported by the Application Owner	2	X	0	0	

Basis For Scoring (4000)

Priority Value 102

Rank

Check Spelling | Calculate Priority | Save Values

The values were successfully Saved.

Figure 2-6 – Example Issue Prioritization Process

Use of both the priority multipliers and the sub-criteria line items are guided by descriptions provided in the governing procedure. For example, a low multiplier (value of 1) has a low probability of occurrence, or could potentially add value but shows little short term benefit (annual benefit or loss <$50k). A high multiplier (value of 5) has a high probability of occurrence; threatens public or personnel safety; results in plant shutdown or delays return to service; or a material financial impact (annual benefit or loss >$3M). The multiplier reflects the importance of the issue the project is intended to resolve. The greater the threat from the issue, the higher the corresponding project is ranked.

A number of important procedural requirements for analysis and review augment the project prioritization process in the IPP. The TRB procedure which governs project development encourages a well researched process, including:

- a systematic and clearly documented review of the collective knowledge of the respective site, other sites, engineering, subject matter experts and industry experience,
- problem identification and root cause determination,
- benchmarking both to determine the industry standard, as well as to challenge traditional thinking,
- clear indication of the involvement and input received from other departments that have gone into preparing the solution that demonstrates teamwork, both in communication and buy-in, and
- a "customer" orientation, namely how well the project serves the intended users, e.g., operations.

The TRB procedure also emphasizes identifying alternatives. A review of alternatives considered and rejected is a key part of the approval process used by the TRB and the PRC. The TRB procedure requires clearly identified and presented impacts on operations and maintenance, as well as other departments. Additionally, the "do nothing" alternative must be fully considered and risks associated with deferral identified and described.

Ballpark estimates are used to compare alternatives. These estimates often are obtained from experienced personnel. The estimates may be based on judgments rather than detailed estimating procedures, but should consider all aspects of the job, including planning, design, procurement, installation, and on-going operations and maintenance costs. Information technology scope is estimated by Corporate IT.

Projects and their assigned priorities are reviewed and challenged by the TRB. The following questions are asked during the TRB meeting:

- Has an acceptable range of alternatives been considered?
- Has there been an effort to reduce engineering costs (such as via use of internal resources)?
- Is the proposed solution a case of "over-engineering"?
- Has the solution taken advantage of all processes available?
- Have all internal department resources been identified and committed to by the respective departments? Are alternate strategies developed to support the work?
- Does the strategy consider leveraging implementation costs across the fleet?

If approved by the TRB, the next step in the approval process is the PHC. The PHC maintains the complete issues list and routinely monitors the actions associated with the list. The PHC also reviews system, component and program health reports and long-term plans. As such the PHC evaluates projects with regard to existing plans, current conditions and possible related actions. Figure 2-7 illustrates the type of information input by the PHC for an issue and its associated project(s). If the PHC approves the project, it moves to the PRC for evaluation.

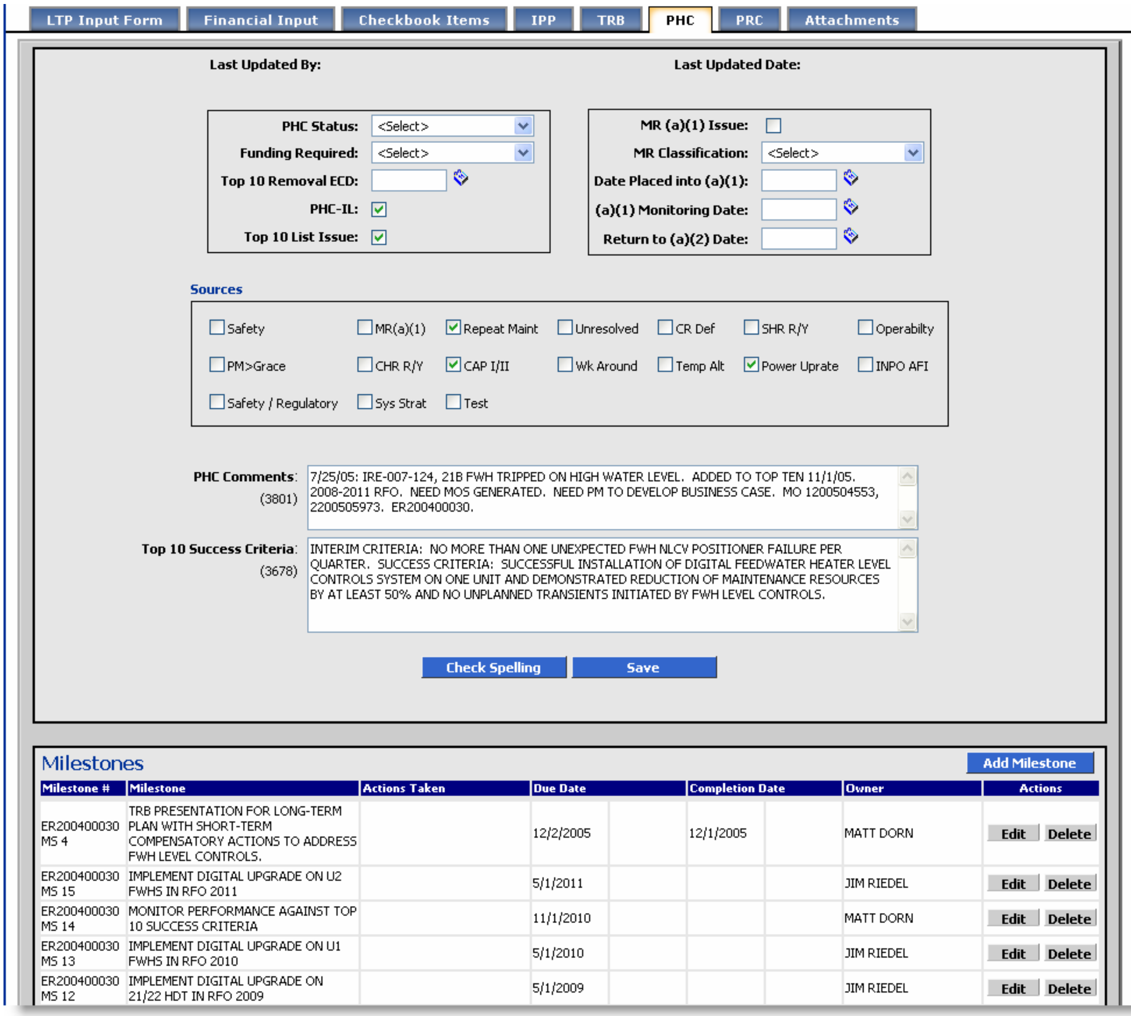


Figure 2-7 – Example Plant Health Committee Input Form

The PRC's scope of evaluation extends beyond the equipment reliability projects and initiatives recommended by PHC. The PRC also evaluates other items greater than $50,000, including:

- projects and initiatives identified in an individual department budget line item.
- infrastructure items (such as tools and equipment, routine furnishings, information technology and facility issues).

For the PHC recommended projects, the PRC reviews the submitted IPP score (which may have been modified by the PHC) and reaches agreement on a final IPP score. When projects have identical IPP scores, the PRC subjectively ranks them to obtain a final comprehensive rank order list. The PRC also subjectively ranks IT and Infrastructure projects. These projects are exempt from the previously described Issue Prioritization Process, which focuses on Equipment Reliability projects.

But the PRC analysis goes well beyond the IPP scores. The PRC ensures the project analysis reflects all options considered and evaluates the cost benefit analysis associated with each option, including a sensitivity analysis of key financial inputs. The PRC comprehensively challenges the proposed project through a series of questions, many of which are repeated in Table 2-4.

Project Review Committee Challenge Questions

<u>Alternatives</u>:

What are the consequences of delaying or not implementing the project? *[Risk of deferral]*

What alternative options have been considered?

Why is the range of alternatives considered broad enough?

What are the short-term and long-term outcomes of each alternative?

What are the key drivers for choosing the recommended solution?

What is the recommended solution?

<u>Benefits and Costs</u>:

What are the benefits of the solution?

What is the basis for the cost? *[Include accuracy of the estimates and contingency amount]*

Is the solution cost-effective?

What are the major assumptions and bases for costs and savings/revenue? *[Validate assumptions. Have industry experts / experience and other stations been considered?]*

If outage related, what is the impact to duration and resources?

Will the solution solve the problem completely?

<u>Corporate Goals</u>:

Are other sites affected?

Can the project be implemented and balance the AIP checkbook?

Is the initiative/project aligned with site and corporate procurement strategies?

What are the risk elements of implementing the project and what actions must be taken to mitigate the risks?

Proposed mechanism for performance measurement

Peer Evaluation:

Have there been previous attempts to address this problem? Explain *[What has been done to tap expertise of peers and using peer reviews?]*.

What supporting groups (corporate and site) are required?

Has collective company (CGG/CEG) knowledge been identified and applied?

What benchmarking has been performed? How are other utilities resolving the issue?

Table 2-4 - Project Review Committee Challenge Questions

The PRC considers the entire project scope based upon a three phase approach whose level of detail is commensurate with project maturity:

- Conceptual Estimate (Alternative Analysis and Conceptual Phase) - Creates a placeholder in the budget for the proposed project using a rough order of magnitude estimate.
- Budgetary Estimate (Design Phase) - Develops a summary-level business case with sufficient justification for the Rough Order of Magnitude total project value and requests partial funding to develop appropriate design details, finalize scope, get vendor quotes and produce a "bottoms up" (or appropriate) cost estimate (± 20% confidence).
- Cost Control Estimate (Implementation Phase) - Completes the detailed business case with a detailed cost estimate (± 10% confidence) that is sufficiently detailed to support a not-to-exceed project estimate.

The PRC makes the final disposition for funding and prioritization in the Asset Improvement Portfolio (AIP) checkbook. The PRC also supports the increasing levels of corporate management review for projects with estimated costs greater than $500,000.

In addition to dispositioning individual projects, the PRC reviews the AIP Checkbook as a whole. When approving a new project, the PRC determines whether a redistribution of projects or initiatives is required. The PRC also verifies that the AIP checkbooks accurately reflect station asset priorities and action plans as well as cash flows and targets for current and future years. Finally, the PRC periodically reviews the accuracy of the baseline major maintenance scope and funding. For example, following the completion of a project, they ensure major maintenance savings are reflected in the AIP checkbook (e.g., after replacing the reactor vessel head, the time and cost for disassembly and re-assembly of the new vessel head will be reduced; thus the PRC verifies this is reflected in future budget allocations.)

As mentioned earlier, the company uses a web-based software tool to facilitate the workflows associated with station and fleet Long Term Planning (LTP) and Life Cycle Management (LCM). This includes gathering issues, prioritization, Technical Review Boards (TRB), Plant Health Committees (PHC), Project Review Committees (PRC), and managing the AIP Checkbook and the resulting financial forecasts. Issues are gathered from other web-based software tools such as system health reporting and program health reporting. Issues are gathered into queues, associated with projects, and tracked for review and approval by the TRB, PHC, and PRC.

Besides automating a potentially cumbersome process, the software tool has helped to create transparency in the process by which an issue evolves into a project and how that project is prioritized by the responsible organizations. The software also prepares reports which support and document the governing procedures for project prioritization as well as related business processes. The reports include the 20/40 Active and Standby lists, the PHC Issue List, the Top 10 Lists, list of PRC Approved projects, and Station and Fleet Checkbooks. The software and associated reports allow both station and corporate personnel to access information for individual plants or the entire fleet.

The business process which supports the company's project prioritization and long term planning process demonstrates many of the characteristics of mature asset management applications[7]:

- Asset managers are aware of the variety of available condition information that is also available across the fleet, allowing comparisons across similar assets.
- Decision support tools for asset replacement and maintenance planning use condition information and degradation models. System health and anticipation of end of asset life play a particularly important role in issue identification and the PHC review.
- Decision support tools are used widely and managers and executives understand their bases and results. The above mentioned health information, prioritization and various bases are accessible to management through the web-based software tools.
- Data collection for ranking applications is automated, and management has confidence in the results. Prioritization information is available in the software tool, including the results from the TRB, PHC and PRC.
- Long range plans for capital investments are developed and comprised of individual projects. In particular, the project level planning addresses a variety of planning windows from the short term to end of asset life and end of plant life.
- Alternatives are considered throughout the decision process. The TRB process emphasizes alternatives and the PRC challenge questions make evaluation of alternatives one of the critical steps in project approval and funding. Emphasis is placed on incorporating peer information from both within and outside the company (e.g., by benchmarking).
- The strategic planning, project prioritization, and budgeting processes are well integrated, and the IPP results are used throughout the Equipment Reliability process.
- O&M budget line items greater than $50,000 periodically are reviewed by the PRC. Further, when projects are completed, planned O&M budget savings are incorporated in future O&M budgets.
- Business processes are documented in procedures or equivalent documents.

Of equal importance as an insight for project prioritization program development, the company's emphasis on identifying and evaluating alternatives throughout the process demonstrate maturity in the program. The use of a consistent set of challenge questions and the nature of the questions help ensure a high value project is generated.

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[7] See Table 2-1, Maturity Index Table in *Information Technology for Enterprise Asset Management, An Assessment Guide*, 1012527, EPRI, Palo Alto, CA: 2007.

2.3 Key Topics in Project Prioritization

The previous discussion provides a description of the current state of the art in project prioritization as conducted in the commercial nuclear power industry. However, it is anticipated that additional benefits could be obtained by evaluating state of the art practices employed in other industrial applications. The remainder of this report looks at project prioritization practices from other high performance organizations and evaluates their applicability for use in nuclear power production. In particular, the following topics in project prioritization were identified by the nuclear community as items of interest related to insights from other industries:

- Key Attributes of LCM Plans (as they relate to prioritization)
- The Project Prioritization and Long Range Planning Process
- Guidance for Selecting and Valuing Prioritization Attributes
- Integrating Project Ranking and Business Strategy
- Metrics to Evaluate Process Effectiveness
- Feedback Mechanisms for Continuous Process Improvement

These topics will be reviewed in our findings, highlighting the insights gained from other industries.

3
CASE STUDIES AND LESSONS LEARNED FROM OTHER INDUSTRIES

This project identified case studies and lessons learned from other industries. For the Information Technology and Transportation industries, the case studies and associated lessons learned are synthesized from an overall evaluation of applications across multiple companies. In the case of the electrical transmission, distribution and generation businesses and the pharmaceutical industry, they are from specific companies, often leaders of their respective industries.

- Transmission and Distribution – good insights are available and accessible for this project through EPRI's Power Delivery Asset Management program. These insights are particularly relevant since nuclear business units may compete for resources with T&D business units. All three T&D case studies are from utilities with substantial nuclear assets. This section also includes an introduction that puts the relevant business issues in perspective.
- Generation – two good utility case studies cover successful and advanced applications of project prioritization and long range planning. This section also includes a case study from EPRI's Environment Sector regarding how regulations about climate change might change how nuclear power generation is valued and how markets play a role in that evaluation.
- Information Technology – IT investment prioritization recently has become a critical management focus across all industries.
- Transportation – State and local governments are leading users of asset management techniques to manage the transportation infrastructure. In particular, states like Virginia and Florida use performance indicators to drive spending. The American Association of State Highway and Transportation Officials (AASHTO) has developed a comprehensive transportation asset management guide.
- Pharmaceutical – These companies spend substantial sums on product development. In this report we present an interesting case study with particular insights on developing alternative projects.
- PAS 55 – An International Standard in Optimal Management of Physical Assets (published May 2004) and just now revised (October 2008). Ofgem, the regulator of electric and gas utilities in the United Kingdom, has stated that all UK electric and gas utilities should be PAS 55 certified by 2008.

The following subsections provide insights and case studies from these industries.

3.1 Electrical Transmission and Distribution Industry Insights

In our examination of project prioritization and long term planning techniques used in other industries, we begin with the transmission and distribution (T&D) sector of utilities. This choice provides a number of advantages. First, it allows us to draw heavily on research and relationships developed in EPRI's Power Delivery Asset Management (PDAM) program. Indeed, each of the case studies described here come from insights developed as part of that program. For further information, including presentations on some of the case studies described here, the reader can examine the proceedings of the four Power Delivery Asset Management Conferences that EPRI has sponsored.[8] In Appendix B, the reader also will find reference to EPRI reports on project prioritization from the PDAM program.

Second, a focus on T&D utilities allows our nuclear members to gain insight from their peers who face similar challenges in obtaining funding and who have many of the same stakeholders. In most utilities today, the nuclear, conventional generation (e.g. fossil / hydro) and transmission and distribution business units all "compete" for capital and O&M resources. Increasingly, we see evidence of development of enterprise level evaluations of funding. In an EPRI survey of leading PDAM practitioners[9] performed early this year, four out of five responders indicated they compete for budget with other business units and three out of five indicated that their companies use an enterprise project prioritization method. EPRI Report 1012954 describes a pilot study of an enterprise project prioritization process conducted by Nebraska Public Power District. Indeed, the three T&D case studies presented below are from utilities with substantial nuclear generating capacity.

We begin this portion of the report drawing heavily from a white paper and presentation developed by Copperleaf Technologies and presented at the EPRI Fourth PDAM Conference. That discussion begins with some background information on the T&D business that we believe is particularly relevant to the case studies that follow. This T&D portion of our report continues with a case study derived from two presentations, one given by Navigant Consulting at the same EPRI conference and another by the subject utility given at another conference. Two more case studies follow, both of which were derived from information received from utilities.

3.1.1 Evolution of Transmission and Distribution Utilities' Needs

Over the past several decades, the electric distribution industry has evolved from a period of heavy build in the 1960s and 1970s, to an emphasis on operations & maintenance in the 1980s and 1990s, transitioning today to a massive infrastructure re-build with an emphasis on balancing long-term sustainability with reliability.

As Table 3-1 illustrates, this industry evolution has shifted the primary focus of industry executives, business processes, and enabling IT systems. Historical core competencies such as project management, work and asset management, and resource management are now considered basic "blocking and tackling". Transmission and distribution utilities are moving increasingly toward project prioritization and long term planning[10] to effectively manage risk, reliability, and capital efficiency.

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[8] The proceedings for the first three conferences are published in EPRI Reports 1008965, 1008552 and 1012497. The latter two are publically available from the EPRI website. The proceedings from fourth conference, held in October 2008, will be published this year.

[9] *Asset Management Practices Survey*, EPRI, Palo Alto, CA. 2008. 1013813.

[10] Copperleaf Technologies refers to this process as Asset Investment Planning to distinguish the process from traditional project prioritization resulting in annually ranked lists of projects. To be consistent with the rest of our

Table 3-1 - Evolution of the Utility Industry

<table>
<tr><th></th><th>Build
Until the 1970's</th><th>Operate & Maintain
1970's through 2000</th><th>Reinvest & Dispose
Post 2000</th></tr>
<tr><td>Executive Issues</td><td>Managing Growth</td><td>Efficiency & Cost Control</td><td>Reliability
Long-term Sustainability</td></tr>
<tr><td>Process Focus</td><td>Project Management</td><td>Operations</td><td rowspan="2">Asset Investment Planning</td></tr>
<tr><td>IT Focus</td><td>Project Management</td><td>Business Intelligence, ERP & EAM[11]</td></tr>
</table>

Electric distribution companies are being pressed by their regulators and shareholders to minimize cost while maintaining or improving reliability, customer satisfaction, and other stakeholder needs. This challenge has led to a need for rigorous investment planning to ensure that the need for capital and O&M spending is clearly understood and outcomes are optimized across all stakeholders.

Ultimately, driving shareholder value from an electric distribution business comes down to maximizing regulatory returns and managing operating costs. In a static environment, this would be a relatively straightforward business model to manage, but there are broad forces at work that present significant business challenges, including:

- Evolving new technologies
- An aging asset infrastructure
- Maturing workforces
- Tightening labor markets that possess critical industry skills
- Rapidly increasing materials costs
- Increasing regulatory scrutiny
- Increasing reliability expectations

In particular, cost and regulatory pressures are presenting clear and immediate challenges, and the plans and actions a distribution company takes will ultimately place it in a position of strength or weakness versus its industry peers. (We note here that some of these dynamics also are present in the commercial nuclear power generation business; thus the insights obtained from

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report, we use the term project prioritization and long term planning which represents the combination of these two disciplines.

[11] Enterprise Resource Planning (ERP) and Enterprise Asset Management (EAM)

electric distribution asset management solutions may provide useful information to address these issues in that application).

- Price increases in steel, copper, aluminium and other key commodities have been dramatic – rising over 15% over the past 5 years
- Availability of skilled labor is becoming even more difficult – 40% of the distribution workforce is eligible for retirement in 5 years
- Aging infrastructure has been the bane of the industry for the past 5-10 years, but utilities are now charged with credibly demonstrating to their regulators the real risk at hand and the need for more capital spend
- Customers who are facing all-time high energy bills are expecting premium network reliability as well
- State regulators are becoming more familiar with infrastructure investment requirements, and are paying closer scrutiny to infrastructure-related rate increase requests

As a result of these and other broad industry pressures, capital spending in the T&D industry has been increasing dramatically and has heightened the sensitivity to future increases. Figure 3-1 isolates capital spending for the largest 30 distribution companies in the US (all utilities with over 1 million customers). Spending has increased at a year-over-year rate of 11% in the past five years, and is expected to maintain this rate of expansion through at least 2010. This rapid increase in spending is driven not only by the need to replace aging infrastructure, but also by the highest spike in material costs seen in decades.

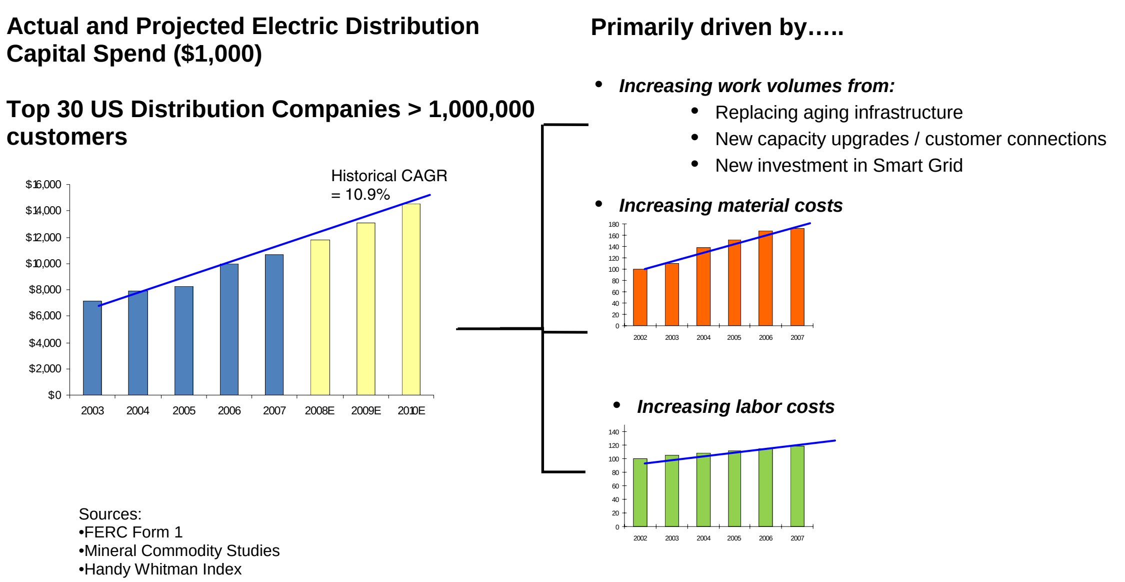

Figure 3-1 - Capital Spend and Contributors for Top 30 US Electric Distribution Companies

Given the ceiling on the amount that regulated energy delivery rates can withstand, along with dramatically increasing demands for capital, there is an acute need for improved credibility in capital planning. Now more than ever, T&D utilities find it essential to demonstrate what is really needed, and to clearly articulate the consequences of a lesser amount.

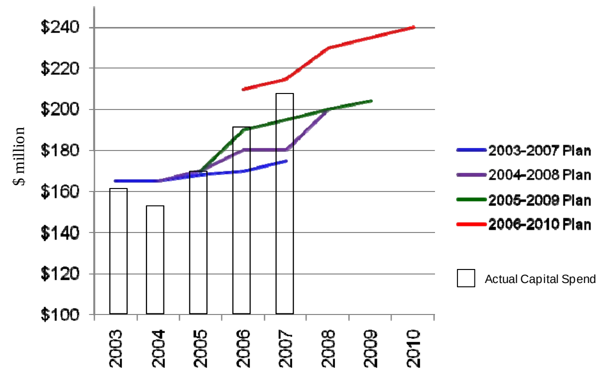

Figure 3-2 - Example Five-Year Capital Plan "Churn"

Figure 3-2 provides an example from a US utility developing a rolling five-year capital plan. This utility is facing typical industry challenges such as aging underground cable replacement and a wood pole replacement program. The figure provides both actual capital spend and four consecutive five-year plans. The figure illustrates typical problems experienced by distribution utilities, including under-spending the plan in 2004, substantial spend differences in 2006 and 2007 from the 2003 and 2004 plans, and significant variation in plans done one year apart.

As the five-year plan has been refreshed over time, the utility has continued to have its credibility erode with both corporate finance and regulators as the plan has "churned". The churn of the plan can be tracked by a metric such as plan-to-plan variance, and keeping this churn threshold below 7% is considered a strong indicator of successful planning. Electric distribution is a relationship driven business and when planning varies at these levels, credibility is called into question with regulators, corporate, investors, and other key stakeholders.

Effective project prioritization and long term planning depends on a recognition that planning and budgeting are two parts of essentially the same overall process – that of setting strategic goals and then executing them. While *Budgeting* involves taking a short-term view of spending with the goal of finding the best use of resources for the immediate fiscal period, *Planning* is focused on setting long term goals to optimize the use of resources well into the future.

With increasing pressures to deliver short term results to shareholders, it is not uncommon for organizations to focus the majority of efforts around the budgeting process and to drive strategic decisions in the context of budgets. This approach, however, is unlikely to maximize value over the long term since decisions driven by a budget are unlikely to present a clear link with long term strategic factors such as corporate and plant strategic direction, asset performance, condition, and risk.

Instead, organizations should be planning for long term performance and refining this plan for each budgeting period. By planning for assets over the long term it is much easier to perform periodic assessments of long-term spending relative to value, and thereby to provide context for specific funding requests within a broader strategic plan. Furthermore, the long term view and rigorous process establish effective governance through a strong historical record of cost and condition, as well as documentation of risk and performance. And, by using the same criteria and underlying data for both short-term and long-term resource allocation, decisions become easier to communicate.

To improve their credibility with stakeholders, the electric distribution industry is placing greater emphasis on improving project prioritization and long term planning. Utilities are beginning to embrace five, ten, and even twenty year asset investment plans for distribution assets. They also are placing an increasing focus on identifying and managing risk. Finally, T&D utilities increasingly are looking for project prioritization and long term planning techniques that increase the transparency of their analysis, both the for the purposes of internal decision making as well as for external reviews by stakeholders. The case studies in this section of the report bear these points out.

3.1.2 Prioritizing Power Delivery Projects with Performance Models

This case study[12] looks at a T&D business unit of a multi-jursidictional utility, which prioritizes its projects based on a model that quantifies project impacts using a value of service approach, then provides reliability performance outcomes based on the corresponding project portfolio. The value of service model quantifies the impact of the different types of customer interruptions. The reliability performance outcomes then allow the T&D business unit to estimate the impact that their projects will have on some of the key indicators used by the regulator to evaluate the utility's performance. The model supports a consistent approach to evaluate and prioritize projects, resulting in improved management decision-making.

The value of service model is necessary because evidence indicates that distribution outages due to weather and normal deterioration generate much less remedial cost than substation and transmission failures or widespread and catastrophic system events. For this reason, values of $13,000-$16,000 per MWh are used for the former, while values of $25,000-$28,000 per MWh are used for the latter. Such a difference in value will affect both which projects "make the cut" and which assets should be focused on to gain the greatest value.

For example, transmission breaker failures are relatively unlikely, based on expected equipment failure rates. However, the impact of such an event can be vary significantly, with widespread impact, particularly if the failure can result in a nuclear plant runback or shutdown. During the capital prioritization process, several breaker replacement projects were justified based on economic value, tied to the higher value of service for these high-impact, low-probability events. In contrast, some projects that addressed higher probability events such as feeder interruptions did not "make the cut" because the impact from the value of service standpoint was far lower than the breaker failures. Thus, the value of service model captures the greater level of risk associated with higher impact events, such as those impacting nuclear plant operations.

The T&D business unit begins its analysis by evaluating individual projects and creating a capital funding curve. Figure 3-3 shows an example capital funding curve for a T&D business unit. The figure also illustrates the type of thinking that the funding curve encourages in the analysis of projects. For example, the funding curve shows that there are a large number of projects near the budgeting cutline, or "on the margin". By focusing their reviews on these projects, the T&D business unit can determine what portfolio is most valuable.

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[12] Information for this case study was provided by Navigant Consulting.

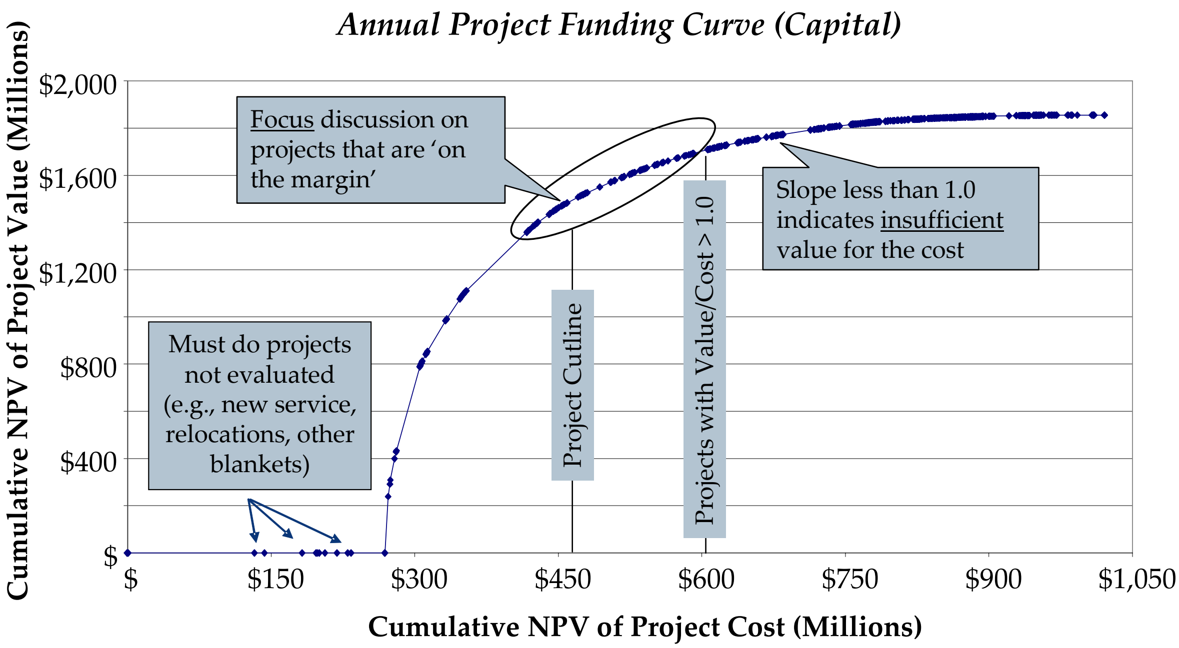

Figure 3-3 - Annual Project Funding Curve for Capital

While this type of analysis is valuable and useful to the asset management group, the utility has found that internal and external stakeholders react more positively to the modeling of their reliability performance outcomes. Figure 3-4 shows three different forecasts of their key reliability indicator, SAIDI[13]. The forecasts represent three portfolios, namely no proposed discretionary projects, budgeted projects and all possible proposed projects. The advantage of this approach is that it keeps communication with stakeholders simple and in terms they can understand. Perhaps more importantly, SAIDI is regularly measured and the actual performance of a portfolio can conceivably be measured against projected performance.

[13] SAIDI is the average outage duration for each customer served, and is calculated as the sum of all customer interruption durations divided by the total number of customers served.

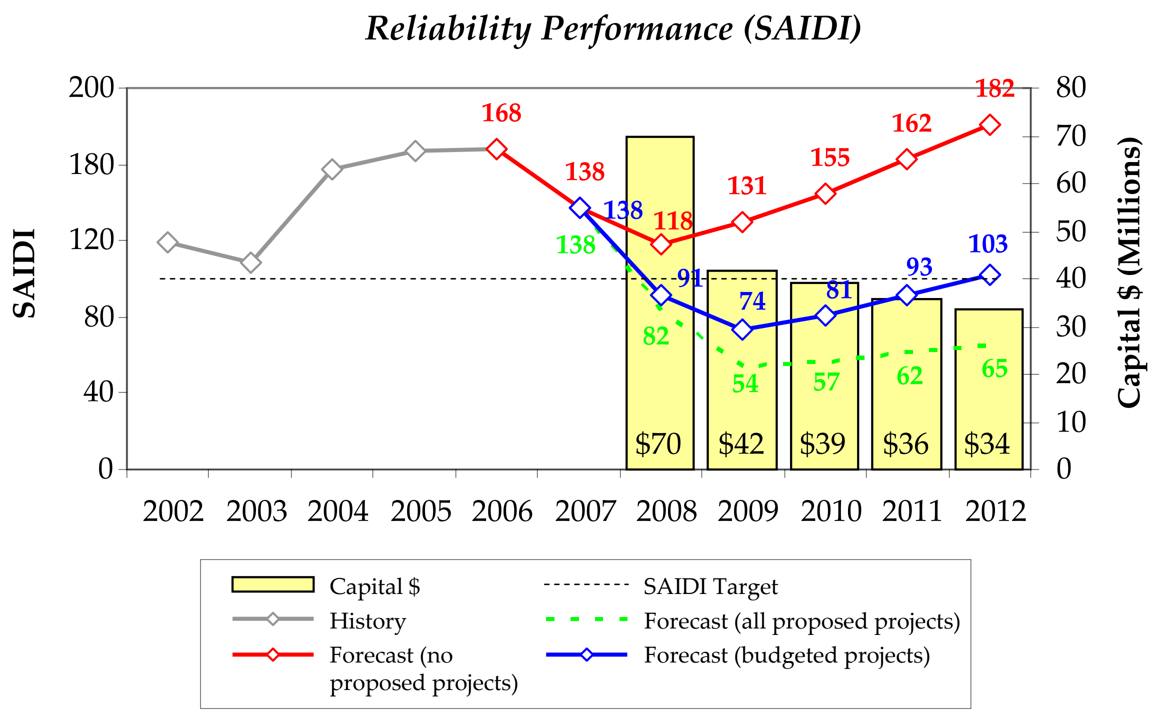

Figure 3-4 – Forecast Reliability Performance by Capital Portfolio

To make the value of service model and the reliability performance models practical to use, the T&D business unit has developed templates for seven (7) different types of projects, e.g., a distribution reliability project, capacitor addition project, etc. The templates help ensure both analysis ease and consistency. The templates each come with an application guide that contains standard assumptions for reliability improvements, O&M costs reductions as well as specialized concerns such as collateral damages associated with particular equipment failure modes that the project might introduce or mitigate.

The T&D business unit also has instituted a post-project evaluation process. The process has been in place for only one year; thus, not all aspects of it have been tested at this time. A project completion audit includes the following key steps:

- Project scope, schedule and budget audit
- Physical audit of the installation
- Reliability performance audit

The project scope, schedule and budget audit is performed by the project manager using a lessons learned worksheet. The physical audit is done on a selective basis, i.e., using sampling, and is designed to provide an independent assessment that ensures the work has been completed as planned.

The reliability performance audit is done annually, but does not begin until two years after the project is complete. The reason for the two year delay is to let biases in reliability performance begin to average out (reliability performance for a T&D business unit is influenced significantly by weather; thus a period to allow these fluctuations to cancel out is needed to obtain a useful measure of performance). The reliability performance audit involves an annual review of reliability related assumptions for the project, as well as assumptions and data for the template reliability model. The audit reviews the continuing validity of these assumptions, as well as any assumptions specific to equipment failure rates.

This case study illustrates a few important aspects of project prioritization and long range planning processes and techniques. First, value can vary significantly between types of outcomes (customer interruptions) and a proper value model is needed to obtain accurate data to permit calculating the value of projects and investment portfolios. Second, because the model and project prioritization approach is so data-driven, data must be rigorously gathered and continuously reviewed. Third, even the best measure of value might not be the most useful measure for communicating with stakeholders or understanding a portfolio's full significance. A model that reveals the expected impact of projects on actual performance indicators might be a better choice for communicating the principal outcome of a portfolio.

This case study also indicates the potential usefulness of developing templates for valuing common types of projects. Besides improving the quality of the analysis, such templates can provide a convenient basis for process improvements such as auditing project performance.

3.1.3 From Asset Health to Risk Management Based Budgeting

The transmission and distribution utility that provided information for this case study set out to move away from traditional asset management approaches to one based on the material condition of their assets. This T&D business unit began with limited views of system and component health and historical performance based on intuition and experience. They transitioned their asset management program to one with standard repeatable processes, obtaining a score for the health of individual assets in most asset classes, and risk assessment capability to identify hot spots. Initial results indicate the overwhelming majority of assets are in fair to very good condition. Instead of the need for large capital injections for these assets, this T&D business unit sees the potential to direct maintenance based on health and mitigate or slow degradation on their assets.

This T&D business unit found that a material condition evaluation was applicable to seventy percent of their installed asset base. They leveraged existing systems to mine over forty five million data points to generate health indices for ten asset groups with forty sub-groups, representing approximately two million assets. Subject Matter Experts challenged the health indices, resulting in a verified consensus view of asset health.

By creating asset health indices, important lessons were learned. In particular they found that the internal confidence in the health index increased when the index became less dependent on asset age as an evaluation criterion. The stratification of assets according to health was a valuable process and the results made sense. They also felt sufficiently comfortable with the process and results to translate asset health into failure rates.

With this view of asset health and the widespread availability of estimated failure rates, this T&D business unit moved toward a risk management approach upon which they could base their programs and spending. The business unit wanted an "apples to apples" comparison of spend, benefits, and risks across all investment categories and they wanted to be able to develop a shared view of risks. Their traditional approach to funding was based on year over year budgets by group, e.g., substations, or by activity category, e.g., corrective maintenance, or by large projects or programs, e.g., equipment replacement. The T&D business unit wanted to disaggregate the large projects into smaller, focused projects. They also wanted to change budgeting conversations to focus on the investment's impact on system performance.

Figure 3-5 illustrates the overall process the company developed to take their asset health information and develop a risk management based budgeting process.

Figure 3-5 - Risk Management Based Budgeting Process

The new process begins by determining the consequences and costs of failures, including the future year risk of equipment failure and the associated costs of equipment repair, refurbishment or replacements. With this information, a remaining economic life is determined. Then an action plan is created with proposed capital projects and maintenance activities. The efficiency of the project or activity also is assessed. The process is implemented by Subject Matter Experts.

The elements of the action plan are then categorized by a risk score. If the risk is high and the project has high efficiency, the project is funded. If the risk is high, but the project has low efficiency, the project is pursued, but only after it has been challenged through a project value analysis to improve its efficiency. If the risk is low, the project might still be funded, depending on the funding cut line. If a project with mid level risk can be disaggregated, the project is broken into separately funded elements and the higher risk / higher efficiency elements are funded.

The T&D business unit finds a number of operational and financial benefits to this process. From an operational perspective, the company benefits from:

- better asset knowledge that guides the entire process
- clearly identified and verified long term resource needs
- targeted, more reachable performance goals
- documented and defendable asset sustainment plan

From a finance perspective, the company benefits from:

- rate submissions that are highly defensible
- more planned costs and less reactive costs
- better scenario planning and decision transparency

This case study represents a good example of a well integrated process that links asset health assessments with a risk management based project prioritization and long range plan. The use of Subject Matter Experts helps ensure consistency in plans and projects. The step to assess project efficiency and the step to disaggregate larger projects or programs with mid-level risks each help to ensure the best "alternative" is identified and funded. Also, maintenance and capital are considered in concert, increasing the likelihood that the best investments are made.

3.1.4 Risk Management Program at a Distribution Utility

Executives at this investor owned utility have concluded that the realities of today's electric utility business environment require risk assessment and management. Those realities include rapidly changing market conditions, reduced regulatory protection, increased competitive pressures and increased scrutiny from the financial community. That increased scrutiny focuses in part on a company's risk management practices. The distribution business unit is an energy delivery company that has broadened its risk management capabilities using an enterprise wide risk management approach.

The company's new paradigm is an ongoing risk management process, broadly focused on all business risks and opportunities and coordinated with senior level management oversight. At the business unit level, the Risk Management Team identifies and quantifies risks, then proposes and manages activities to mitigate them. The Corporate Risk Officer manages risk across functional and business groups of all the affiliated companies and maintains active involvement in the capital investment process that funds risk management activities. The Board of Directors oversees critical risk management issues.

This distribution company's risk management program builds upon the following practices[14]:

- Make a formal, dedicated effort to identify all significant risks.
- Identify risks dynamically and continuously using the various available techniques.
- Rank risks on some scale by evaluating both probability and impact.

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[14] The corporation's risk management program also builds upon these two additional state of the art practices: 1) measuring financial risk with the relevant tools available, such as VAR (Value at Risk) and stress testing, as well as 2) knowing the company's and shareholder's appetite for risk.

- Develop tools and measures that meet the organization's needs and that are easy to understand and utilize.
- Apply more rigor to measuring non-financial risks, whenever possible.
- Manage risk with various combinations of acceptance, transfer, and mitigation.

The company measures and manages a broad scope of risks including operational, credit, business continuity, regulatory, legislative, commodity, environmental and human capital risks.

One example of an operational risk is failure of a major facility or key asset in the T&D network due to aging, third party damage or security attacks. Other important sources of operational risk are: major storms impacting customer satisfaction, potential regulatory mandates, and / or loss of goodwill due to media coverage.

Credit risks include default, bankruptcy or insolvency of wholesale suppliers, retail suppliers or retail customers resulting in a financial loss. Regulatory risks primarily stem from exposure to revenue loss due to a State Commission rate case, regulatory mandates and FERC or IRS rulings. Environmental risks can result from the identification of potential superfund sites, spills and cleanup of old contaminated equipment.

Risks are identified and then quantified in terms of impact and probability. Figure 3-6 illustrates how operational risks in transmission and distribution are quantified by impact.

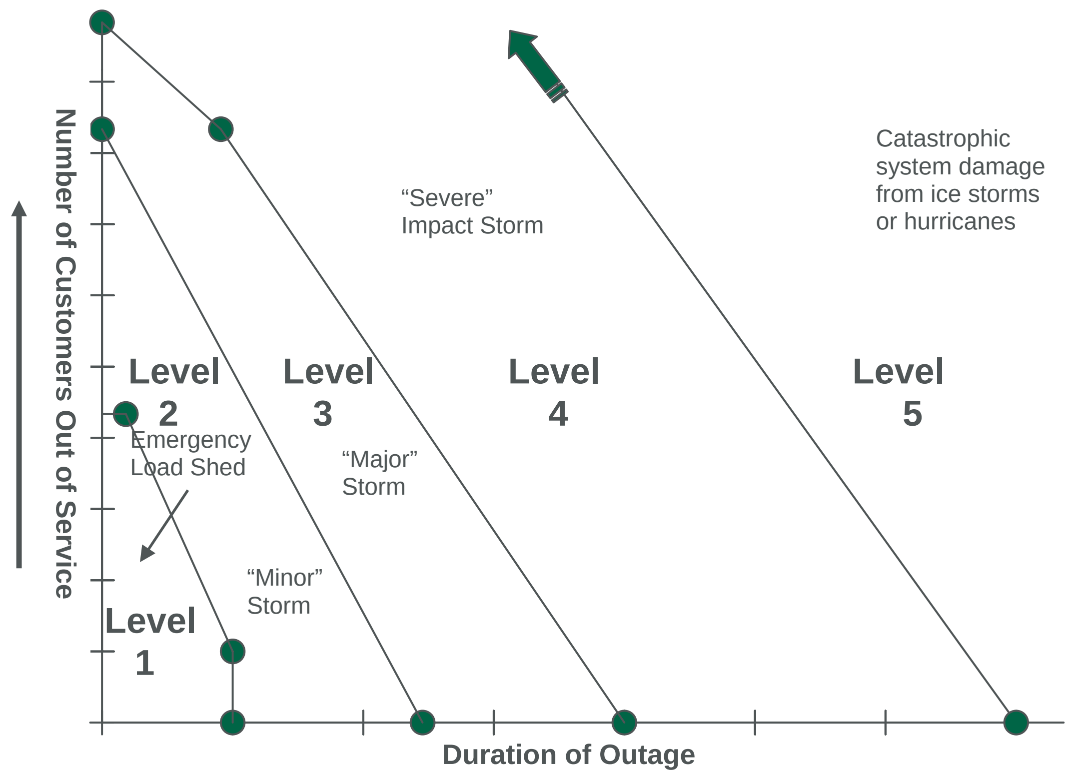

Figure 3-6 - Framework for T&D Operations Impacts

For example, Level 1, 2 and 3 impacts may include lower voltage radial feeds or network losses while Level 4 & 5 impacts may include significant substation failures, oil filled pipe cable failures or various N-2 contingencies or greater. Impacts also can be further characterized by the criticality of customers affected.

The company also estimates a probability level for each of these events. Then the probability and impact are combined into a risk severity level, also scaled one to five. Figure 3-7 shows an example of how the company combines impact and probability into risk levels.

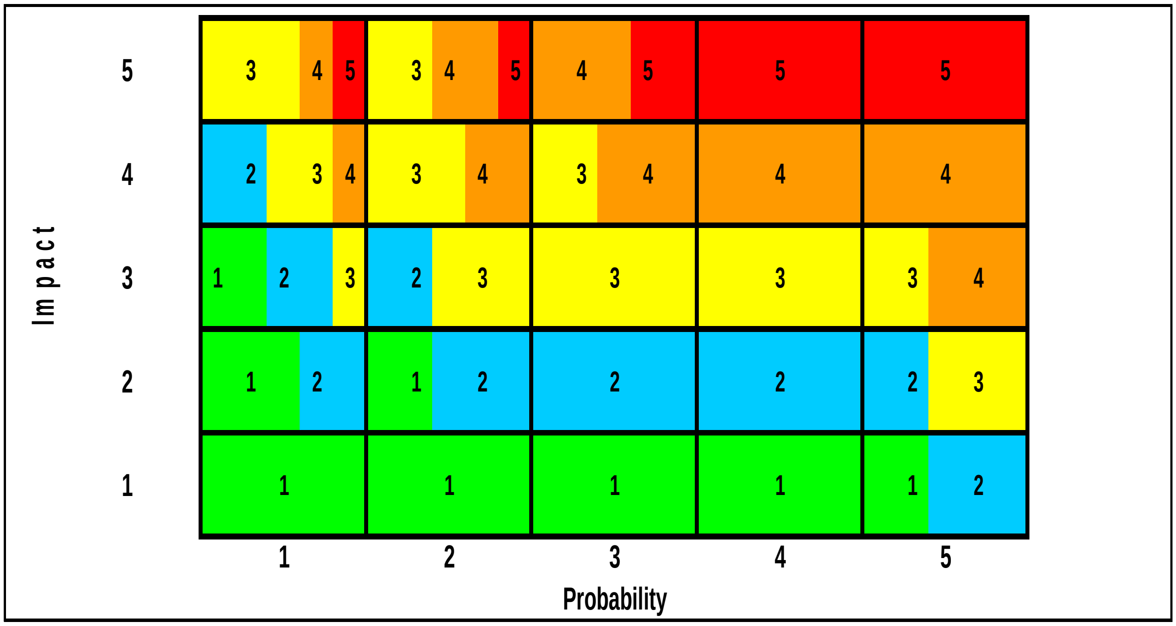

Figure 3-7 - Sample Risk Level Categorization

How risk is managed depends on the risk severity level. Figure 3-8 shows this conceptually.

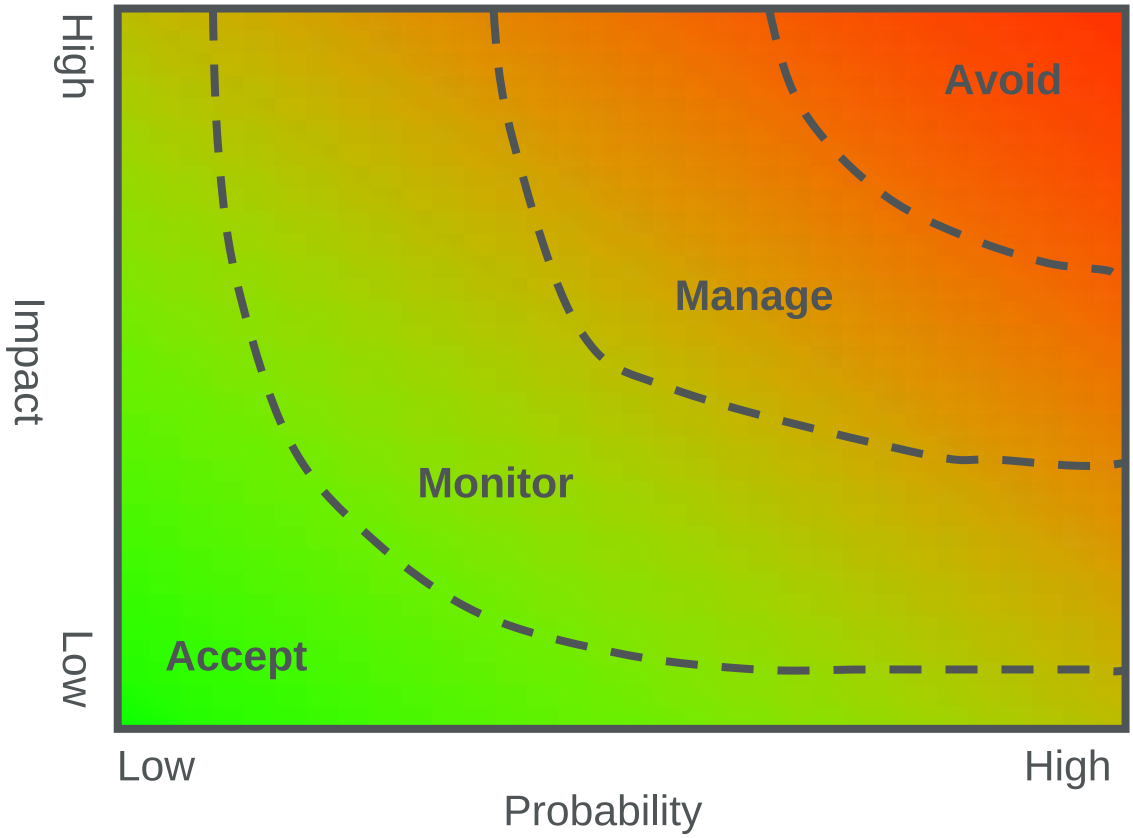

Figure 3-8 - Risk Mitigation Planning

Risk mitigation activities (RMAs) are planned based on the assigned risk level using the following typical guidelines:

- Risk Level 1 – Monitor only
- Risk Level 2 – Discretion used to either monitor or develop a RMA.
- Risk Level 3 – Develop RMA; add project to prioritization system.
- Risk Level 4 - Pursue RMA.
- Risk Level 5 - Pursue RMA.

To develop an RMA, potential actions are evaluated and prioritized and then an action is recommended to mitigate, accept, transfer or avoid the risk. At the distribution business unit, most of the RMAs result in projects involving capital and O&M spending. As such, an RMA is not "physically" different from a project input into a project prioritization process. In this case, however, the value underpinning the prioritization is based on mitigation of the risk.

Effectiveness ratings are assigned to the RMA to indicate how much the risk will be mitigated. Then an RMA owner is assigned, the project is prioritized, and the RMA is tracked. The distribution company uses the corporation's web based Enterprise-Wide Risk Management System (ERMS) to track mitigation activities and create periodic management reports. The distribution company has strong corporate oversight of risk management and much of the T&D

activities described above are implemented by the Risk Management Team. The ERMS quantifies and aggregates risk, determines risk performance and verifies management guidelines. Reports include the risk assessment and actual performance of RMAs.

The ERMS is an excellent example of information technology used to support a leading edge asset management core process. However, the information technology used for enterprise risk management does not have to be sophisticated. The technology need only be effective in making the required information accessible to all management levels within the organization. Those levels range from the owner of an RMA who must manage its successful completion to an officer of the company who must oversee the process.

The ERMS demonstrates many of the characteristics of more mature asset management applications[15]:

- Risk management techniques and tools are used routinely. One particularly important aspect of this company's program is the fact that the techniques and tools to identify risk are secondary. The important point is that once identified, risk is managed dynamically and continuously.
- Risks are estimated and quantified for significant business threats. In this application, these estimates include both the numbers of customers affected and duration for T&D operational risks.
- Risk management plans encompass all business critical assets. The company's plans vary according to risk level and are funded and tracked by management.
- Risk mitigation and hedging routinely are used for large risks. The use of RMAs is particularly comprehensive in its scope. The efforts to track them and ensure their effectiveness are thorough and information technology is an important part of making the process work.
- Indicators of risk are monitored by the ERMS and the monitoring process at the company is well integrated into management and business unit responsibilities.
- Clear risk related goals are specified, explicitly modeled, and measured.
- Risk management is integrated into the capital investment process.
- Risk management is a critical part of the company's business, involving roughly two dozen employees who develop and manage RMAs.
- The Corporate Risk Officer is an executive sponsor for asset management who ensures asset and risk management are an essential part of the corporate culture and that they are integrated into the appropriate business processes.

Of equal importance, the distribution company's enterprise wide risk management process and tools are an example of how financial risk management techniques have been extended from the corporate level to merge with equipment based asset management processes and tools initiated at the business unit level. In this way, corporate strategy and business unit strategy are merged through risk management techniques.

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[15] See Table 2-1, Maturity Index Table in *Information Technology for Enterprise Asset Management, An Assessment Guide*, 1012527, EPRI, Palo Alto, CA: 2007.

For a nuclear utility, the equivalent business risk that would be of highest interest is the probably of lost generation (we note that safety risk is already modeled extensively for regulatory purposes via probabilistic risk assessment and controlled through risk-informed regulations and associated performance indicators). This example then indicates the value of how ER criticality or a Generation Risk Assessment might be incorporated into a project prioritization process.

3.2 Electrical Generation Industry Insights

In this subsection, we again turn to the electric industry, specifically the electrical generation industry. Again, as with insights from the transmission and distribution industry, the perspective is useful because of the shared corporate interests between the nuclear generation business unit and the (conventional) generation business unit. However, there is also a greater similarity in the application of project prioritization and long range planning techniques because both business units are comprised of generating assets.

We begin with two utility case studies illustrating the use of project prioritization and long range planning techniques in the electrical generation industry. The case studies, drawn from information provided by Copperleaf Technologies, Inc., illustrate how these techniques have been used both for internal decision making as well as for successful interaction with regulators.

We continue by drawing upon reports from EPRI's Environment Sector. We include a hypothetical case study on the addition of a new biomass generation plant. The case study provides a good representative example of the impact that different analysis techniques can have on estimating value. The case study also illustrates the importance of basic analysis assumptions. Finally, we also wanted to provide insight into the potential impact of environmental policy on project valuations.

The Environment Sector excerpts continue with an analysis of how the value of generation capacity is influenced by market factors associated with environmental policy, e.g., a cost for carbon emissions. This analysis would seem to indicate that the value of projects that increase generation capability can depend significantly on market effects. A utility's strategic plan for future generation capacity additions can influence the value of an overall generation asset. This insight combines well with the first two case studies which in turn illustrate the influence that the value of the generation asset can have on the value of a project.

A generation company faces different issues than a transmission and distribution company. In this case it is critically important to look at the entire plant as an asset. Asset investment planning requires planners and decision-makers to view the lifecycle needs of productive assets (not individual equipment items) based on the value proposition of the overall asset base. Most business unit leaders develop 1-3 year plans that list "one-off" projects and recurring maintenance activities. Typically, each project will have a business case justifying the investment. However, the one-off investment could be a single piece of equipment that is just one of many equipment items that enables asset productivity. Finance needs to understand the value proposition of the asset base to minimize the risk of stranding investments, maximize the allocation of all resources, and increase the likelihood of achieving corporate goals.

As an example, imagine that a utility needs to replace a governor at a particular plant. The governor replacement activities are estimated to cost $3 million and in the event a governor fails, an outage would occur at that plant. If however, the governor is replaced, the outage potentially could be avoided. The economics for the governor are such that replacement is approved. Two years later, the transformer begins gassing and requires replacement. Again, if a transformer fails, an outage occurs. If the transformer is replaced, an outage could be avoided. Again, the transformer replacement is approved because it makes economic sense. However, assume in another few years the remaining power train equipment items also need replacement, as well as other equipment items representing balance of plant. While each power train item makes sense as individual investments, does the collective whole of replacement activities make sense over ten or twenty years? Answering this question tends to minimize the validity of the classic project economics and shifts organizations to focus on the economics of the overall asset – where the asset is that collection of equipment items that creates a value stream for the business.

3.2.1 Efficiency and Confidence in Planning

Recently, a Canadian utility in the course of its regulatory rate case proceedings was asked by its regulator (as well as multiple interveners) to demonstrate it had selected the best multi-year investment portfolio. With its multiple asset classes and major projects, as well as multiple internal and external assumptions, there were over 38 different investment portfolios with over 120 cases that required analysis.

Historically, the utility had increased its project prioritization and long term planning capability by developing a growing number of Microsoft Excel files and worksheets. The analysis had grown to a series of 1900 worksheets from over 150 different Excel files to capture project information and develop its multi-year plans. The utility estimated it would have required over 2,000 man-hours to vary different assumptions and scenarios necessary to demonstrate what the regulator wanted to see. It also recognized that with that many worksheets, the likelihood of introducing errors had increased.

Automation with a commercial asset investment planning solution[16] was used to enable this utility to provide the information that the regulator and interveners desired quickly and with confidence in its accuracy and quality. As we have mentioned in other case studies, automation also can lead to improved transparency; and improved transparency can lead to improved credibility in a long term plan. The utility that is the subject of this case study was able to use the dramatic time savings obtained from automation to focus on clear and simple communication of the plan and its key characteristics. Equally important, the rigor of the plan created a new, higher level of internal confidence in the results, and armed the utility to assertively defend the plan during the regulatory proceedings.

The utility's process was comprehensive and involved developing portfolios based on various project alternatives and expenditures as well as the specified "available spending" over the planning period. The utility created a set of portfolios for a variety of different prioritization cases, using standard financial measures like NPV and benefit to cost ratios as well as critical performance measures, resulting in the many different investment portfolios and cases mentioned above.

The utility used the commercial asset investment planning solution to iterate through the list of potential projects and "include" those that meet the prioritization criteria, in their prioritized

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[16] The Copperleaf Technologies product ESP.

order, until all available funding was committed. The utility used the tool to list those projects that, regardless of the prioritization case, always are included or excluded. The projects always included were funded; the projects always excluded were rejected.

The evaluation then moved on to better understand the projects that met some prioritization cases, but not others. These projects are the projects on "the cusp", i.e. they are the ones still in consideration for the remaining funding. Management then adjusted the portfolio to reflect the projects they believe should be funded based on stakeholder priorities and business objectives. By building a portfolio based on prioritization criteria that related to key management and stakeholder values, the utility was able to evaluate critical values of key parameters that would threaten the success of the portfolio. For example, the utility considered how much access to capital, prices of external labor, and the price of energy might change before the portfolio was no longer the best portfolio. These critical values helped management understand the risks they were taking and obtain buy-in from the regulator on taking them.

The resulting multi-year capital plan still had to demonstrate to all utility stakeholders that their needs were sufficiently considered. Key stakeholders made requests during the public hearings and comment periods. This input was considered in various portfolios and used to select the investment plan that best suited both the utility's needs and achievable stakeholder input.

3.2.2 Credibility for Requesting an Increase in Capital

This case study addresses a western US utility that had historically predictable capital spend over the last several years. The utility was in a rate case proceeding seeking a twenty five percent increase in capital spending that it needed to mitigate infrastructure risk and cover expected cost increases. The magnitude of the increase was unprecedented, and the utility knew it needed to clearly demonstrate that they were addressing the disparate needs of all involved stakeholders.

Using a commercial asset investment planning solution[17], the utility developed methodical 10- and 20-year investment plans that clearly identified the investment needs and expected outcomes. A top level view of the approach taken by the utility is illustrated in Figure 3-9. Certain key inputs directly affected the investment plan (such as the different asset classes, funding availability, and variability of key assumptions). An efficient modeling capability was needed to analyze the multiplicity of cases necessary to find the best investment plan. Finally, asset and resource plans and long-term financial forecasts, were required to understand the implications of the plan; and budgets and performance reports were required to implement the plan.

[17] The Copperleaf Technologies product ESP.

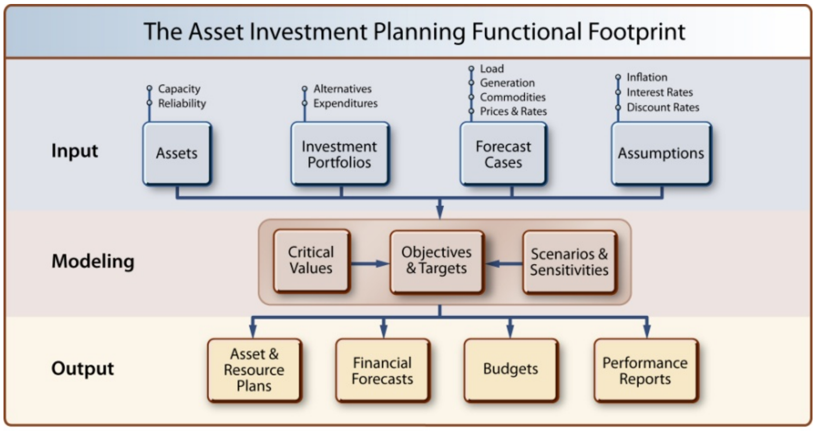

Figure 3-9 – Asset Investment Planning and Functional Footprint

The utility took an asset centric approach that it developed using a bottom up assessment of the condition and needs for all its asset types. We note that there is an important disadvantage to asset-driven capital plans that are derived from infrastructure replacement schedules and major capacity upgrades. Whereas traditional year over year plans will appear more continuous, asset-centric plans will have "lumps". These lumps represent the construction activity increases of prior infrastructure build ups.

However, the advantage of the asset centric approach is that it can be explained in a straightforward manner taking a utility away from rate cases that are defended with complex engineering and deep financial analysis. Regulators and interveners can understand (and often see) an infrastructure that has aged along with the communities it serves. They can understand that a fifty year old transformer designed to last twenty five years represents a substantial reliability risk. By linking assets to needed expenditures, both investment and risk can be understood by all stakeholders, both internal and external.

The utility discussed in this case study developed investment strategies for each of its generating assets covering a twenty year window. The investment strategies indicate the amount of investment that makes economic sense given objectives for equipment condition, tolerances for equipment risk, and expectations around financial return. As a result of this information, the next question that needs to be addressed is priority of investment; however, in this approach, this merely consists of the context of when to make the investment.

To answer this question, the utility evaluated its investment needs relative to expected financial constraints coupled with equipment condition, tolerances for equipment risk, and expectations of financial return. The utility evaluated portfolios of investment to understand which portfolio maximized the key investment attributes of:

- Benefit/cost ratios
- NPVs
- Asset conditions
- Risk (qualitative)

- Key business drivers (e.g., reliability, mandatory projects);
- Performance Indicators (e.g., EFOR[18]); and
- Project status (i.e., ongoing vs. new)

In this instance, management was able to select the portfolio that maximized long run return while minimizing equipment risk.

The resulting multi-year investment plan was communicated to internal and external stakeholders. Since these stakeholders focused on significant issues such as what happens if you delay or accelerate a particular $100 million project or what happens if the price of electricity decreases by 50%, the analyses positioned the utility well to respond to these types of questions.

The transparency and credibility of the plan enabled the utility executives to articulate clearly the different investment cases and each case's impact on cost, risk, and performance. As a result of both the quick turnaround on public comment and the quality of their project prioritization and long term planning capability, the utility's rate increase was approved in record time.

But after the rate increase and associated multi-year plan was approved, the utility still needed to deliver on the plan. In the earlier discussion on transmission and distribution, we noted a utility that under spent its plan by almost ten percent the very year after it was submitted and then overspent the plan by even more only two years later. The key to both managing costs and meeting deliverables is to get ahead of the curve by anticipating specific resource requirements for infrastructure replacement and system capacity upgrades. The asset and resource information provided by the plan enabled the utility described in this case study to secure the necessary scarce skilled contract resources, long-lead time items, and materials, which in turn reduced their overall costs and minimized their overall risk of not delivering on stakeholder expectations.

3.2.3 Considering Greenhouse Gas Emissions in Valuing Generation Projects

In this section, the reader will find that the value of projects that increase generation capability can depend significantly on market effects, whether the markets involve greenhouse gases or the price of generated electricity. In this way, a utility's strategic plan for future generation capacity additions can influence the value of an overall generation asset. As we illustrated in the earlier generation case studies, the value of the overall generation asset can, in turn, influence the value of a project for that generation asset. The reader will also see a biomass generation case study that illustrates some important points about the use of sophisticated valuation models, in this case real options analysis. Although the examples discussed in this section may be somewhat removed from what decision-makers involved with prioritizing projects to be implemented in nuclear power plants typically consider, the principles that are illustrated are applicable. The intent of this section is to demonstrate that for the organization to achieve a prioritization list that delivers optimal value, the evaluation must consider both the strategic objectives of the entire enterprise and the complete spectrum of interactions in the analysis.

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[18] Equivalent Forced Outage Rate (EFOR) measures the hours of unit failure as a percentage of the total hours of unit availability.

Simulation is a valuable capability for evaluating investments. EPRI's Environment Sector has made particular use of market simulations and investment analysis tools to help members evaluate how their investments might perform under a variety of climate change policies. In this subsection, we selectively excerpt from the following EPRI reports:

- *Program on Technology Innovation: A Conceptual Framework for Modeling the Impact of CO2 Policy on Generator Cash Flows. EPRI, Palo Alto, CA: 2006. 1013296.*
- *Program on Technology Innovation: Managing the Risks of Climate Policies: The Effect of a Carbon Price on Existing Generation and Evaluation of Emission Reduction Investments, EPRI, Palo Alto, CA: 2006. 1012577,*

These reports are part of a continuing series[19] addressing the critical issues, challenges, and opportunities facing senior executives, analysts, planners, and other personnel charged with making decisions that may be influenced by climate policy.

EPRI 1012577 addresses the many electric companies who are actively considering substantial investments in new generation capacity. The technology choices these companies make and the financial returns on investments are integrally tied to future environmental policies and, in particular, to climate policy. EPRI's Greenhouse Gas Emissions Reduction Cost Analysis Model (GHG-CAM) is an analytical framework that was developed to help companies to evaluate new generation capability and GHG abatement project opportunities on a consistent basis. The model estimates the "levelized" cost-effectiveness and the net economic benefits (or costs) of potential greenhouse gas (GHG) abatement projects. Levelized cost-effectiveness is estimated in terms of dollars per tons of CO_2 emissions (\$/ton CO_2e).

Each type of GHG abatement strategy can be analyzed from a variety of different analytic perspectives with regards to the *uncertainty* inherent in the values of key underlying modeling variables, and the expected value of the "real options" embedded in each strategy. The GHG-CAM model analyzes proposed projects from three different perspectives: *deterministic*, *stochastic and real options*.

The *deterministic* approach is the simplest and most common analytic approach that can be used to compare the expected costs of different GHG abatement strategies. This approach assumes the quantitative values of key model variables are completely known, or can be estimated using a point estimate or "best guess" approach.

The *stochastic* approach differs from deterministic models because they incorporate estimates of the uncertainty inherent in key underlying model variables. For example, an analyst using a stochastic modeling approach might assume the expected price of a GHG emissions allowance can be represented in any one year by some type of statistical distribution like the one shown below in Figure 3-10, rather than by a single-point estimate. In this case, the analyst would assume the GHG allowance price might fall somewhere between a low value of \$0 per ton CO_2e to a high value of \$20 per ton CO_2e, with a mean value of \$5 per ton CO_2e.

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[19] The series includes other reports on GHG-CAM and associated case studies, including *Program on Technology Innovation: Managing the Risks of Climate Policies: Assessing Potential Financial Risks and Evaluating the Option Value of IGCC Plants*, EPRI, Palo Alto, CA: 2005. 1010173; as well as *Methods for Systematic Evaluation of Greenhouse Gas Emissions Reduction Options: New Approaches for Examining Possible Actions*, EPRI, Palo Alto, CA: 2004. 1008488.

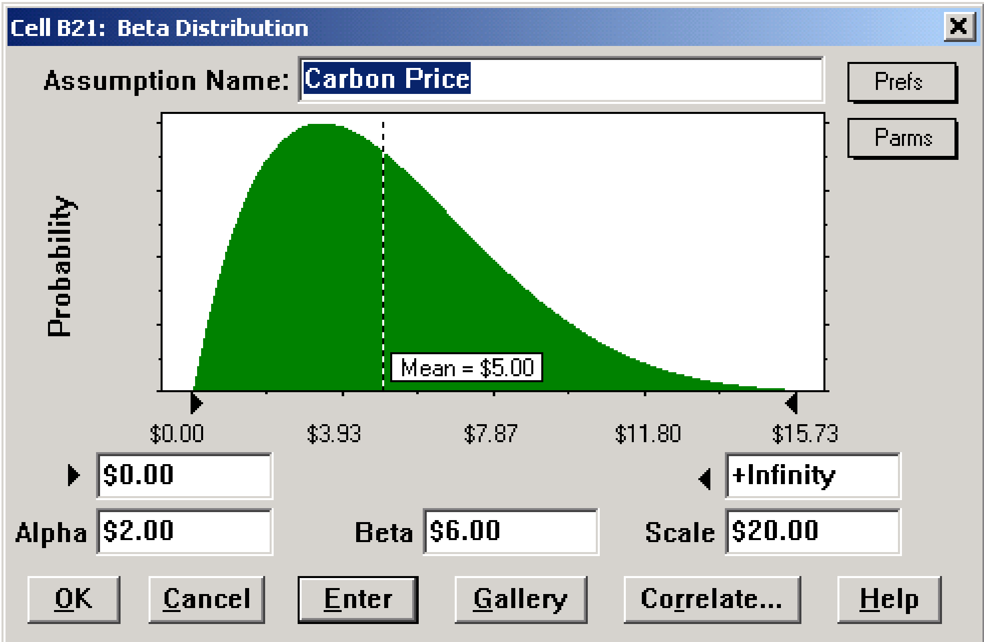

Figure 3-10 - Expected GHG Emissions Allowance Prices (\$/ton CO_2e) (Illustrative Only)

To incorporate the probability distribution shown in Figure 3-10 into a computer simulation model, GHG-CAM uses Monte Carlo simulation which calculates numerous scenarios of a model by repeatedly choosing values from the probability distribution used to define the uncertain variables, and then it uses those values for whatever additional calculations are dependent upon that value in the model.

In contrast to *deterministic* modeling approaches that yield a single answer, a *stochastic* analysis provides the model user with output that reflects the underlying uncertainty in key model variables. A Monte Carlo simulation typically produces investment value estimates in the form of a statistical distribution, or histogram[20]. This type of statistical output provides the model user with a range of values that represent the expected change in after-tax gross margin for a specific GHG abatement project. This is a key input for calculating its cost-effectiveness. It is represented by the "levelized cost" of GHG emissions abatement associated with the proposed GHG abatement strategy and a probability estimate of the likelihood that any particular value in the range will be realized.

Whether or not to fund GHG abatement projects, or continue funding them is management's option. The *real options* approach accounts for this value. For instance, the traditional net present value of a proposed project, like a heat rate improvement project on a coal-fired power plant, often does not capture the financial value derived from the "real" options that corporate management has to delay, expand or abandon the proposed project. In effect, management "owns" a *Call Option* that provides the firm with the right but not the obligation to delay, expand, or abandon the proposed project. The "exercise cost" for this option can be considered to be the present value of the capital costs the company would bear to implement any one of the selected strategies – delay, expand or abandon the proposed project.

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[20] See examples of this type of visualization in Section 4.

In 1973, Fisher Black and Myron Scholes published a relatively simple formula to estimate the general equilibrium price of a stock option. Since this seminal work was published, attention increasingly has turned towards using option pricing theory to value options on real assets, including natural resources. These same real options concepts are directly applicable to the strategic decisions faced by companies as they consider the economically optimal time and conditions to make capital investments to reduce their GHG emissions.

EPRI 1012577 compares these three approaches for a proposed biomass facility. The cost-effectiveness of this project depends somewhat on which analysis perspective is used. From the stochastic analysis perspective, the proposed biomass project can be expected to yield 3.5 million tons of CO_2 ($mtCO_2$) emissions reductions on an undiscounted basis, and 1.6 $mtCO_2$ on a discounted basis over the life of the project, as shown in Table 3-2. As shown, this biomass project also can be expected to increase after-tax net income by $15.2 million.

Table 3-2 - Summary Analytic Results for a New Biomass Power Plant

	Deterministic		Stochastic		Real Options
Includes CO_2 Forward Price?	No	Yes	No	Yes	Yes
Change in PV Gross Margin (After-Tax) ($ million)	(3.5)	15.2	(3.7)	15.2	16.5
GHG Emissions Reductions (million tons CO_2e over Project Life)	3.5	3.5	3.5	3.5	2.6
PV GHG Emissions Reductions (million tons CO_2e over Project Life)	1.6	1.6	1.6	1.6	1.1

We see that, from the perspective of real options, the analysis results are different from those obtained using the other analysis approaches. First, there is only about an 80 percent probability that the company would actually exercise its real option and build the new dedicated biomass power generation facility. In contrast, the discounted cash flow analysis used in both the deterministic and stochastic approaches assumes the company exercises the option 100% of the time in Year 1 and builds the new dedicated biomass plant. This difference has important ramifications for both the cost-effectiveness of the proposed project and also the expected quantity of GHG emissions reductions it may yield.

As shown in Table 3-2, the real options approach estimates that the biomass facility will yield an expected 2.6 $mtCO_2$ over the life of the project on an undiscounted basis, and only 1.11 $mtCO_2$ discounted. Clearly, these expected GHG emissions reductions are significantly less than are expected based on the stochastic analytic framework. The reason for this large difference is the 80 percent probability that the real option will be exercised sometime during the period of years

1-5 of the project, rather than 100% chance of building in Year 1 as is the case in the deterministic and stochastic analysis frameworks.

The cost-effectiveness of the example biomass project improves a bit when viewed through the lens of real options analysis as compared to stochastic analysis. As shown, this project has the potential to increase an electric company's after-tax net income by $16.5 million in the real options analysis as compared to $15.2 million in the stochastic analysis.

This comparison between the stochastic and real options analyses illustrates an important tradeoff for companies to consider. On the one hand, the stochastic approach provides greater up-front certainty about the quantity of GHG emissions reductions the company can expect to generate over the life of the project because this method implicitly assumes the project will be implemented in Year 1 and operate throughout the full 20 year time horizon. On the other hand, the real options approach does not assume the project will automatically be implemented in Year 1, but rather that the company has the *option* to choose the best time and market conditions under which to implement the project. This *optionality* improves the cost-effectiveness of the proposed project.

Table 3-2 points out a few important items about analysis assumptions. The reader can see that the most important factors in the analysis are whether a CO_2e forward price curve is used and whether CO_2 emissions are discounted over the life of the plant. The important lesion to be derived form this point is that if different assumptions are used for different projects, the wrong project prioritization and long range planning result will almost certainly occur.

Table 3-2 also shows that while the real options approach improves the cost-effectiveness of the proposed biomass power plant, the difference is less than ten percent. One would expect the difference would be even less for a typical nuclear plant project because the shorter timeframe over which the option could be exercised for would reduce the optionality inherent in such a project.

In EPRI report 1013296, the impact of market factors on generation investments was evaluated. For utility investors and planners committing to new coal generation, the question is whether the opportunities afforded by high gas prices offset the potential risk of a climate policy that imposes a substantial price on CO_2 emissions. A price on CO_2 will raise generation costs, but the rise in generation costs will increase power prices as well.

Since gas- or coal-fired electric plants usually set the market price, higher dispatch costs will, in turn, lead to higher bids into the power market, and higher bids will mean higher wholesale prices for power. From a generator's cash flow perspective, what matters is the increase in market prices vis-à-vis the increase in dispatch costs for these units. The net revenues to any individual generating unit will depend on the net balance of the cost impacts for its own operation against the revenue impacts from the higher market prices.

To address this question EPRI built a conceptual framework to assess the effects of CO_2 policy and natural gas prices on the economics of IGCC generation over an annual operating cycle. While providing a powerful approach to understanding the impact of climate policy through a market in any given year, the framework also provides an analytically-consistent approach for evaluating risk and opportunity over time as climate policy evolves, fuel prices change, and the mix of generation changes to reflect new economic incentives and the availability of advanced generation technologies.

EPRI 1013296 shows how the single-year conceptual framework analysis can be extended to support multi-year analysis of investment decisions. While within a year the examples show a CO_2 price leading to only a modest decline in fossil generator cash flows, net revenues drops much more if and when large quantities of low- or non-emitting generation are added to the region.

Results from the conceptual framework indicate that additions of new generation will have the greatest impact on the highest cost plants (including CO_2 charges). Initially, the highest cost plants are gas fired, but once over 20,000 MW of new non-emitting capacity has been added (consistent with a CO_2 price of about $15/ton) new capacity begins to impact the dispatch of the coal plants in addition to their hourly net revenues. CO_2 emissions drop more rapidly as CO_2 price rises until the CO_2 price reaches $33/ton and non-emitting capacity additions exceed 50% of the legacy generating capacity.

We drew the above excerpts from EPRI 1013296 to illustrate a point about project prioritization and long range planning. These analyses would seem to indicate that the value of projects that increase generation capability can depend significantly on market effects and whether or not the analysis window includes multiple years. In this way, a utility's strategic plan for future generation capacity additions can influence the value of an overall generation asset. As we illustrated in the earlier generation case studies, the value of the asset can, in turn, influence the value of a project.

Because there are many assumptions inherent in these analyses, the interested nuclear asset manager should refer directly to these reports and their associated case studies. The nuclear asset manager also may wish to consult with peers at their utility who are participants in these EPRI programs and who may have applied these techniques internally in their own case studies.

3.3 Information Technology

Corporations, including electric utilities, have placed significant attention on managing their investments in information technology. Information Technology Asset Management (ITAM) or Information Technology Portfolio Management (ITPM) are the more common names used for the process of prioritizing and planning for IT investments. This business is a popular service offering for the major consulting firms, many of which offer their own methods and information about the prioritization techniques which are restricted due to their proprietary nature.

To gather information about this "industry", we reviewed a number of publicly available sources[21,22,23,24,25]. For the most part, prioritization techniques were very similar to the techniques

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[21] *Beyond the Business Case: New Approaches to IT Investment*, Jeanne W. Ross & Cynthia M. Beath, MIT Sloan Management Review, Winter 2002.

[22] *Best Practices in IT Portfolio Management*, Mark Jeffery and Ingmar Leliveld, MIT Sloan Management Review, Spring 2004.

[23] *Commonwealth of Virginia Balanced Scorecard Decision Criteria for Proposed Information Technology Investments* (author unknown) and *Improving IT Investment Management In The Commonwealth* (of Virginia), ITIM Customer Council Status & Recommendations, Jerry Simonoff, Director, IT Investment & Enterprise Solutions, January 17, 2008, both available from the VITA website.

[24] *Information Technology: A Framework for Assessing and Improving Enterprise Architecture Management (Version 1.1)*, US General Accounting Office, Executive Guide, April 2003.

we have explored elsewhere in this report. For example, one popular approach is to adopt the Balanced Scorecard method[26] to information technology.[27] Other examples include mention of peer review of prioritization values, importance of organizational aspects of the methodologies, consideration of a range of different types of costs (e.g., indirect costs), evaluation of risk, and more. In this regard, we recommend reading *Best Practices in IT Portfolio Management*, Mark Jeffery and Ingmar Leliveld, MIT Sloan Management Review, Spring 2004, which has one of the better summaries of the issues involved and includes a maturity model for assessing one's ITPM capabilities.

Having pointed out the common lessons learned, it is appropriate to note that one of the more critical aspects of ITAM is improved business-strategy alignment. This issue is critical to IT because of its pervasive nature in the business process. Unfortunately, there were no silver bullets to describe techniques to make this happen. For the most part it would seem that overcoming institutional barriers between technical experts (IT and the CIO) and corporate and business leaders was a critical lesson learned for the more successful efforts. Often the most strategic investments, ones that might transform an IT infrastructure, were funded directly from the CEO, i.e., not out of an IT or line organization budget.

One other thing was relatively clear; IT investments were evaluated separately from other investments, at least as far as prioritization techniques are concerned. The reader will recall that in the second nuclear case study, the PRC, or the highest authority short of the executive, was responsible for evaluating IT investments relative to the nuclear plant. Those investments were not subject to the IPP process, but were evaluated separately and directly by the committee. From reading the variety of ITAM and ITPM sources, this appears to be true in most, if not all, companies.

Nevertheless, the review did uncover one particularly interesting insight in the "Best Practices" paper mentioned earlier. This paper was based in part on 130 completed surveys of Fortune 1000 CIOs. The survey responses were used with the maturity model to classify companies according to four stages. A statistical link was found between return-on-asset performance and the highest level of performance. Hence the study of IT portfolio management would seem to indicate that, for information technology at least, those companies that adopt the types of structured / formal project prioritization processes, organization and technical skills described in this report have a strong likelihood of being the better business performers.

3.4 Transportation

The transportation industry has developed extensive, well-tested guidelines on asset management for the country's substantial investments in roadways and bridges. The interest in asset management implementation by state Departments of Transportation has been motivated by:

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[25] There are numerous other references. These four are merely representative. The MIT Sloan Management Review articles are recommended reading and can be downloaded from the HBR website.
[26] Kaplan, R. and Norton, D. "The balanced scorecard - measures that drive performance," *Harvard Business Review*. January-February 1992, pp. 71-79.
[27] *The Balanced Scorecard and IT Governance*, by Wim Van Grembergen, Ph.D., published by the Information Systems Control Journal.

- increasing emphasis over time (dating back to the 1980's or earlier) on the need to maintain infrastructure,
- emphasis on use of performance measures beginning with the passage of the Intermodal Surface Transportation Efficiency Act (ISTEA) legislation in 1991, and
- increasing interest in using information systems to improve management decision-making.

State transportation officials have been challenged to manage a wide range of assets while meeting public, agency, and legislative expectations. The American Association of State Highway and Transportation Officials (AASHTO) in 1998 adopted transportation asset management as a priority initiative. As a result the Transportation Asset Management Guide[28,29] was developed and published in 2002.

Additionally, the Governmental Accounting Standards Board (GASB) adopted new standards in Statement 34 that require periodic financial reporting of the value, condition, and level of expenditure related to the transportation infrastructure owned by state and local agencies. GASB allows agencies to use a modified approach employing the agency's asset management systems as the basis of reporting.

To develop the asset management maturity matrix in the Enterprise Asset Management program[30], EPRI reviewed and identified applicable criteria from many sources. One of the most useful sources for this effort was the Transportation Asset Management Guide.

The Guide is a valuable resource for asset managers. Section 6 covers prioritization and long range planning. This eighteen page section constitutes more than a guidance document, but less than a procedure. The Guide places strong emphasis on ensuring investments are consistent with the policies and plans of the public, agency and legislative expectations. The Guide is very consistent in emphasizing process improvement and assurance methods with the intention of ensuring that asset management initiatives successfully follow through, for example, we quote from the Guide as follows:

> "Asset management entails the translation of policies and plans into cost-effective investment strategies, and the translation of investment strategies into cost-effective program delivery. The essence of asset management involves a combination of resource allocation decisions and program delivery strategies that reflect policy-driven criteria and the resources available."

The Guide's best practices for project prioritization and long range planning include (again quoted from the Guide):

- "Methods, formulas, and criteria to prioritize projects reflect stated policy objectives and performance measures and targets."
- "Projects are evaluated in terms of realistic estimates of lifecycle costs, benefits, and performance impacts."

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[28] Transportation Asset Management Guide - Final Report. Prepared by Cambridge Systematics, Inc. for the National Cooperative Highway Research Program (NCHRP) Project 20-24(11)

[29] William Robert of Cambridge Systematics, Inc. provided words and insight that helped in the writing of this subsection.

[30] Table 2-1 in *Information Technology for Enterprise Asset Management, An Assessment Guide,* 1012527, EPRI, Palo Alto, CA: 2007.

- "Program[s are] based to the degree possible on objective information, supported by sound analytical procedures."
- "Information from condition surveys and management systems directly informs the process that builds the recommended program and budget."

The Guide also encourages tradeoff analyses to consider alternative resource allocations at a program level. These tradeoff analyses are considered a complementary analysis to project-to-project evaluations that result from project prioritization. The analysis involves testing the consequences of shifting funding from one program to another, and making a judgment as to which resource allocation option is the most favorable. For the analysis to work, value (and performance) must be able to be estimated at both the program and project level.

Some of the more forward thinking states use performance measures to influence development of their transportation infrastructure capital plans. The idealized process is to establish a set of performance measures and targets that are consistent with agency goals and available funding. Next, the state will establish overall levels of funding by investment category (including system preservation), and then proceed with detailing the capital plan consistent with the budget levels set by category. A number of states have shifted money between capital improvements and system preservation on the basis of such approaches. Typically the shift is from adding lanes to existing roads to more resurfacing and reconstruction of pavement and / or to more bridge rehabilitation work.

The leading practitioners of Transportation Asset Management are the states of Florida, Oregon, Montana and Virginia. Case studies for these and other programs can be found on the Federal Highway Administration website[31]. Virginia also has a dashboard[32] that displays performance measures on projects and programs that is available for viewing by members of the public.

With the abovementioned exception of tradeoff analysis, the specific insights from the transportation industry are well represented by the Transportation Asset Management Guide and that guide is well represented by the guidance contained in the Enterprise Asset Management program. As mentioned above, the state DOTs also provide good examples of linking capital investment to performance indicators. As we have seen in the transmission and distribution industry, this experience is growing within the utility industry as well.

3.5 Pharmaceutical Industry Insights

The following pharmaceuticals case study was developed based on a presentation provided to this project by Strategic Decisions Group[33]. This case study reports on the progress of a large pharmaceuticals company in improving its resource allocation decision-making[34].

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[31] http://www.fhwa.dot.gov/infrastructure/asstmgmt/index.cfm
[32] http://dashboard.virginiadot.org/
[33] Strategic Decisions Group is the author of one of the Enterprise Asset Management reports that we draw from in Section 4, namely "*Program on Technology Innovation: Enterprise Asset Management – Executive Primer*", 1015385, EPRI, Palo Alto, CA: 2007.
[34] The presentation "Optimal Resource Allocation: The Third Generation of Portfolio Management," November 19, 2003, which can be downloaded from the SDG website, provides many insights and details.

The pharmaceuticals company, like many electric utilities, had tried many different approaches to project prioritization. When various levels of management made the investment decisions, they learned that no one manager had a complete knowledge of all aspects of the relevant issues, that their decisions lacked organizational buy-in, or that championing and posturing by well-intentioned advocates undermined belief in the results. Recommendations from outside experts or decisions made via "democracy", i.e., prioritizing by voting, also suffered from lack of credibility and organizational buy-in. When they tried multi-attribute prioritization or sophisticated modeling such as options analysis, they felt that they often added sophistication without adding quality and they tended to lose transparency in the valuation process.

Like many other companies that have tried a wide variety of prioritization approaches, the pharmaceutical company's experiences taught them that they needed to find an approach that solved both the organizational and the technical issues. They started with what they felt they needed to improve most, namely a better process for generating alternatives. To improve this process, they began with a simple step – requiring a consistent set of alternatives be developed for all projects. They required each proposed project to develop at least four alternatives:

- The existing base case
- An alternative with a reduction in costs
- An alternative using more expenditures
- An exit strategy for the project that preserves the benefits generated to date

They found that forcing this type of thinking into the process generally led to a consensus feeling among project members that the best alternatives had been identified. In practice, one or more other alternatives in addition to the minimum set often also were developed.

Besides having a greater set of options from which to choose, they achieved a few important and immediate process improvements. First, their thinking on one project often could be applied to other projects. Second, some of the projects that previously would have been rejected, ended up in identifying alternatives that were funded at a later date. Third, the process helped to identify the most critical steps in the proposed project's development, which in turn improved the project's implementation plans.

When the company created portfolios from the resulting alternatives, they found that they dramatically improved their shareholder value for the same investment. Figure 3-11 illustrates three ways that shareholder value was increased by the new process. The figure employs an efficient frontier visualization (see Section 4 for more discussion of this display). First, the best portfolio with the same budget results in a thirty percent increase in shareholder value, of $2 billion. Second, the same portfolio had roughly three times higher marginal investment productivity (i.e., shareholder value divided by expected investment for the last project funded with the budget constraint). Third, if they increased their investment, they could generate an additional $0.6 billion in shareholder value.

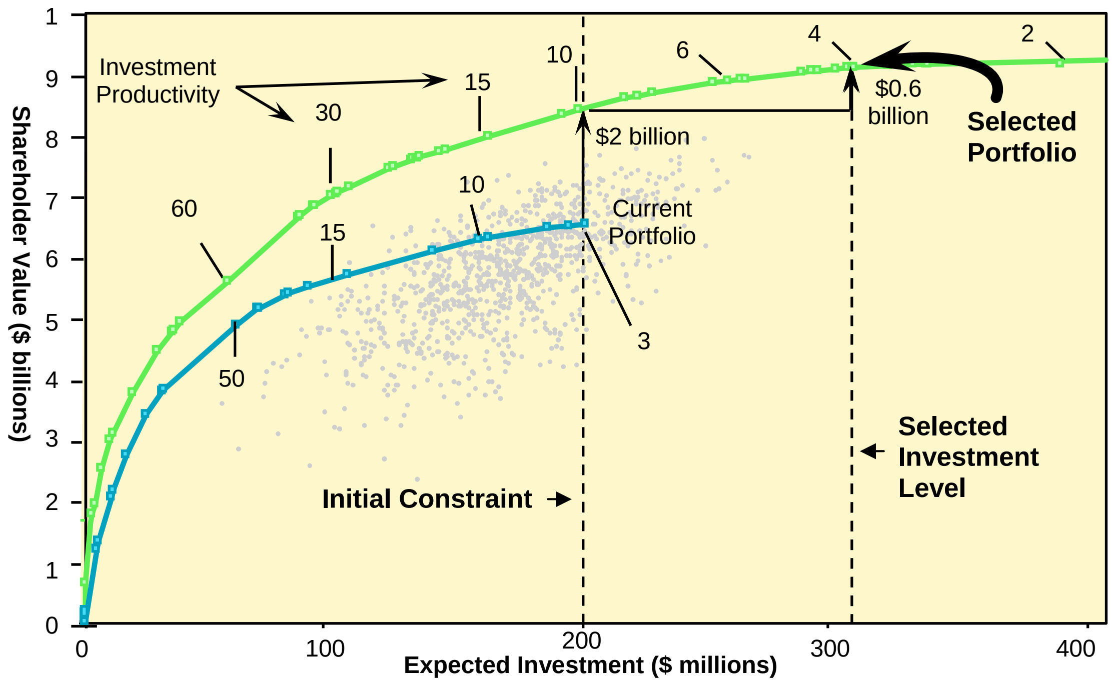

Figure 3-11 - Portfolio Shareholder Value versus Investment

Because of their past experiences, ensuring credibility in the process was a critical measure of success. Thus, the company developed rules to ensure consistent, reliable and well-documented information for each project and alternative. Their rules addressed internal peer review and validation against external sources. Lastly, the company insisted on sensitivity studies for variables common to many projects.

In the end, the company also believed that how they managed the implementation of the new methodology was important to obtaining organizational buy-in and process credibility. Some of these items included initial testing of the method, performance of a gap analysis to compare the new process with the current approach and development / implementation of training to ensure proper integration with related business processes.

3.6 Asset Management Standard PAS 55

PAS-55 is an international standard for optimal management of physical assets (originally published in May 2004 with recent revision in October 2008). The Office of Gas and Electricity Markets (Ofgem), the regulator of electric and gas utilities in the United Kingdom, sees the utility infrastructure as an "increasingly demanding and high profile responsibility" and that "Asset Risk Management is therefore a key function". Ofgem has stated that all UK electric and gas utilities should be PAS 55 certified by 2008. Certification generally involves an independent audit.

PAS 55's development was sponsored by the Institute of Asset Management (IAM)[35]. Its development included participation from industry, regulators and asset management specialists. The standard includes twenty one requirements that can be used to provide evidence of competence in asset management. PAS 55's focus is on physical infrastructure assets and it places particular emphasis on continuous improvement.

While the standard is used primarily in the UK (and increasingly in the rest of continental Europe), National Grid has adopted it for their US operations. The Long Island Power Authority (LIPA) is another US electric utility company that has begun a PAS 55 certification process (National Grid serves as LIPA's asset manager).

While PAS 55 does not provide specifications for project prioritization, it is nevertheless worth mentioning because of its increasing international influence on asset management processes. For example, PAS 55 requires an organization to establish and maintain asset management plans which would include capital and maintenance among other items. PAS 55 also requires the plans to be optimized and prioritized with effective and efficient delivery plans.

The emphasis on continuous improvement makes these plans subject to performance monitoring and auditing. Therefore, it is expected that PAS 55 compliance would include establishing performance criteria by which to measure funded projects as well as audits of the effectiveness of projects in meeting their objectives. In previous case studies we have seen one such example of how a transmission and distribution utility audits its projects and their associated performance.

At this point, there is no indication that PAS 55 will be adopted by US regulators. However, as this standard gains acceptance, it will be important for companies with international operations to take note of it. PAS 55 compliance efforts in the UK also may provide useful case study information in the future as the number of assessments and audits lead to insights about UK utility asset management programs.

The discussion of PAS 55 closes our review of asset management outside of the nuclear generation industry. In the next Section, we look at insights for project prioritization and long range planning that were developed as part of EPRI's Enterprise Asset Management program

[35] See www.iam-uk.org to purchase PAS 55 or obtain further information on the standard and on developments in asset management practices at its member organizations.

4

PROJECT PRIORITIZATION GUIDANCE FROM EPRI'S ENTERPRISE ASSET MANAGEMENT PROGRAM

EPRI initiated an Enterprise Asset Management program in 2007. While this program was subsequently sunset, it produced two reports which provide useful information for project prioritization:

Information Technology for Enterprise Asset Management, An Assessment Guide, 1012527, EPRI, Palo Alto, CA: 2007.

Program on Technology Innovation: Enterprise Asset Management – Executive Primer, 1015385, EPRI, Palo Alto, CA: 2007.

These two reports can be downloaded from the EPRI website by any EPRI member.

This section provides selected excerpts from these reports regarding the following topics:

Project Prioritization Process Improvement

- Self-Assessing Using a Maturity Index Approach
- Improving Decision Quality in Project Prioritization
- Conducting Peer Reviews of Projects
- Selecting Project Prioritization Software Tools

Guidance on Selected Project Prioritization Techniques

- Using Screening Analysis
- Evaluating "Mandatory" Projects
- Creating a Corporate Value Model
- Evaluating Projects Using a Value Model
- Two Important Considerations in Using Value-to-Cost Measures
- Visualizing Project Value and Risks

4.1 Project Prioritization Process Improvement

Both EPRI 1012527 and EPRI 1015385 identify opportunities for process improvement in project prioritization. The following excerpts from the reports provide guidance in four specific areas of process improvement.

4.1.1 Self-Assessing Using a Maturity Index Approach

EPRI 1012527 developed a self-assessment process for enterprise asset management. The maturity index includes five levels of maturity: reacting, awakening, organizing, processing and continuously improving. Criteria are provided for each level of maturity, organized by twelve technical disciplines, one of which is project prioritization.

In this subsection, we excerpt from Section 2 of EPRI 1012527 which discusses project prioritization and provides questions to guide a self-assessment and determine the maturity level of a project prioritization program. The questions are provided in Table 4-1 at the end of this subsection.

Effective project prioritization processes and tools are one of the most important indicators of a mature asset management program. As the maturity of a project prioritization process increases, regulatory projects are evaluated more critically. The temptation to gold plate a "mandatory project" often overwhelms the organization that can be classified as one that is reacting or awakening. As an organization advances in this maturity model, projects evaluation becomes more precise and they are broken into smaller parts with a variety of alternatives. Thus, it becomes easier for the organization to increase the sophistication of the investment analysis methods and supporting tools. Developing alternatives is important to creating value for the company, but it is even more important that these alternatives are considered throughout the evaluation process so the best portfolio can be generated (see for example the Pharmaceuticals case study in Section 3).

Another characteristic of a maturing asset management program is the increasing precision of long-range plans. Long range plans help avoid surprises in increased expenditures and reduced levels of service because of the need to replace large assets. They also provide a repository for unfunded projects which may be good investments in future years. Because of the long lifetime of nuclear power plant assets, long range plans also provide a framework to monitor changes in technology and to create a vision for its future incorporation. In a mature asset management organization, long-range plans also include contingency plans for dealing with uncertainties.

Lastly, as companies mature, their focus on capital begins to extend to O&M. The extension first appears in large, infrequently scheduled O&M activities, like major overhauls or refurbishments. Since these do not necessarily occur in a levelized manner, it is inefficient to include them in a routine maintenance budget. Often O&M budgets are the same as, or a percentage different, from prior years. Said another way, they are not strictly based on need. But employees are less fungible than capital so often there is logic to small swings in O&M budgets. Companies with the flexibility to move people from O&M projects to capital projects, from one large asset to another or even from one department to another will have the greatest capability to take full advantage of asset management techniques. In a mature asset management organization, capital costs trade-off against O&M costs in a lifecycle cost analysis.

The following provides the Maturity Index Table for project prioritization. The interested reader may also wish to examine the criteria contained in Table 2-1 of EPRI 1012527 for General Decision Support Capability and for Risk Management.

Table 4-1 - Maturity Index Table for Project Prioritization

Reacting	Awakening	Organizing	Processing	Continuously Improving
Regulatory requirements dominate capital investment decisions for existing major assets. O&M budgets are based primarily on prior year spending.	A process for evaluating capital investments exists, but the resulting investments are still strongly influenced by management preferences.	A robust ranking process emerges for capital investment. Large O&M expenditures are separated from O&M budgets and ranked. A robust set of alternatives are generated as projects are defined.	The strategic planning, project prioritization, and budgeting processes are well integrated, and decision support tools are used throughout. Long-range plans for capital investment are developed and comprised of individual projects. Alternatives are considered throughout the decision process. Project cost and performance are measured and compared against original estimates. Lifecycle costing is used to trade off capital and O&M expenses. All major assets and asset types have long range plans.	Investment risks and returns are evaluated and balanced. O&M budgets are increasingly flexible in responding to changes in investment strategy. The hidden costs, risks, and benefits of new technology are well understood. Optimization techniques are employed in determining the project investment portfolio, including the selection of alternatives.

4.1.2 Improving Decision Quality in Project Prioritization

EPRI 1015385 describes how improving decision quality can improve project prioritization. We excerpt from Section 4 of that report which suggests a self-assessment of the decision quality of the project prioritization effort provides a useful starting point.

Decision quality can be used to clarify how the project prioritization process needs to be improved, to reveal where additional work is needed to complete the budget, and to build consensus on the rationale for every resource investment. Having key participants assess decision quality (on a scale from 0 to 100 percent) in each dimension of quality indicates where further work is needed.

The following are dimensions of decision quality that should be evaluated:

Appropriate Decision Frame

- Develop a clear understanding of how the asset provides value.
- Invest only in assets that will be valuable in a competitive market.
- Develop collaboration among key contributors; avoid adversarial and advocacy-based processes.

Creative, Doable Alternatives

- Encourage staff to look at a broader, more creative range of options.
- Make use of industry experts and experience.
- Quickly identify alternatives likely to be valuable.

Commitment to Action

- Get the right people informed and involved early in the process.
- Get senior management's understanding and support early in the process.
- Build buy-in and avoid second-guessing.

Meaningful, Reliable Information

- Identify what information is important.
- Validate assessments - what's possible from broad experience.
- Obtain and calibrate the best expertise through "peer reviews".

Clear Values and Tradeoffs

- Focus on the value created by achieving operating performance goals.
- Focus on value to customers and shareholders.

Clear Value Translation

- Develop a clear "line of sight" from investment decisions to value creation.
- Develop effective ways to communicate recommendations and decisions.
- Capture all sources of value and risk in logical model linking alternatives and information to value creation.

4.1.3 Conducting Peer Reviews of Projects

EPRI 1015385 suggests that a utility can improve its project prioritization process by conducting peer reviews of projects. In one of the case studies presented in Section 2, we have seen how one fleet operator uses the TRB to conduct such peer reviews. Here we excerpt from Section 4 of EPRI 1015385 which describes the purpose and benefits of project peer reviews as well as offering the suggestion of cross-business unit peer reviews.

Peer review of project assessments provides an effective means of identifying overly aggressive or conservative assessments; it also helps to ensure that quality information is developed for use in the evaluation phase. It is more difficult to game the system knowing that information will be scrutinized by peers. To set the right tone, emphasis is placed on the quality of inputs. Because this is not a decision meeting, any attempt at an advocacy-based argument gets defused. The purpose of the peer review is to:

- ensure that assessments of individual projects are reasonable and are based on comparable assumptions;
- share knowledge among company experts and identify better approaches to enhance projects;
- test that results match the information and, if this is not the case, learn more about the unexpected situation and adapt appropriately.

The benefits of peer review include:

- increasing the quality of information included in the decision basis;
- ensuring consistency between project analyses and assumptions;
- increasing understanding and buy-in to the resource allocation plans;
- building trust;
- creating management awareness that the "best available judgment" has been used to develop the best portfolio.

Cross-business peer reviews of the integrated portfolio are especially important to:

- ensure quality and fairness at the enterprise level;
- develop investment alternatives that increase overall enterprise value and address significant issues and tradeoffs;
- foster greater appreciation of value creation in other business units;
- encourage managers to look at the enterprise as a portfolio of value creating investments.

4.1.4 Selecting Project Prioritization Software Tools

Project prioritization requires enough data processing and calculations to warrant automation. Currently, many organizations use spreadsheet based techniques. However, as the decision process becomes more sophisticated, a utility might want to consider selecting a commercial application for project prioritization. EPRI 1012527 developed a set of criteria for evaluating project prioritization tools. The discussion from Section 4 of that report is repeated here.

The following are key capabilities of project prioritization and investment tools:

- Supports creation of a corporate value model, including the following:
  - supports qualitative and quantitative approaches
  - includes value attributes, scales and weights
    - values can be represented hierarchically
    - scales may be non-linear and also qualitative

        - weights can be developed by comparison of projects with different attributes and not just by top level specification

    - specifies uncertainty / risk information

    - develops a "user guide" for project originators to input their projects

- Supports project definition

    - specifies all values and scales for any project

    - includes life cycle value and cost estimates

    - specifies a variety of alternatives, including mutually exclusive and contingent alternatives

    - specifies job done and job not done values

    - supports input of uncertainty / risk information

- Supports optimization and portfolio selection

    - selects a portfolio given a constraint (budget at a minimum and preferably other constraints)

    - selects the best alternative for a portfolio

    - evaluates project deferral as an alternative

- Supports a variety of visualizations for management and project originators for the purposes of reviews and intermediate and final approvals.

An increasing number of commercial products can be found with all or many of these capabilities. Alternatively, some utilities have had success developing custom spreadsheets to perform the calculations for evaluating and prioritizing investments. Although such spreadsheets do not have the full capabilities mentioned above, they can be sufficient (but possibly cumbersome) even for a company with a well developed project prioritization capability.

But the real challenge for project prioritization information technology is the amount of pertinent information that needs to be retained, managed and exposed to decision makers and reviewers. If the associated business processes are well documented and described, it is possible that the company IT group can develop capability to help manage the information. For example, data mining tools might be used to gather information that would determine or validate cost estimates and potential benefits. Portals might be created to provide access to projects, alternatives and their analysis of value. Otherwise it is better to focus on documenting the business process and improving it, then looking for information technology that can aid the analysis and more clearly communicate the results and their bases.

To conclude, the following steps should be considered when building or acquiring and when implementing software capability for project prioritization and investment:

- Develop a good understanding of the investment process (explicit and implicit) before focusing on acquiring any project prioritization tool.
- Select a tool for assisting in the project investment analyses. Choose a tool that is either technologically simple, e.g., Excel, or one that has the capability to grow in analysis sophistication. The criteria above are a good guide.
- Build a documentation process around the tool to ensure that the basis for the input, models and decisions is clear and reproducible during the budget cycle.

In the next subsection, the report describes a variety of ways that project prioritization information can be visualized.

4.2 Guidance on Selected Project Prioritization Techniques

Both EPRI 1012527 and EPRI 1015385 provide guidance on selected project prioritization techniques. The following excerpts from the reports provide guidance on seven specific aspects of project prioritization techniques.

4.2.1 Using Screening Analysis

Screening is the process by which an asset management decision is analyzed at a level of detail commensurate with the result and its importance. A company with a mature project prioritization process recognizes that a detailed analysis of all asset management decisions is counterproductive. The ERWG guidance described previously suggests that a screening process should evaluate the same core attributes throughout to ensure that outcomes of the screening process are compatible with the full prioritization process. The following approach from Section 4 of EPRI 1012527 is consistent with that guidance.

EPRI research across the full spectrum of electric utility operations has found that the project prioritization process can be applied with three levels of increasing complexity, thereby conserving analysis resources. A process much like this has been applied at a US utility for some years and the recommendations include lessons learned from that implementation.

Many potential investments are not effective and can be analyzed and eliminated from consideration rather quickly. Basically, the three level screening approach uses the same overall analysis thought process in each level. The principal changes in analysis are the increasing degrees of sophistication for inputs and / or for the calculational approach. Using a three level screening process, a project that "fails" in either of the first two levels is screened out and the proposed action is not taken or not funded. Projects that "pass" warrant the most detailed analysis, a level which in this example addresses uncertainty explicitly.

This simple screening process can be made slightly more sophisticated. First, if the second level of analysis shows that the project is a clear winner regardless of uncertainty, no further analysis may be needed and the third level of analysis can be avoided. Instead of avoiding uncertainty analysis completely, its analysis might be made simpler by focusing on how to reduce it or exploit its option value. Another process improvement is to send a screened project back to its sponsors for improvement. The screening analysis will help expose a project's faults and the sponsors might develop alternatives that represent better investments.

Next we look at the three levels of analysis in further detail (see Table 4-2). The level 1 analysis bounds benefits and operating costs, determining whether a proposed change is profitable under the most optimistic conditions. The method / tool determines the most optimistic effect of the proposed investment on reducing the present value of operating costs and increasing the present value of revenues. As an example, optimism in performance might be reflected by assuming an asset's reliability could be improved to perfection. The resulting benefit is then divided by an optimistically low estimate of project cost (i.e., the investment). The project is screened out (or revamped) if this benefit-to-cost ratio is not significantly greater than a certain "hurdle" value. If the project is not screened out by this criterion, a level 2 analysis is performed.

Level 2 analysis employs "best estimate" assumptions of expected improvement effects for the investment. This provides a "realistic" forecast of profitability, operating cost, and project cost, recognizing that either an optimistic or pessimistic forecast can lead to a wrong decision. If the point-value benefit-to-cost ratio is significantly less than one, the project is rejected (or revamped). If the benefit-to-cost ratio is significantly greater than one, the project is selected. In this case, further probabilistic analysis in level 3 would not be warranted unless a portfolio evaluation considering uncertainty and optionality is desired. A level 3 analysis should be performed if the level 2 point value analysis predicted a benefit-to-cost ratio near or somewhat greater than one. An uncertainty analysis would alert the decision maker to the risk of a failed project and the potential sources of that risk.

A level 3 analysis is a detailed analysis of the distributions of the benefit, costs, and profitability of the project and assists in facilitating risk management. The first step in a level 3 uncertainty analysis might be to perform a sensitivity analysis using the level 2 model to examine the effect on project profitability of varying one parameter at a time to its high and low values (or by plus and minus some predefined fraction, e.g. ten percent, of its best estimate). Results may be displayed in a conventional "tornado diagram". The two or more parameters that produce the widest range of variation in profitability (NPV change or benefit-to-investment ratio) are identified as "decision drivers."

In the level 3 analysis, these drivers then would be treated as uncertain parameters with estimated probability distributions used as inputs to a random sampling stochastic analysis of profitability, (with non-driver parameters kept at their best-estimate values.) Examination of the resulting probability or cumulative probability distributions of profitability allows the owner / investor to select projects that either minimize the risk of a loss or maximize the chances of high returns. In a portfolio analysis, the distribution of profitability results allows an efficient frontier to be used in selecting projects for investment. Section 5 of EPRI 1012527 and Section 4 of EPRI 1015385 discuss risk management techniques. Later in this subsection, we describe different ways to display the results of level 3 analysis.

Table 4-2 - Characteristics of a Three-Level Screening Analysis

	Level 1	**Level 2**	**Level 3**
Main feature	"An optimistic assessment to rapidly reject clear losers"	"A realistic point value assessment to reject clear losers and accept clear winners"	"An uncertainty analysis to quantify up- and down-side risks for decision makers"
Inputs	Optimistic Point Values	Realistic Point Values	Expert judgment probability distributions for parameters that drive the decision
Models	Simple	More sophisticated	Most sophisticated
Main Outputs	Optimistic Point Value	Best-estimate Point Value (sensitivity studies can provide point estimates of high / low what-ifs)	Risk profiles = uncertainty distributions and risk measures (such as confidence intervals, probability of regret)
Decision	Reject if BOI<1 Results can help revamp proposed project	Accept project if very beneficial (e.g. BOI>2) Reject project if very bad (e.g. BOI<0.8) Otherwise, perform level 3 analysis Results can help revamp proposed project	Decision based on quantitative estimates of risk Results can help revamp proposed project

This three-level approach ensures that the cost of more sophisticated and accurate risk-informed project evaluation is incurred only when there is a benefit in performing the asset management analysis. The factor that often determines the level of overall sophistication that is cost effective is the project size, which can be characterized by investment cost. In general, only very large projects that cost on the order of millions of dollars warrant a complete probabilistic level 3 analysis. For intermediate-sized projects costing tens or hundreds of thousand dollars, a level 2 point-value analysis likely would suffice. It is reasonable to assume that only large and intermediate-sized projects would be evaluated with the more sophisticated decision support tools. Table 4-2 summarizes the characteristics of the three analysis levels.

Another important factor in deciding the level of analyses employed in asset management decisions is the maturity of the asset management program. This report anticipates that only companies with more mature project prioritization processes and capabilities would employ risk analyses of the type described here. A significant education process may be required for management and business analysis staff to facilitate meaningful interpretation of the results obtained from application of these methods. However, as more and more managers are trained in the principals and details of financial analysis techniques, there will be more and more receptivity to the use of similar techniques for investments in the electric utility infrastructure. In the beginning, it may be appropriate to keep risk analyses at a more qualitative level, focusing on risk drivers and mitigating actions. An example of this kind is presented in the previous section, under the subsection entitled Risk Management Program at a Distribution Utility.

The challenge imposed by screening is not trivial. Different levels of analysis produce results with different levels of quality that cannot be compared directly and without qualification. If a screened project is returned to its sponsor, the action expected must be clear. If the sponsor submits an alternative, a process may need to be maintained to facilitate reanalysis. Changes in assumptions are often critical in such an iterative process; however experience has indicated that it is precisely this key information that can be lost. We are aware of no easy solution to the process and to date it has been managed manually in all prioritization approaches of which we are aware.

To conclude, the following steps should be considered when implementing a screening approach:

- Understand that screening is a complex business process, even if it does reduce the need for analysis resources.
- Think carefully about screening criteria and be sure that they are robust and defensible both with management decision-makers and process participants.
- Manage information flows, retaining screened items and their bases. Provide feedback to owners of screened investments so that they can see the benefit of the process and improve subsequent investment proposals.
- Document the lessons learned from the business process and information flow and be prepared to use them in future asset management applications.

4.2.2 Evaluating "Mandatory" Projects

EPRI 1015385 reports many utilities still allocate a large amount of capital and O&M dollars to projects that have been identified as "required" or "mandatory." The following excerpt from Section 4 of that report discusses techniques for improving the analysis of this type of project. We should note that the following thoughts about mandatory projects might tend to apply more to non-nuclear electrical utility business units. For nuclear plants, "mandatory projects" typically are considered those necessary to meet requirements specified by the nuclear regulator (e.g. the US Nuclear Regulatory Commission). In addition, nuclear business units similarly face requirements from other regulatory bodies (e.g. OSHA and EPA), as well as manufacturer and insurance recommendations, all of which can sometimes lead to "mandatory" projects for reasons not related to nuclear safety.

Maintaining a safe environment for employees and customers is a core value of all utilities. Projects required by law always get higher votes, but often we are hard pressed to identify under which law the projects are mandated. Is there a specific timetable for meeting legal requirements? When possible, delaying investment may prove beneficial (for example, the need to comply disappears when an asset is retired) and allows high value discretionary projects to be funded earlier.

Engineering standards and maintenance practices (such as turbine outages) generate a large fraction of "required" projects. These standards and practices are based on manufacturers' recommendations and engineering standards rather than on the value (or cost avoidance) they create. In a competitive environment, standards and practices should be reevaluated.

Projects that are legally required, projects that ensure safety, and projects undertaken for economic reasons are evaluated using different objectives. Projects and programs that satisfy legal requirements are evaluated based on which option meets requirements at the lowest expected cost over time. Projects required for safety are evaluated based on the lowest expected cost of ensuring an operating environment that minimizes worker and community exposure. Proposed projects that are truly mandatory should be removed from the process so attention can be focused on discretionary funding decisions.

4.2.3 Creating a Corporate Value Model

Both EPRI 1012527 and EPRI 1015385 provide guidance on identifying corporate value during project prioritization. Research done by EPRI and others[36] indicates that the corporate value model developed as part of an asset management program can be aligned with performance indicators. The result of such an alignment is an organizational "line of sight" from the stakeholders and the corporate office that lay out goals and objectives to the supervisors and personnel who propose and prioritize projects. In the previous section, we presented a case study from a transmission and distribution business unit in which projects were prioritized based on value and various portfolios of projects were evaluated in terms of their impact on reliability, the company's most critical performance indicator.

The purpose of a corporate value model is to quantify value, so that the value of various activities, such as capital investments, maintenance programs, and the like, can be measured and compared. Some kinds of value are readily measurable; for instance, the value of a kWh of electric production is simply its price. However, other kinds of value are more elusive; for example, what is the value of "reliable electric service or of a reduction in personnel radiation exposure?" Nevertheless, it is a fundamental principle of economics that value can be assigned to any tangible good or service.

In general, three difficulties arise in trying to assign value: precision, preference, and consensus. *Precision* means that one must describe precisely what one is trying to value. For example, what does "reliable electric service" mean precisely? Answering this question leads naturally to a breakdown of this attribute into various subattributes, such as "duration of outages" and "frequency of outages" and also to specifying the means of measuring them. *Preference* means that one must be able to distinguish different levels of value for a particular attribute. For

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[36] Ittner, Christopher D. and Larcker, David F., "Coming Up Short on Nonfinancial Performance Measurement", Harvard Business Review, November 2003. This paper reports on a study of 157 manufacturing and service companies use of value models. The report identifies significant performance improvements for the quartile of companies that use causal models that directly relate to value.

instance, clearly fewer outages are preferred to more outages, but how much more valuable are, say, two outages per year versus three? *Consensus* means that among any group of decision-makers, preferences are likely to vary in ways that usually cannot be resolved objectively; thus, to have a credible analytical method to guide decision-making, the relevant people must reach a consensus about the value model. These difficulties can be overcome using a systematic process for defining a value model.

The following set of characteristics represents objectives in the design of a corporate value model.[37]

Level playing field. The value model should allow fair evaluation of all activities. The only reason to undertake an activity is its contribution to achieving overall corporate objectives. No other characteristics should influence the choice of whether or not to do it. All activities are evaluated on the same basis, and the relevant people should be able to agree on the measurement of value provided by the activity.

Resolve differences of opinion rationally. The value model should provide a system for resolving differences of opinion as well as determining which differences matter. The value analysis of all activities should focus on the attributes that provide value, the corporate objectives, and the structure of the portfolio of activities.

Defensible logic for peer review. The value model should make it possible to explain in detail why a particular activity or portfolio of activities is undertaken. Reviews, like differences of opinion, should be based on attributes, objectives and portfolio structure.

Transparent analysis. Not only should the specification of all activities be clear, but the evaluation criteria should be readily apparent. It should be possible to explain why an activity has been undertaken. Further, it also should be possible to observe how changing the specification of an activity results in obtaining different evaluation / conclusion. The value model should attempt to eliminate all ambiguity regarding decisions whether or not to undertake a particular activity.

Completeness with respect to performance measures. The value model should encompass multiple performance measures for multiple objectives. It should be possible to compare value with respect to different or competing objectives.

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

Practically applicable with respect to cost and time. If development or use of the value model is cumbersome and time-consuming, it will not be used. The development process usually requires significant efforts, but subsequent analyses should be relatively simple and timely. For example, having too many attributes or not having readily available data to describe an attribute will prevent simple and timely application.

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[37] Adapted from *Project Prioritization System: Methodology Summary*, EPRI, Palo Alto, CA: 2001. 1001877

Compatible with existing business practices. The value model should support existing processes for capital and maintenance prioritization and performance monitoring.

In general, a value model consists of three major components:

- A set of *attributes* of value representing the potential ways activities can contribute to corporate value.
- A set of *scales* to measure the value of each of the attributes.
- A set of *weights* that enable one to compare and trade-off value among the various attributes.

The foundation of value modeling is a set of attributes. Attributes of value generally fall into three categories:

- Financial attributes, such as revenue, earnings, share price, etc.
- Quantitative, non-financial attributes, such as reliability.
- Qualitative attributes, such as corporate reputation.

Since high-level objectives, such as reliable electric service, usually are not defined precisely enough to measure, the attributes usually must be refined by defining component subattributes. Thus, the attributes of value form a hierarchy, with the high-level corporate goals at the top. Successive levels in the hierarchy represent increasing specificity, until, at the bottom level, the attributes are readily observable and fundamentally measurable. The hierarchy defines each component of value that an activity may contribute and establishes the relationship between that value attribute and the overarching corporate goals. Development of the hierarchy requires definition of each value attribute, including as necessary, additional levels of sub-attribute definition to permit the adequate capture of all unique sources of value.

Usually, such attributes have readily observable natural units, but such units do not necessarily represent value, so a means of translating the natural units into units of value must be devised. The means of such a translation is via use of a *scale*.

How does one create such a scale? Generally, a scale is developed through a group elicitation process relying on the judgment of the individuals involved. A series of comparisons are posed of the form "Is it more valuable to reduce outage time from a to b or from b to 0?" or "At what point *x* between a and 0 would it be of equal value to go to from a to *x* or from *x* to 0?" By successive refinements, the group can fill out the entire scale.

The process does not have to rely entirely on judgment, although there are perfectly valid ways to use judgment to establish preferences[38]. For instance, in establishing a scale for customer outage minutes, many transmission and distribution utilities have customer satisfaction data from surveys that can estimate customers' value of reliability.[39]

Developing scales for qualitative attributes presents further challenges, since a qualitative attribute has no "natural units." In this case, a scale has to be described by descriptive statements

[38] The Analytical Hierarchy Process (AHP) is one such approach. This approach was employed in EPRI 1007385 and 1012954.

[39] See. *Customer Needs for Electric Power Reliability and Power Quality: EPRI White Paper*. EPRI, Palo Alto, CA: 2000. 1000428

indicating the various levels of value, and there is no direct way to determine the value of changing levels. Nevertheless, it is possible to assign value to changes in a qualitative scale. These attributes use “anchored scales,” which are numerical scales with verbal "anchor points" at various values. “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 and 10, producing the desired quantitative value.

While scales measure the value of changing an individual attribute, they say nothing about the relative value among different attributes. To compare value between two activities that affect multiple attributes, it is necessary to have a way to compare value among the attributes. For instance, one might ask “How much is moving electric service reliability from *x* million customer outage minutes to 0 worth compared with addressing a safety concern that significantly would contribute to resolution of multiple regulatory issues?”

The weighting process starts at the lowest levels of the attribute tree. At each step of the process, people are asked to compare the relative importance of changing two or more attributes. When all the subattributes that roll up to a particular attribute have been weighted, the process moves to the next set of attributes, and when all of the attributes at a particular level of the tree have been weighted the process moves up to next level. The basic approach to eliciting accurate weights is to structure a process that enables people to compare a small number of attributes at a time and to always look at specific examples of the value impacts to anchor the comparisons in concrete terms.

While the above discussion often describes how expert opinion and judgment can be used to create value models, the same process can be applied to more quantitative sources of information and to existing models. The EPRI references in Appendix B provide further examples of creating value models for project prioritization and performance modeling.

4.2.4 Evaluating Projects Using a Value Model

EPRI 1015385 focuses on evaluating projects across and electric utility enterprise. The following excerpt from Section 4 of that report discusses techniques for improving the analysis of projects. The discussion elaborates on what would constitute a Level 3 analysis of a project, per the previous discussion of screening.

Evaluation of each proposed project delivers the key results necessary to determine how good the investment would be. In performing the evaluation, the team identifies the major uncertainties affecting project value, quantifies the project’s risk and return, and measures project productivity (return on investment).

The first step in a quantitative evaluation of each decision alternative involves using the value model to perform a deterministic sensitivity analysis. This technique reveals which variables contribute the most to the uncertainty in project value and enables the team to quantify uncertain variables in order to evaluate their impact on value. Initially, the model evaluates the impact of the capital or O&M project with all variables set to their base case value. After establishing the base case value, we run a series of what-if analyses by setting each uncertain variable to its low value, then to its high value, and ranking these variables according to the magnitude of their potential impact on value. This analysis produces a “tornado” diagram that clearly identifies the variables that have the most significant impact on the value of the project (see Sub-section on *Tornado Diagrams* and Figure 4-5 below - note the tornado diagram is so named because of its shape).

Simply stated, good resource allocation decisions incorporate uncertainties that have the greatest impact on the value actually delivered to stakeholders. This analysis integrates uncertainty and produces risk / reward profiles (Figure 4-3) that reveal the benefits that would result from implementing a particular strategic alternative. (see Sub-section on *Risk vs. Return Curves* and Figure 4-6 below).

The ratio of expected net present value to investment required is a good filter for quick identification of the sure winners and losers. Using this technique, we assume that proposed projects have similar risk characteristics and that each requires only a small fraction of the overall budget. These assumptions enable a reasonable prioritization in a single pass, using probability-weighted returns for each project without much emphasis on the risk involved. Playing the odds is a good general approach: some projects will deliver more than expected, some less, but the overall portfolio value should remain close to expectations.

However, the strategic implications of very large projects should be considered very carefully in the portfolio analysis process. In side-by-side comparisons we must ensure that all projects are of the same nature. Removing exceptional or significantly risky proposals yields a more balanced portfolio and helps to clarify which projects should be funded. Beyond risk and return, other factors also should be considered. The analysis should balance projects with short-term benefits against those with longer term benefits. Also, the feasibility of the optimized portfolio must be examined. The dollars invested are only one of many resources required. As examples, questions such as the following need to be addressed. Is staff available for implementation? Does this prioritization need to reflect any significant delays in receiving parts?

Portfolio selection requires good funding criteria in combination with guidelines for balancing risk and return and making trade-offs between short-term and long-term benefits. Finally, the feasibility of implementing the selected portfolio always should be verified.

4.2.5 Two Important Considerations in Using Value-to-Cost Measures

EPRI 1015385 makes some important points regarding the use of value-to-cost measures. Selecting a value to cost measure can provide an inadvertent influence on investment strategy. For this reason, it is important to consider multiple value-to-cost measures, e.g., both Net Present Value and Internal Rate of Return (IRR). IRR hurdle rates favor projects with short-term return. Consequently, a project prioritization process using only IRR could systematically bias the portfolio against strategic investments that produce a high NPV over a long time horizon.

When evaluating risks in a project's value-to-cost measure, the description of the project risk should provide a clear differentiation between different sources of risk in the following manner:

- Separate general business risk (that should be reflected in the market cost of capital) from project risk (that should not).
- Identify risks that are significant in driving overall value or switching the preference among competing alternatives.

- Clarify which project risks can be managed and identify ways to mitigate these risks and create more value.

The project prioritization process also should account for the fact the value and risk of technology investments are especially dependent on clarity in strategic direction since these investments often require a number of years to mature and create the anticipated benefits. Additionally, the reduction of major outage risks are difficult to measure and therefore are often incorporated inconsistently or are overlooked or forgotten entirely. The examples from the Transmission and Distribution industry provide case studies in how risks can be addressed. However, the points above should be considered.

4.2.6 Visualizing Project Value and Risks

Both EPRI 1012527 and EPRI 1015385 place significant attention on how to visualize project prioritization results, including more important investments that require a detailed evaluation of project values and risks.

4.2.6.1 Displaying Results for Project Prioritization Using Best Estimate Values

When a project prioritization analysis is done with best estimate values resulting in a single value to cost measure, the analysis results are relatively easy to display and describe. Sometimes a table or a list in an Excel spreadsheet is used. Another popular display is a funding curve (Figure 4-1)[40] because it displays a number of useful attributes. For example, the slope of the funding curve is the value to cost ratio. The distance between projects represents the cost versus value, so a tightly grouped set of projects represents a number of projects with similar values and costs. The budget, or the project cutline, indicates the projects that are on the margin.

[40] This project funding curve was provided by Navigant Consulting and was presented at EPRI's Fourth Power Delivery Asset Management Conference.

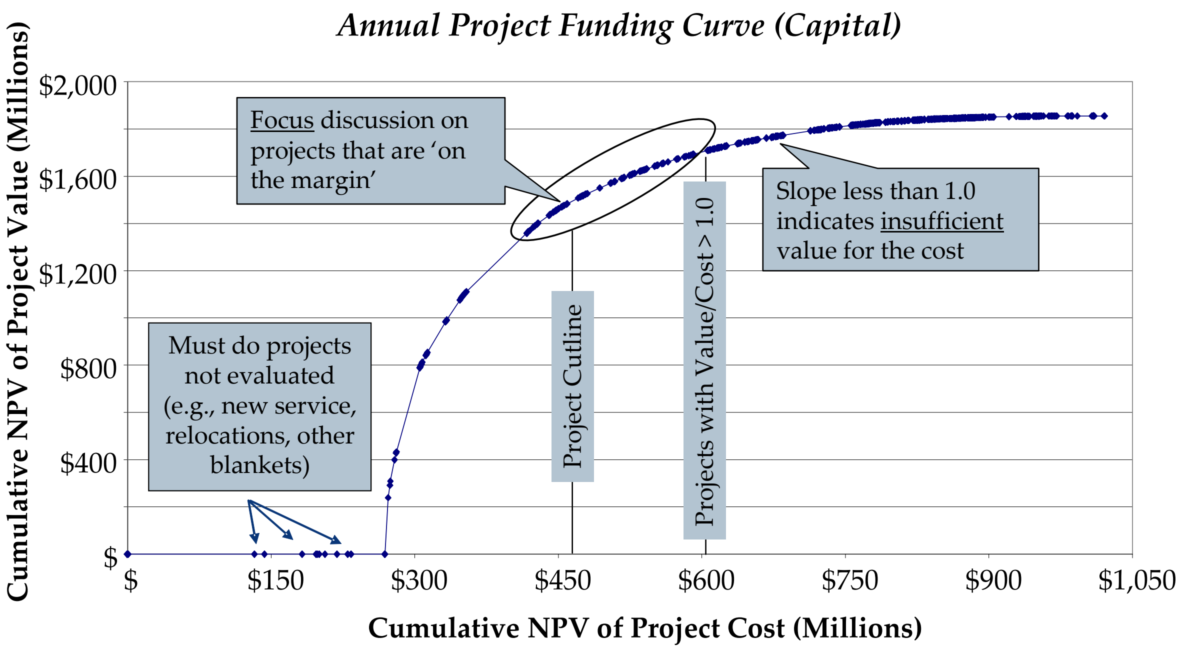


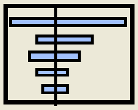
Figure 4-1 - Annual Project Funding Curve

The project funding curve has been found useful by a wide range of decision-makers, including executives, senior management, engineering management, engineers, financial analysts, and others.

The following two figures from EPRI 1015385 provide a nice summary of the types of project prioritization results displays (which we refer to as "visualizations"). The key results illustrated in these figures provide the insights decision-makers need to make productive resource investment decisions. Figure 4-2 illustrates the types of visualizations useful for the peer review process and Figure 4-3 illustrates displays for executive review and disposition. Each of these results enables the comparison of proposed projects and the selection of those having the best chance of meeting the objectives of corporate and business strategies.

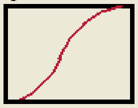
For Peer Reviews

Tornado Diagram



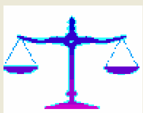
The tornado diagram–deterministic sensitivity chart–ranks the project uncertainties and helps identify quickly which uncertain variables are the key drivers of project value.

Project Risk/Return Curve



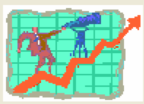
The risk/return curve depicts the full range of potential value for a given project. The curve is supplemented with the project's expected net present value, a probability-weighted average.

Producitivity Measure



The ratio of expected return over the investment is used to prioritize project proposals. Investments with the greatest leverage should be sought.

Project Cash Flow



The display of project's investment and return is often useful. It provides a visual clue about when an investment is expected to be recovered.

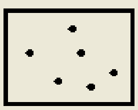
Impact on Key Attributes

Keeping track of promised impacts on key attributes as a sanity check and to monitor projects.

Figure 4-2 - Visualizations of Project Prioritization Results for Peer Reviews

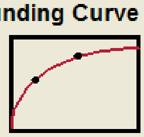
For Executive Reviews

Prioritization Map



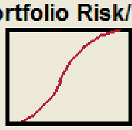
Plotting each project on a graph that shows the project investment on one axis and the expected value on the other creates a visual screen for highlighting the "sure winners," "sure losers," and "tough-to-decide" projects.

Funding Curve



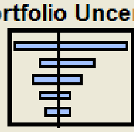
Using the ranking established in the Prioritization Map (or productivity ratio), the funding curve shows how value is created for a given set of budget constraints.

Portfolio Risk/Return Curve



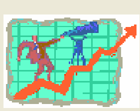
The portfolio risk/return curve depicts the full range of return (with associated risk) for the portfolio as a whole, taking into account dependencies among the proposed projects.

Portfolio Uncertainty



Portfolio uncertainty charts identify which investments have the greatest impact on the portfolio value and require management attention.

Portfolio Cash Flow



The portfolio cash flow serves a similar purpose as the project cash flow and is often required at the corporate level.

Figure 4-3 - Visualizations of Project Prioritization Results for Executive Reviews

4.2.6.2 Visualizing Project Values, Uncertainties and Risks

As the projects become more costly and the analysis becomes more detailed, the results must address various financial indicators, performance indicators, cash flow projections, expenditure projections, and various ways of displaying uncertainties and risk. Decision- makers must be able to use the results across a generation plant / fleet; a transmission substation, a distribution feeder, or a power delivery network; or a corporation as applicable. This subsection provides examples using hypothetical results of various ways of effectively displaying the results of asset management analyses in the power delivery industry. The various examples were collected from both the nuclear asset management and power delivery asset management programs at EPRI and are equally applicable to both.

The first few visualizations are described in the context of an analysis of project value and risk. We begin with a diagram (Figure 4-4) representing the model for project values and continue with a depiction of sensitivity studies obtained using the model (the tornado diagram of Figure 4-5). The next figure (Figure 4-6) illustrates the range of project values and their associated probabilities, i.e., a project risk curve. The figure is followed by a portfolio risk curve, which includes an illustration of an "efficient frontier" (Figure 4-7), a common method of displaying portfolio options in financial risk analysis. Corporate executives, particularly CFOs, will be familiar with these curves from their finance training.

We follow this series of visualizations, with a set of visualizations designed to depict risk. EPRI research has shown that risk is often difficult to understand when comparing multiple projects. The majority of these displays provide examples, any one of which may be the one(s) that work best for different levels of review.

4.2.6.1.1 Influence Diagrams

To clarify how the various factors influence a decision, it is helpful to construct a conceptual model (see Figure 4-4) that represents their interrelationships, or a so-called influence diagram. Note that the top five elements lead directly to cost. Also, note that the right side of the diagram addresses ordinary conditions, while the left side of the diagram addresses storm conditions.

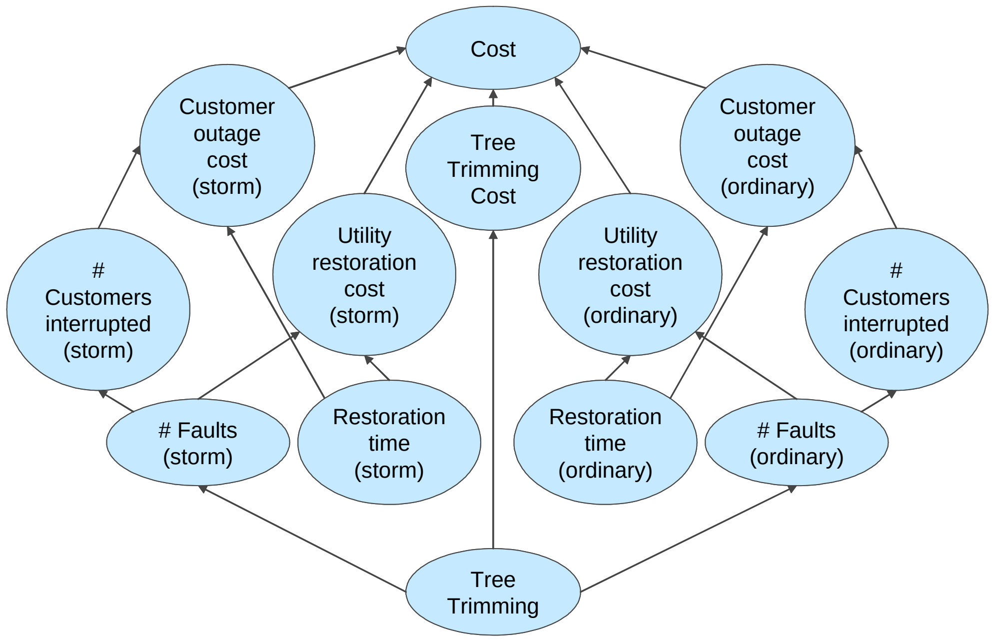


Figure 4-4 - Example Influence Diagram for Tree Trimming

4.2.6.1.2 Tornado Diagrams

Sensitivity analysis is used to identify the factors that most influence the results. The model is quantified, then each parameter (e.g., tree trimming cost, customer outage cost, storm probability, etc.) is varied independently. The same percentage change is applied to each parameter in each sensitivity run. The funnel shaped set of results shown in Figure 4-5 is called a "tornado diagram." The diagram shows, for example, that for a given percentage change in a parameter (e.g., the tree trimming cost), the impact on study results was an increase or decrease of $2500 (i.e., the "delta cost").

This sensitivity analysis and the resulting tornado diagram do not consider probability or risk; its results pertain to the deterministic results obtained from the model.

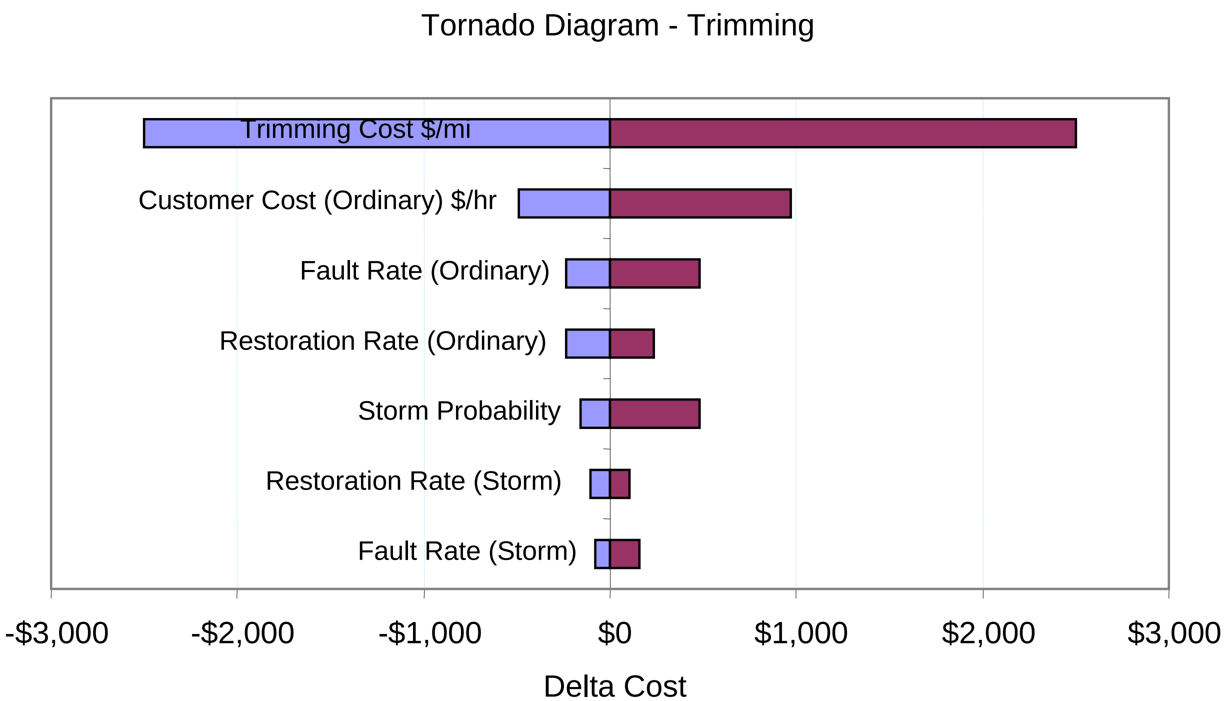


Figure 4-5 - Example Tornado Diagram for Tree Trimming

4.2.6.1.3 Risk versus Return Curve

In addition to judgment and historical data, analytical risk models are very useful in risk assessment because the uncertainties involved are often quite difficult to gauge. Figure 4-6 illustrates the results derived from such a model, applied to one particular feeder. The diagram shows the expected values from the deterministic analysis as the two dotted vertical lines – the total cost of trimming on the right, and the total cost of not trimming on the left. The two curves represent the plot of the analytical risk model for the two scenarios. While the expected cost of not trimming is lower than that of trimming (the two vertical lines), the range of possible costs for the trimming case is much narrower than the no-trim case; that is, trimming has much less risk (i.e., uncertainty) than not trimming. Furthermore, the two curves cross at the 75 percent probability point. According to this analytical model, there is a one in four chance (from 75-100 percent) that not trimming will cost more than trimming. Whether a utility's management considers such a risk to be prudent is a matter for their judgment.

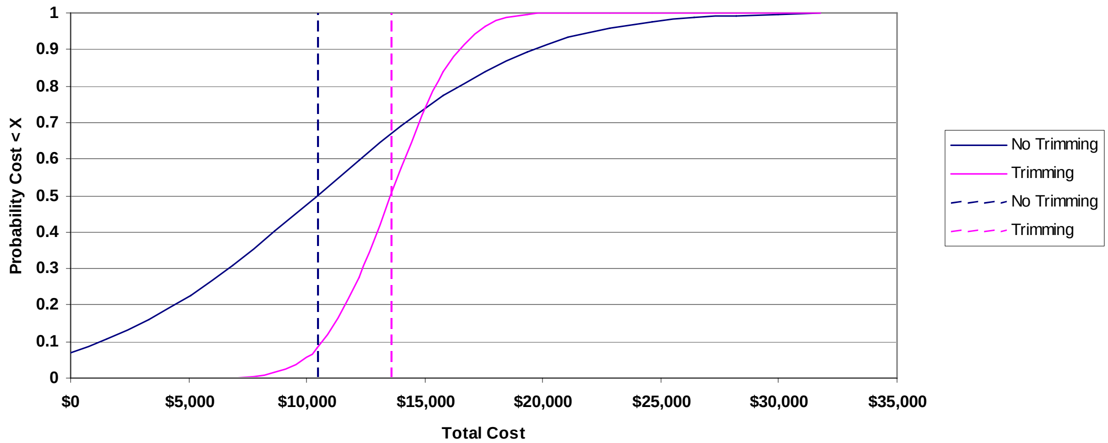


Figure 4-6 - Example Risk versus Return for Tree Trimming

In addition to the risk assessment for one project (i.e., a particular feeder), risk assessment techniques can be applied to examine a portfolio (i.e., multiple feeders). For example, if ten feeders are being considered for tree trimming, but the budget only allows for tree trimming to be performed on five feeders, then various portfolios can be defined, each consisting of a different combination of five feeders. For each portfolio, the expected total cost and risk (measured by the standard deviation of this cost) can be calculated. Figure 4-7 illustrates a plot on which each data point represents a portfolio. The line connecting the lower-most data points, for a given expected total cost, is called the "efficient frontier." For a given expected total cost, this line represents the "best" portfolio because it yields the smallest risk (standard deviation) in the total cost. This means that any portfolio above the line would not be selected, because a portfolio with a lower standard deviation at that cost is a better option. Note that the shape of the efficient frontier reflects the fact that the various risk factors involved in this problem are not independent.

The decision then becomes which portfolio on the efficient frontier to select. The portfolios at the right end of the diagram reflect the lower standard deviation, and hence less risk, albeit at a higher cost. Highly risk adverse managers would tend to select a portfolio at this end of the frontier. Conversely, the portfolios at the left end of the diagram reflect the higher standard deviation, and hence more risk, albeit at a lower cost. Highly risk tolerant managers would tend to select a portfolio at this end of the frontier.

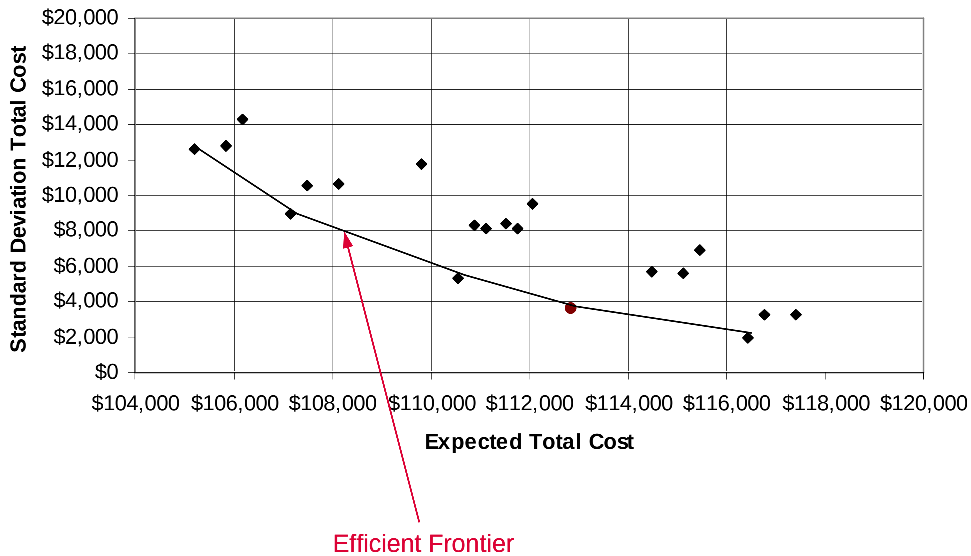


Figure 4-7 - Example Efficient Frontier for Tree Trimming

4.2.6.1.4 Phase Plane Graph

Figure 4-8 illustrates a phase plane graph. This type of illustration is particularly useful when two important stakeholder values (in this case, reliability and profitability) involve trade-off decisions. Plotting one value against the other in this manner can produce some useful insights. For example, projects in the upper right quadrant (e.g., tree trimming) improve both values, while projects on the left side decrease one of the values.

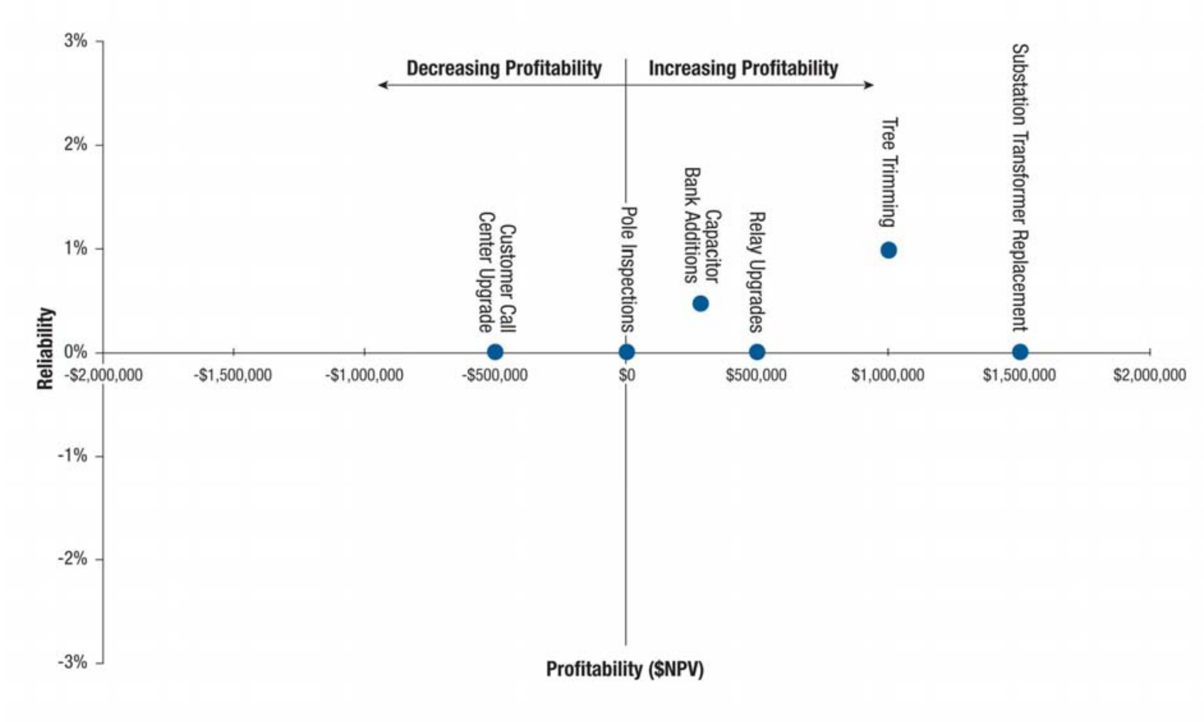


Figure 4-8 - Example Phase Plane Graph

4.2.6.1.5 Plot of Cumulative Benefit versus Investment

A plot of cumulative benefit versus investment (often mistakenly called an "efficient frontier") is useful for illustrating the effect of a constraint (e.g., a fixed budget) on the incremental value of a ranked ordered list of investments. In Figure 4-9, the projects are shown in ranked order from left to right along the curve. The budget constraint is shown as a vertical dotted line. In this case, the first three projects (substation transformer replacement, tree trimming, and relay upgrades) could be implemented and remain within the budget constraint.

A scaled-back version of the capacitor bank addition project or some other highly ranked, lower cost project, also could be implemented and still remain within the budget constraint. If the budget constraint could be relaxed somewhat, the capacitor bank project also could be implemented in its entirety. The figure also illustrates the decreasing value of performing subsequent projects. If the budget constraint could be relaxed further and the pole inspection project funded, because the slope of the curve has flattened out in this region, the incremental benefit of that project is less than that of the previous projects, and thus, the value derived from it may not be sufficient to warrant its implementation. In the second T&D utility case study in Section 3, these two projects most likely would be disaggregated and the highest value portions of the projects would be funded. That is, the utility would most likely add the highest value capacitor banks and replace the highest valued poles, instead of making a simple Yes / No decision regarding funding of the entire project.

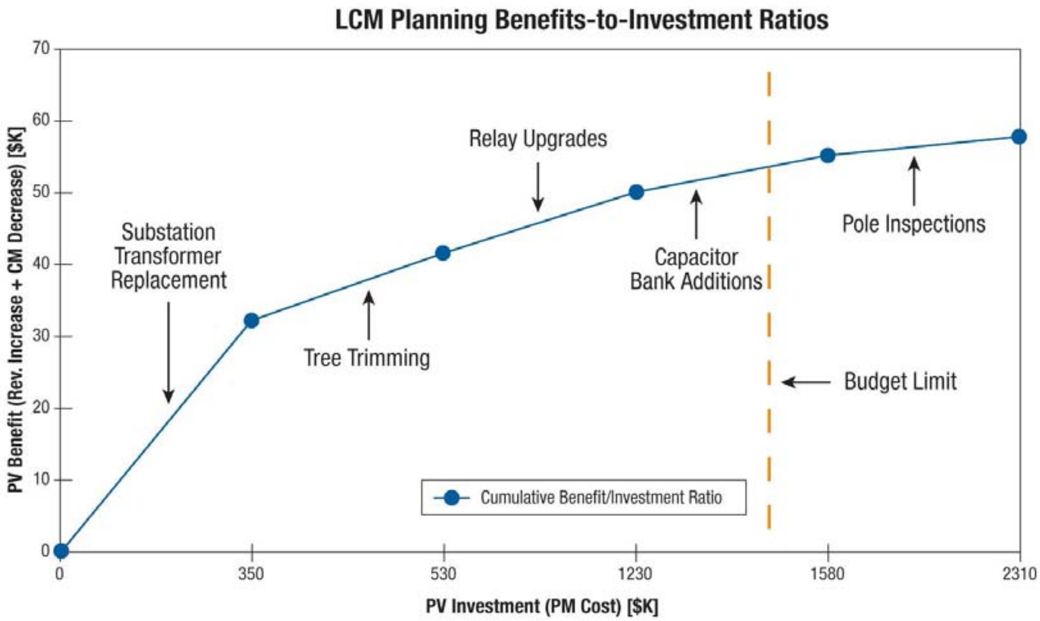


Figure 4-9 - Example Cumulative Investment Graph

4.2.6.1.6 Project Uncertainty Comparison

Figure 4-10 illustrates a case in which two investment options have the same mean net present value (NPV) of $300,000, but different levels of risk. This visualization enables the decision maker to evaluate the probability of loss as well as potentially higher gains. In this example, option A is a safer investment, because its probability of loss is zero (no part of the curve crosses the vertical line at zero). Conversely, option B presents a 6 percent chance of loss, and a 7 percent chance of a higher NPV than option A. Hence, option B is “riskier.” Of course, this presentation technique also provides useful information when the two investments have different mean NPVs and less extreme differences in the shape of the probability distribution.

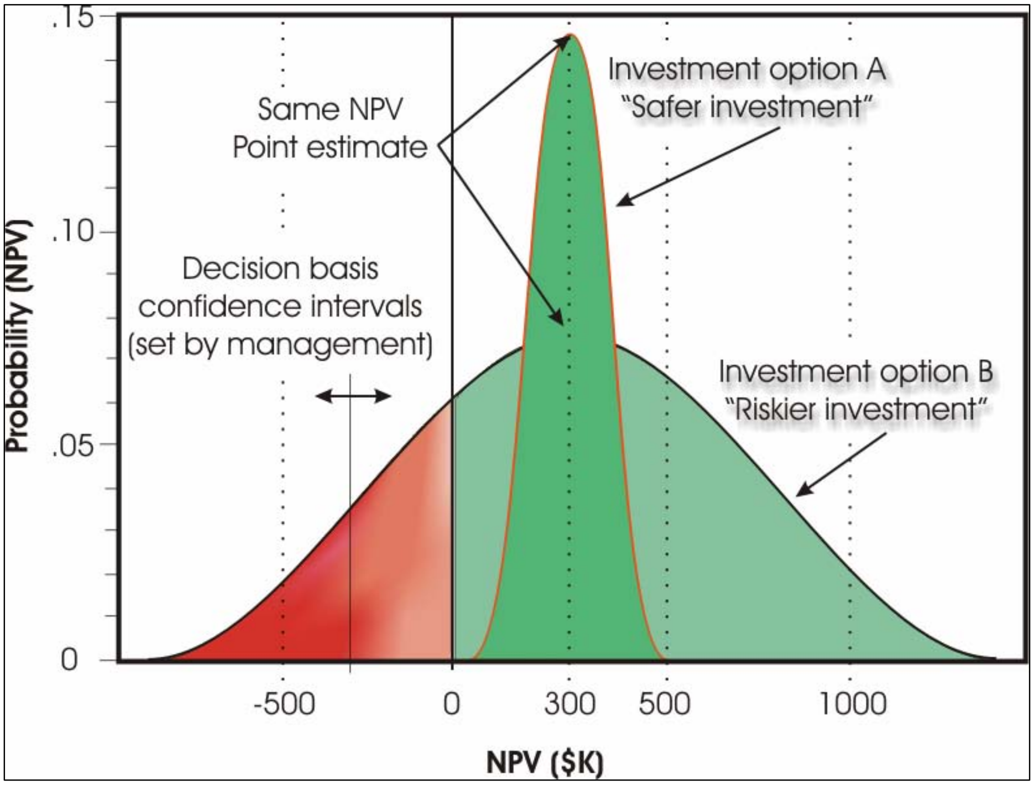


Figure 4-10 - Example Project Uncertainty Comparison Graph

4.2.6.1.7 Probability of Loss for Multiple Projects

Probability of loss is a key concern for many decision makers. Figure 4-11 shows a convenient way to illustrate results of multiple projects by displaying the probability of loss. By comparing this loss probability to internal rate of return (IRR), decision makers can see at a glance which projects are more favorable than others. In the example, substation transformer replacement offers a favorable IRR with no loss probability. The relay upgrade project provides a much higher IRR (note the logarithmic scale for IRR), but with a significant loss probability. By these measures, a clear project to avoid in this example is pole inspection, which shows a very high loss probability and very low IRR.

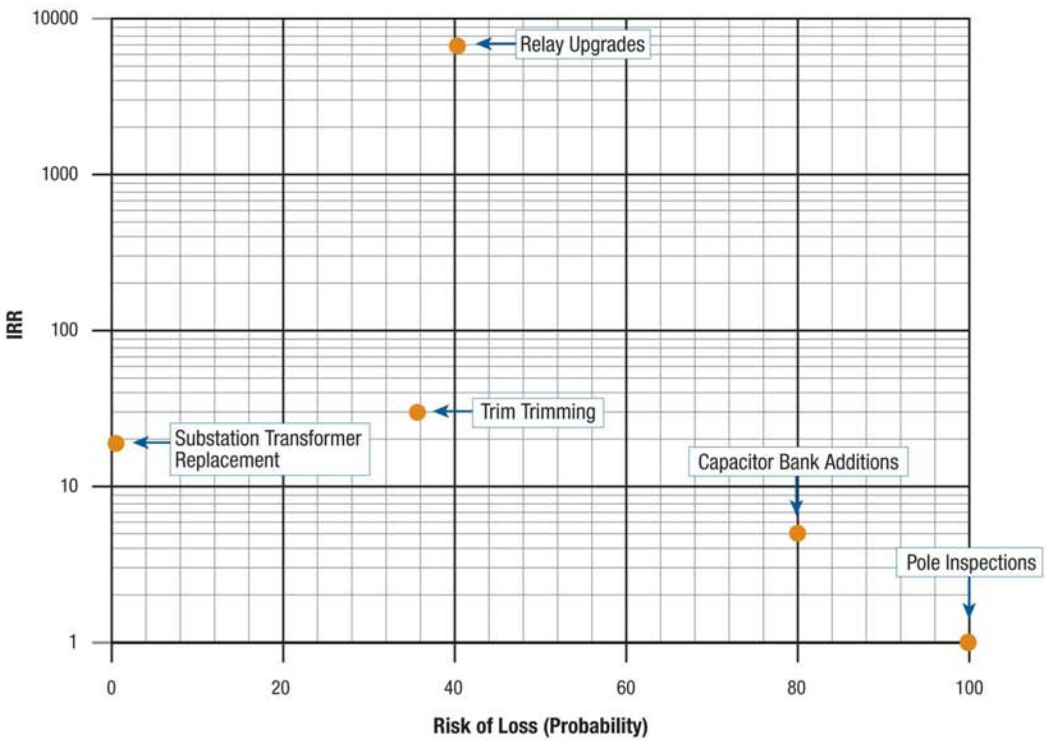


Figure 4-11 - Example IRR Versus Probability of Loss Graph

4.2.6.1.8 Project Specific Uncertainty Histogram

The visualization illustrated in Figure 4-12 focuses on the uncertainty in IRR for a particular project. The histogram (cluster of bar charts) shows the probability distribution across IRR. The histogram is generated by making numerous simulation runs using a Monte Carlo analysis. The curve represents the cumulative probability in percent. Hence, there is about a 50 percent chance that the IRR will be lower than about 21 percent.

In addition to helping decision makers understand the risks of a project, this representation also allows consideration of the value of information that might help to reduce this risk. For example, the decision-maker could commission an engineering study of the uncertain parameters in this project that caused the "tails" of the histogram to occur. Such a study could reduce the uncertainty or help identify changes to the project to reduce it. Similarly, the study could find ways of increasing the likelihood of attaining a high IRR by emphasizing those factors that led to the highest IRR. In one such study, the analyst could change the value of one of the parameters – preferably one that has the largest impact on cost as identified in a tornado diagram such as Figure 4-5 (e.g., price of power). By obtaining a better evaluation of the market price of power or investing in a hedge to eliminate this risk, the project's IRR can be increased.

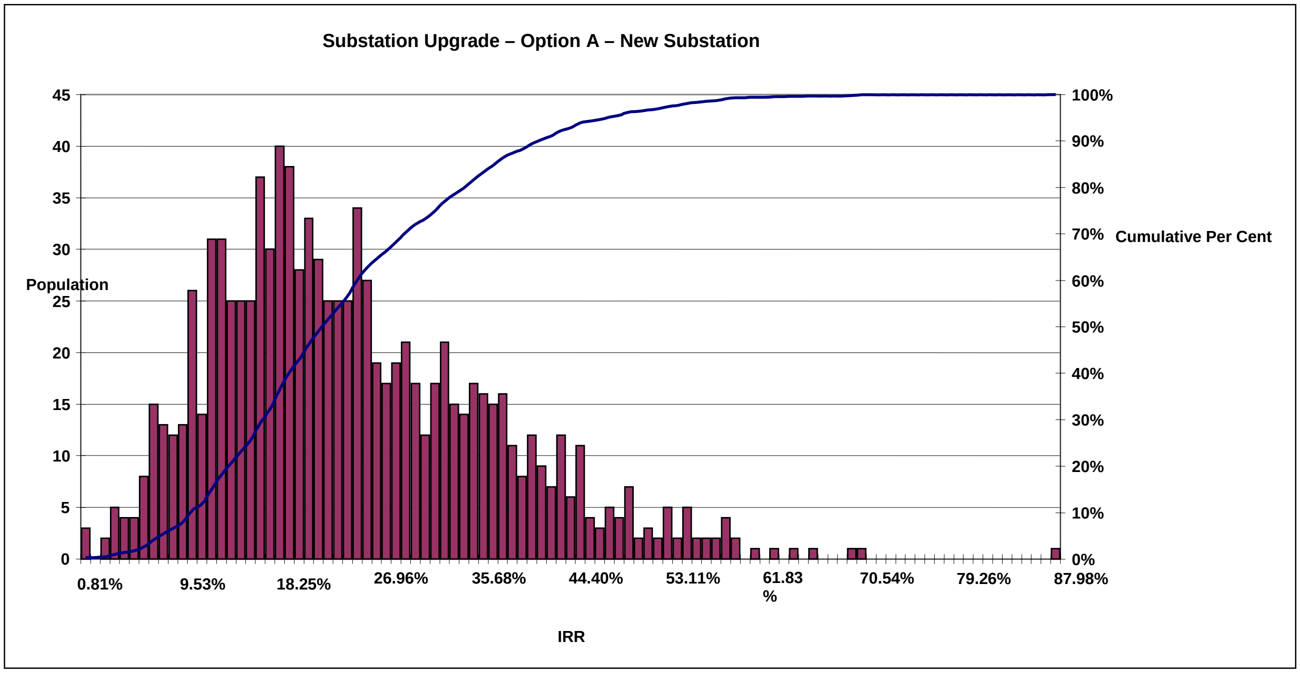


Figure 4-12 - Example IRR Uncertainty Histogram

(Note: histogram refers to left vertical axis; curve refers to right vertical axis)

To conclude this section, we recommend that a project funding curve be used for straightforward best estimate analyses of projects using typical value to cost measures. For larger or more strategic investments, we recommend the project prioritization results be displayed in a variety of forms keyed to the unique needs of peer and executive reviewers. When risk information is critical to an investment decision, we recommend an evolution of displays beginning with the model and ending with project risk versus value and cost. When risk information is being evaluated for multiple projects or portfolios, we recommend that one or more of the displays in this subsection be considered.

5
SUMMARY AND CONCLUSIONS

This section summarizes the lessons learned from project prioritization experience and methods employed in applications external to commercial nuclear power production. From this summary we draw specific conclusions and recommendations for enhancements.

5.1 Summary of Findings from Other Industries

The following topics in project prioritization were identified by the nuclear community as items of interest related to insights from other industries:

- Key Attributes of LCM Plans (as they relate to prioritization)
- The Project Prioritization and Long Range Planning Process
- Guidance for Selecting and Valuing Prioritization Attributes
- Integrating Project Ranking and Business Strategy
- Metrics to Evaluate Process Effectiveness
- Feedback Mechanisms for Continuous Process Improvement

The following uses these six topics as a framework to summarize the insights we identified in Sections 3 and 4.

5.1.1 Key Attributes of LCM Plans

A good Life Cycle Management Plan for each critical asset is the foundation for a good Long Range Plan. In this respect, we draw good attributes for an asset's Life Cycle Management Plan primarily from the first good practice case study in the nuclear power industry and from the introductory discussion of factors facing electric distribution utilities when developing long range plans. We also refer the reader to the full guidance document developed by the Equipment Reliability Working Group (the portion of which that relates to project prioritization has been discussed earlier in this report).

One very important attribute of a good LCM plan is the development of alternatives and contingencies. We will talk more about alternatives in the next topic (which discusses the process for prioritization); however developing good alternatives starts early and should be included in an asset's LCM plan. Additionally, the results of evaluating the various alternatives and their disposition (and bases for decisions relating to them) should be documented therein. Related to alternatives are contingencies. A contingency is an immediate and possibly temporary solution that is required when a risk manifests itself, such as the risk of a material degradation or even the risk of a catastrophic failure. A good LCM plan identifies risks and associated contingencies and assessments of the risks are used in the project prioritization process to develop the final list of selected projects.

As discussed in previous sections, Subject Matter Experts (SMEs) play a key role in several of the case studies presented. We note that there can be multiple SMEs some of which can be from outside the company. The important consideration is to incorporate a viewpoint that includes a broader perspective than that provided by a limited focus on a specific plant or a specific system. For fleet operators, efficiencies and consistency can be enhanced by use of the SME to develop a corporate level strategy for the asset with feedback provided from site asset owners and operators. A corporate level asset strategy should be easier to integrate with a corporate level business strategy, thereby making prioritization and long range planning easier.

The success of an LCM plan also depends on comprehensive and accurate asset condition information. The nuclear good practice case studies and the second T&D case study both depend on such information for developing projects and managing equipment risks.

To be effective in helping long range planning, an LCM plan also needs to reflect anticipated business challenges. See the introductory material to the T&D industry portion of Section 3 for a list of some possible business challenges which may be useful to address in a nuclear generation LCM plan. As an example, a business challenge such as rapidly increasing materials costs could influence which project alternative would be the most cost effective to address a specific issue. More importantly, early identification of a materials cost issue might allow a utility to consider strategic sourcing options that could lower cost or ensure availability of needed materials. The first generation application case study refers to identification of “critical values” which include items like materials availability or cost which, if exceeded, could threaten the success of the long range plan.

Finally, an LCM plan needs to be complete in identifying activities in the out years, preferably until the end of asset life. Without complete LCM plans for major assets, an overall long range plan might be subject to the excessive variability, such as that illustrated in Figure 3-2. The LCM plan also should identify what activities are outage related and in particular make clear which activities could extend the length of a standard refueling outage. This type of information will help ensure good outage planning and also allow the company to plan and schedule necessary specialized corporate resources. Also activities that have the potential to extend a standard refueling outage potentially could be grouped into the same outage to minimize cumulative outage time over the life of the plant.

5.1.2 The Project Prioritization and Long Range Planning Process

The case studies presented in this report provide a number of lessons learned for project prioritization and long range planning. As indicated earlier, the starting point for good project prioritization and long range planning processes are good LCM plans that incorporate the results of asset health assessments to identify issues and the use of Subject Matter Experts to help ensure consistency in plans and projects.

In this subsection, we discuss insights related to the following:

- organizational aspects of the planning and prioritization process,
- increasing the planning time horizon,
- the importance of beginning with a good understanding of the value of the generating assets,

- the critically important issue of identifying and evaluating alternatives,
- efficiencies gained by considering both O&M and capital expenditures during prioritization,
- developing multiple portfolios and using the insights generated to select the best set of funded projects,
- obtaining transparency in the analysis through automation and then using that transparency to effectively communicate to stakeholders.

Consistently, the case studies show that organizational aspects of project prioritization and long range planning processes are every bit as important, if not more so, than the analysis techniques employed. In subsequent subsections, we discuss metrics and feedback mechanisms which can help to measure the effectiveness of these activities. Applying the nuclear industry's well recognized skills in continuous process improvement and organizational awareness / training to evaluate and implement insights discussed in this report should permit obtaining further improvements and efficiencies in project prioritization and long range planning processes.

The case studies have shown that increasing the time horizon addressed by asset LCM plans and associated plant / fleet Long Range Plans can improve the stability of resource projections. The second T&D case study carried the planning process through until the asset's end of life; additionally, all of the case studies showed an objective (and trend) to increase the planning time frame. As we saw in the introduction to the T&D and generation industry case studies, the asset and resource information provided by a long range plan can enable a utility to secure scarce skilled contract resources, long-lead time items, and materials, which in turn result in reducing their overall costs and minimizing the overall risk of not delivering on stakeholder expectations.

Consistency in planning year over year is difficult to accomplish without such a long range plan. Such consistency is important to maintaining credibility with stakeholders. Materials costs in particular are increasing dramatically; thus that it is important to ensure that various cost components are being accounted for accurately, especially over the long term. A few of the case studies used forward price curves for key plan elements, including materials, and the use of those curves significantly affected the planning results and decisions.

Another critical input to the planning process was seen to be the value of the nuclear plant itself. Generation assets in particular must be valued as a whole before an underlying asset can be correctly valued. Otherwise the utility may find itself slowly investing resources in project after project over and above the value of the generation asset. This same logic may apply to other asset hierarchies, for example individual structures, systems or components. The generation case study on climate change also illustrates the importance of considering market effects on the price of electricity, which in turn, could include potential climate change policy impacts on the market.

Once the value of the plant is estimated and comprehensive baseline asset life cycle management plans are developed, a number of the case studies showed the importance of identifying a suite of alternatives to be evaluated. In the second nuclear case study, emphasis was placed throughout the evaluation process on developing good alternatives. This case study described a number of questions in the TRB and PRC challenge processes that were used to ensure an appropriate set of alternatives were developed and considered in the evaluation process.

The pharmaceuticals industry case study also described a systematic approach to developing alternatives and showed how the approach can create substantial added value to a portfolio. To improve this process, they began with a simple step – requiring a consistent set of alternatives be developed for all projects. They required each proposed project to develop at least four alternatives:

- the existing base case,
- an alternative with a reduction in costs,
- an alternative using more expenditures,
- an exit strategy for the project that preserves the benefits generated to date.

They found that forcing this type of thinking into the process generally led to a consensus among project members that the best alternatives had been identified. In practice, one or more other alternatives in addition to the minimum set often also were developed. With multiple alternatives, more effective portfolios were created with an outcome that thirty percent additional value was obtained compared to the original list of projects.

In the second T&D case study, the utility systematically assesses project efficiency to help ensure the best "alternative" is identified and funded. This critical review of the project is performed by Subject Matter Experts. For larger projects or programs with mid level priorities, the utility disaggregates the work so that the best "alternative" is identified and can be funded.

In summary, identifying alternatives helps create potential value, especially when the approach creates a discipline around developing the alternatives. When the alternatives are then considered in developing portfolios, evidence from the case studies indicates the total investment can be substantially enhanced.

Another important process element for project prioritization and long range planning that was indicated by the case studies is to consider maintenance and capital expenditures in concert as part of a single action plan. In the nuclear case studies this is done by not only identifying O&M spending associated with capital, but also by including in the project prioritization process all O&M line items above a certain value. Further, when a project is initiated that will result in reduces O&M expenditures, those expenditures should be removed from future O&M budgets upon completion of the project.

In the second T&D case study and in the guidelines provided from the transportation industry, large O&M programs and capital expenditures are considered together. A replacement program is considered explicitly in the context of on-going repair costs and refurbishment options.

In the transportation industry, the Transportation Asset Management Guide encourages tradeoff analyses to consider alternative O&M resource allocations at a program level. These tradeoff analyses are considered a complementary analysis to project-to-project evaluations that result from project prioritization. The analysis involves testing the consequences of shifting funding from one program to another, and making a judgment as to which O&M resource allocation option would be the most favorable. We note that for this analysis approach to provide useful results, value (and performance) must be capable of being estimated at both the program and project level.

The third T&D case study focused on risk management and investment in activities that mitigate risks. The way risk management projects are analyzed can be much different from more traditional projects. One reason that they are hard to measure is due to the fact that if the consequence does not occur, the investor may not know whether it was a result of the risk mitigation investment or because the risk itself was overestimated. Regardless, risk management activities can be a significant source of value and should be actively evaluated. If necessary, activities to mitigate risk can be prioritized separately from other projects.

The reader also should take note of the first generation case study. Here, the utility created different portfolios using different prioritization criteria, e.g., NPV, risk, and the performance measure EFOR.[41] The utility identified those projects that, regardless of the prioritization case, always were included or excluded. The projects always included were funded; the projects always excluded were rejected. The evaluation then moved on to provide a better understanding of the projects that met some prioritization cases, but not others. These projects are those that are on "the cusp", i.e. they are the ones still in consideration for the remaining funding.

The utility also was able to evaluate critical values of key parameters that would threaten the success of the portfolio. For example, the utility considered how much parameters such as access to capital, prices of external labor, and the price of energy might change before the portfolio was no longer the optimal portfolio. These critical values helped management understand the risks they were taking and to obtain buy-in from the regulator on taking them.

The two generation case studies used a commercial software package to automate the analysis, as did the utilities that supplied the second nuclear case study and the first T&D case study. In each case the utility observed how automation can increase the transparency of the analysis dramatically. In the nuclear case study, the software helped to create a track record of how the prioritization was modified at the different stages (i.e. by the TRB, PHC and PRC).

In the generation case studies, the power of the analysis and data integration capability of the software provided another kind of transparency. By helping to perform a robust analysis that revealed what aspects were most important, the software identified how the selected projects differed due to differing prioritization criteria and how much critical values, like materials costs, could change before the portfolio was no longer the best one. The robustness of the analysis enabled management to understand the analysis better and allowed stakeholder values and concerns to be addressed and communicated in a direct manner.

The generation case studies and the T&D case studies also illustrated important lessons learned about communicating project prioritization and long term planning results to stakeholders. For example, an asset centric approach to planning can help communicate the need for the projects (and their expenditures) to stakeholders. As one example presented, stakeholders understand that assets are more likely to fail when they are operating near or beyond their design life. Reporting the effectiveness of the proposed plan against the key performance criteria of interest to the different stakeholders also provides an effective mechanism to obtain ongoing communication and support. An important element of these communications was to keep them simple and provide the information in a form that addresses their particular concerns. Emphasis on numerical prioritization scores or financial returns was found to be less effective at achieving this objective.

[41] Equivalent Forced Outage Rate (EFOR) measures the hours of unit failure as a percentage of the total hours of unit availability.

5.1.3 Guidance for Selecting and Valuing Prioritization Attributes

The ERWG guidance document recommends a variety of prioritization attributes that are currently in use at one or more nuclear power plants. Because different industries and business units would be expected to have different prioritization attributes, we did not attempt to use the case studies to identify specific attributes or weighting factors for nuclear power plants.

However, it is appropriate to understand what the case studies tell us about how the prioritization attributes were selected and valued. For example, the following describes insights on using value models linked to performance indicators, pitfalls in selecting financial measures, evaluating different types of projects, and the critical correlation between companies that make models of value and their relative financial performance.

The case studies indicate that different types of value can have significant impacts and it is important to make sure the prioritization approach reflects these different values. For example, in the first T&D case study, the utility provided different value to customer interruptions that were widespread compared to those that were limited. From their own experience, and from industry studies of losses from customer interruptions, they identified a factor of two difference in the two types of losses.[42] These differences can in turn result in different project rankings.

This same case study illustrated the importance of developing a value model which includes measurable performance indicators. The achieved value of a project is much easier to audit when it is described in terms of performance indicators. The nuclear industry is particularly strong with respect to its development and use of performance indicators, including indicators used in system health, the Equipment Reliability Index and the NRC's Reactor Oversight Process. These indicators provide an opportunity for developing robust prioritization attributes which can provide a measure of value, applicable to both anticipated value used during project selection and achieved value as measured after implementation.

The choice of a financial measure also can have important implications to how projects are valued. EPRI 1003050[43], which included a survey of Wall Street analysts and plant owners and a comparison to financial indicators from airlines and telecommunications industries, calls NPV "the most fundamental measure of value". The financial community clearly favors its use as the metric of choice as a measure of value; particularly in view of known limitations in other financial measures. As one example, although IRR represents a measure that often is employed as a measure of value, it is known that it favors projects with short-term return. Consequently, a project prioritization process using only IRR systematically could bias the portfolio against strategic investments that produce a high NPV over a long time horizon.

On the other hand, determining the best portfolio can become even more complex if there are some very large projects with high NPV (especially if they also have high associated implementation costs). In this case, analysis approaches designed to solve the so-called "knapsack problem" come into play. These solutions are so named from the following: if I put one or more very large projects in my knapsack (budget constraint), little room remains for many

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[42] Industry studies indicate the difference can be up to a factor of ten.
[43] *Nuclear Power Financial Indicators for a Competitive Market*, EPRI, Palo Alto, CA. 2001. 1003050.

other projects. If I take one of those projects out of my knapsack, I can carry quite a few more projects. In these cases, determining the optimally packed knapsack is an iterative process[44].

Many experts believe that all benefits and therefore all attributes cannot be related to financial performance, or "monetized". When all project benefits are not monetized, there are other consequences that need to be addressed in the attribute models. For example, the choice of whether or not to discount non-monitized benefits can affect the results of the analysis. For example, by not discounting future non-monitized benefits but discounting future monetized benefits, projects that produce a long duration stream of non-monitized benefits are preferred. Further, non-monitized measures of benefits also can bias the project prioritization results in favor of lower cost projects when the overall valuation measure is benefit per cost. These types of biases should be considered when interpreting the results of a project prioritization process.

The generation case study for climate change illustrates another consideration, namely that the choice of assumptions often can be more important than the choice of value measurement techniques. The ultimate value of the biomass projects was much more significantly affected by whether a forward price curve for CO_2 emissions was used (resulting in a factor of five difference in benefits) than whether or not real options analysis techniques were used to calculate value (resulting in only a ten percent difference in benefits). Similarly, whether or not to discount reduced CO_2 emissions (factor of two difference in benefits) also was found to be more important to the conclusions than the analysis technique employed.

Each of these financial lessons learned indicate that choice of a financial value measure and assumptions can influence the final ranking of projects. The planner therefore must understand these influences, understand their impact on the final ranking, and communicate the information to relevant decision makers.

One of the original objectives of this report was to look to other industries for insight into how prioritization attributes could be used to evaluate different types of investments, e.g., physical assets and information technology. Where the case studies spoke specifically to this point, in general the different types of investments were evaluated separately. In the second nuclear case study, the PRC evaluated different investments together. However, the IPP process was used only for Equipment Reliability projects. IT and other infrastructure projects were evaluated subjectively by the PRC. In our review of the IT portfolio management processes, all the case studies seemed to indicate that IT was evaluated separately from other investments. So while in principal widely different types of investments should be able to be valued with a consistent set of prioritization criteria, we found no specific insights or guidance from our studies.

Returning to the first lessons learned for this topic, it would seem even more important to remember the relationship between a company's ability to develop attributes which accurately measure value and a high level of company performance[45]. Given the diversity of nuclear industry key performance indicators and their perceived importance to operations and safety, it

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[44] Ongoing EPRI research has been conducted to investigate applications of variations of the knapsack approach to develop an optimized portfolio under various budgeting scenarios. See the following publications: *Program on Technology Innovation: Project Prioritization Optimization Under Budget Uncertainty*, EPRI, Palo Alto, CA. 2007. 1015092 and *Capital Budgeting Under Uncertainty: Project Prioritization*, EPRI, Palo Alto, CA. 2008 (currently in publication). 1016734.

[45] Ittner, Christopher D. and Larcker, David F., "*Coming Up Short on Nonfinancial Performance Measurement*", Harvard Business Review, November 2003.

would seem that these indicators (like the reliability indicators used in the T&D case study) would be a good source for developing a robust value model and associated prioritization attributes.

5.1.4 Integrating Project Ranking and Business Strategy

One important nuclear industry goal is to obtain consistency between project ranking and business strategy and ensure the project planning process integrates with the strategic planning process. In many of the case studies presented, one of the company's principal goals for improving their project prioritization and long range planning processes was to improve the consistency between project ranking and the organization's business strategy. Despite this, the case study information often is not very specific about how to accomplish this goal (in particular, see the IT case study discussion in Section 3).

We do know that solely calculating a cost benefit measure like NPV or IRR certainly will not accomplish this goal because corporation's have more than purely financial objectives. In Section 4, there was much discussion about developing a corporate value model. And in the case studies, the reader can find evidence of prioritization processes which set out to determine the values and their relative importance to the corporation. In essence, a company's ability to succeed in integrating project ranking and business strategy depends on establishing prioritization and decision criteria which reflect the business strategy.

Since business strategy can have many attributes, e.g., financial, business transformation, corporate responsibility, customer satisfaction, etc., it also seems clear that the prioritization process should include the ability to consider multiple criteria. In this regard, the reader should consider the first two generation case studies and the first T&D case study. In those examples, the generation utilities prioritized projects using multiple criteria. Their approach allowed them to focus on the business strategy related prioritization criteria for projects on the cusp. In the T&D case study, a financial measure was used followed by a subsequent evaluation of a reliability measure. In this case study, the reliability measure was a critical measure for two important stakeholders, the regulator and the customer, and thereby reflects other aspects of the organization's business strategy.

5.1.5 Metrics to Evaluate Process Effectiveness

The case studies we reviewed identified few specific process metrics to evaluate the effectiveness of project prioritization and long range planning decisions. In the introduction to the T&D business in Section 3, we identified a metric related to the level of "churn" in long range plans. The churn of the plan can be tracked by a metric such as plan-to-plan variance, and, in this organization, it is an objective to keep this churn threshold below 7%; successfully achieving this objective is considered a strong indicator of successful planning by this organization.

The first T&D case study described a post-project audit process. One of the key goals of the audit was to understand if a project delivered on its stated objectives, and in particular on its reliability goals. Thus, some measure of how well projects delivered on their goals would represent a useful process metric. In the transportation industry, the state of Virginia uses a dashboard to display performance measures on the VA Department of Transportation funded projects and programs; additionally, the dashboard is available for viewing by stakeholders, in this case members of the public.

Another good way to measure process effectiveness is to survey employees performing or otherwise involved in the process. In the pharmaceuticals industry case study, process participant surveys were conducted before and after process implementation to determine potential refinements to the process and measure overall satisfaction of participants. Two of the references for IT portfolio management refer to surveys of process participants.

In Section 4, we describe a number of process improvement techniques that implicitly involve metrics. The maturity index was one such approach. The subsection on improving decision quality in project prioritization suggests a method for measuring process effectiveness. Finally, performing peer reviews of projects not only would benefit the definition and value creation potential of projects, it also could lead to improvements in the prioritization process itself.

5.1.6 Feedback Mechanisms for Continuous Process Improvement

In the above discussion about metrics, we refer to a number of lessons learned that can help enable continuous process improvement. We also referred to the T&D business unit that instituted a post-project evaluation process. At this organization, a project completion audit is conducted that includes two aspects relevant to the nuclear industry[46]:

- Project scope, schedule and budget audit
- Project performance audit

The project scope, schedule and budget audit is performed by the project manager using a lessons learned worksheet. Many nuclear utilities already do these types of audits. For example, utilities often assign a skilled project manager to projects that require extensive engineering or regulatory interaction, or to projects that involve a difficult implementation process or must be "fast-tracked".

Nevertheless, to improve the project prioritization process in a fundamental manner, a utility would have to understand how well its prioritization attributes conformed with real performance improvements. To understand this, a utility would have to identify the expected performance of a project, determine how to measure it, perform the project and see if the predicted performance did indeed occur.

In the T&D case study, the reliability performance audit is done annually; however it does not begin until it is reasonable to expect measurable performance information to become manifest after project implementation is complete. Their reliability performance audit involves an annual review of reliability related assumptions for the project, as well as assumptions and data for the template reliability model. The audit reviews the continuing validity of these assumptions, as well as any assumptions specific to equipment failure rates. Such an audit does depend on a robust valuation model, namely one with the ability to determine how to measure performance. In the case study, the utility built a model based on their internal and external industry studies of reliability performance. In that case, the audit fosters continuous improvement of the model.

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[46] Note we assume that QA/QC processes will ensure that the project is implemented as it was designed to be implemented.

Finally, we recommend that the reader remain aware of developments related to PAS 55, the asset management standard initiated in the United Kingdom. The standard emphasizes continuous improvement of asset management programs. PAS 55 compliance efforts in the UK also may provide useful case study information in the future as the number of assessments and audits lead to insights about UK utility asset management programs.

5.2 Conclusions

In the discussion above, we provided some highlights and summaries of important insights from case studies from other industries and lessons learned from EPRI's Enterprise Asset Management program. And, while these insights and lessons learned are valuable, probably no insight is more important than the studies which found that the companies with the most mature processes and the best measures of value also were the companies that performed the best among their peers.

In "*Coming Up Short on Nonfinancial Performance Measurement*", Christopher Ittner and David Larcker (Harvard Business Review, November 2003), the authors describe the importance of developing and validating causal[47] value models. Based on surveys of 157 manufacturing and service companies, including more than 60 field studies, the authors found that significantly higher return on assets and return on equity were achieved by the twenty three percent of companies which did extensive causal value modeling and validation.

In "*Best Practices in IT Portfolio Management"*, Mark Jeffery and Ingmar Leliveld (MIT Sloan Management Review, Spring 2004), a statistically significant link was found between higher return-on-asset performance and use of the most advanced portfolio management processes. In this study, the authors based their findings on 130 completed surveys of Fortune 1000 CIOs.

Clearly, these studies of business performance improvement show that much is at stake for nuclear utilities, with ample financial and performance incentives to improve the effectiveness of their project prioritization and long range planning processes and techniques.

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[47] A causal value model is a model in which a clear relationship is established between company value and performance indicators.

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PROJECT PRIORITIZATION EXCERPTS FROM THE ERWG LCM GUIDANCE

This Appendix repeats guidance provided in Section 2 of the ERWG Life Cycle Management Guidance issued in September 2008 ("Life Cycle Management Guidance Document for Implementation of the Life Cycle Management Block of AP 913"; R0; Produced by the Long Term Asset Management Subcommittee of the Equipment Reliability Working Group; September 2008). It is presented here to serve as a reference describing the current state of the art practices employed in the nuclear power industry.

Section 2

Project Prioritization Guidance

Purpose

This section of the Life Cycle Management guideline was developed to provide nuclear power plant (NPP) operators with information to support improved project prioritization decision-making with respect to efforts to maintain and improve plant equipment reliability. It was developed by evaluating prioritization processes currently in use at numerous operating NPPs in the United States and Canada. The processes were evaluated by industry experts as part of an initiative of the Equipment Reliability Working Group (ERWG). Based on these evaluations, this guidance document was developed to provide a standard set of practices and recommendations that plant operators can use to evaluate and enhance their processes to evaluate and prioritize projects which impact equipment reliability.

Prioritization processes are intended to allocate resources in a manner that provides maximum benefits to the NPP stakeholders. To achieve this objective, prioritization processes need to allocate available resources (financial, physical and human) to projects across the entire spectrum of activities necessary to ensure long-term safe and economic operation of the NPP. Thus, in addition to projects that address equipment reliability issues, projects that address security, emergency preparedness, information technology and other issues also must be evaluated and prioritized. Hence, the attributes that are considered in the prioritization need to reflect this broad scope and be sufficiently comprehensive to support effective integrated decision-making. The intent of this guidance is to provide a set of attributes that support evaluating equipment reliability projects within this broad perspective so that executive decision-makers are presented with complete and accurate information from which effective resource allocations can be made.

I. How to Use this Guide

This section of the guidance is intended to provide NPP operators with a set of standard characteristics to prioritize equipment reliability projects within the asset management process. These standard attributes are intended to be used as a benchmark to evaluate and enhance plant and fleet long-term planning (LTP) / equipment life-cycle management (LCM) programs.

It is recognized that the long-term operational strategies and the investment decisions necessary for their execution are an integral part of the corporate business planning and executive decision-making process. As a result, the details of the process used to prioritize funding requests for LTP / LCM, including the specific attributes that are evaluated and the degree to which these are weighted in the decision process will be specific to each organization. Additionally, as corporate business strategies change to reflect changed business conditions, the details of the prioritization process (i.e. attributes and their weightings) also will need to be modified to reflect these new circumstances and relative importance of the attributes. As a result, the ERWG views application of this guidance to be an ongoing effort that is periodically evaluated to ensure the plant / fleet prioritization process is aligned with the organization's long-term business objectives.

Within this guidance, prioritization activities are conducted on a set of candidate "projects". The use of the term projects is intended to be interpreted broadly. Thus, for the purposes of this guidance, the term project is defined as follows: a discrete working objective requiring budget and business planning support to track costs and ensure completion.

Application of this guidance is accomplished by performing four specific activities.

(1) Review plant / fleet strategic objectives and existing project prioritization guidance applicable to LTP / LCM.
(2) Review recommended practices identified in this guidance against existing program and plant / fleet strategic objectives. Identify any gaps.
(3) Incorporate attributes identified in the gap analysis to the existing prioritization process to add value to plant / fleet.
(4) Verify category / attribute scoring & weighting support corporate / management strategic objectives. Modify category / attribute scoring & weighting as appropriate.

Guidance on core attributes (by category) that are recommended for inclusion in a LTP / LCM prioritization process is provided in Section II. These core attributes are those that were identified by the industry experts as being significant contributors to the decision-making process. Thus, these provide a minimum set of attributes that the ERWG recommends be included in a prioritization process that supports an effective LTP / LCM program. Section III provides a list of secondary attributes that are used in one or more of the prioritization processes at the NPPs that provided data for this evaluation. These attributes were evaluated by the industry experts that developed this guidance and were identified as being of lesser importance than those included in the core list presented in Section II. Thus, they constitute a listing of optional attributes that a NPP operator should evaluate to determine those which add sufficient value to include in their prioritization process.

As noted previously, it is recognized that long-term operational strategies are developed as part of the corporate business planning and executive decision-making process. Thus, this guideline does not provide specific guidance on selecting weights and scores to be assigned to each attribute in the evaluation process as these will be specific to each organization. However, because the weighting and scoring applied to the individual attributes are critical elements in the evaluation process, this document provides a brief discussion of generic guidance on methods to select appropriate attribute weightings and scorings in Section IV. The key success criteria is to have a set of attributes that is clear, easy to interpret and can be applied consistently at the plant or fleet level.

II. Core Attributes by Category

This section presents a listing of attributes, currently in use at one or more plants, that were identified as being important considerations in the prioritizing of projects that impact long-term equipment reliability. To facilitate the evaluation and ranking process, these attributes are grouped in the following categories. (Note that the groupings below were developed to provide a mechanism to review and evaluate the attributes that are considered important for project prioritization. It is recognized that individual NPPs may utilize alternative groupings in their prioritization processes.)

A. Nuclear / Industrial / Radiological Safety

B. Plant Operation Impact

  i. Plant Generation

  ii. Plant Condition / SSC Health

  iii. Operational flexibility

  iv. Operational Risk

C. Regulatory Impact

D. Human Performance

E. Financial (Costs / Savings) Impact

F. Other Business Impacts

  i. Strategic Value

  ii. Uncertainties

  iii. Dependencies

  iv Risk/Consequences

Since the specific scoring and weighting associated with each category and attribute are specific to each organization's values and business objectives, no specific guidance is provided in this section on their specification. However, within each category the attributes are presented in the order in which the industry experts prioritized them from the perspective of an equipment reliability viewpoint. Thus, one can consider the listing of the attributes to represent a rank ordered list and can serve as a point of calibration against which individual NPP operators can compare their weighting and scoring systems.

Nuclear Safety

- Project addresses identified nuclear safety issue.
- Project provides enhanced safety margin (e.g. reduced core damage frequency, improved margin to fuel thermal limits, etc.).
- Project addresses identified issue in reactivity management.
- Project will provide additional safety margin or accident mitigation capability.

Industrial / Radiological Safety

- Project addresses identified personnel or industrial safety issue.
- Project addresses personnel dose reduction objectives.

Plant Operation Impact

- Project addresses issue that has resulted in plant trip / derate or resulted in extended outage duration.
- Project addresses issue identified in SSC health action plan.
- Project addresses identified SSC related threat to plant operation (e.g. SSCs with identified degraded performance, lack of ability to obtain replacement parts, etc.).
- Project will result in improved plant generation capability / unplanned capacity loss factor.
- Project addresses design deficiency / weakness that has high likelihood of impacting plant operation.
- Project will provide enhanced monitoring / diagnostic capability for critical SSC(s).
- Project will result in improved industry monitored SSC unavailability performance indicator and reliability indicators (e.g. ER Index).

Regulatory Impact

- Project addresses issue associated with NRC identified order or finding.
- Project addresses issue associated with NRC commitment.
- Project addresses resolution of 10CFR50 Appendix B issue or 10CFR50.65 maintenance rule (a)(1) performance issue.
- Project addresses issue associated with finding / order identified by or commitment to other government agencies (e.g. EPA, OSHA, etc.).
- Project addresses commitment to other government agencies (e.g. EPA, OSHA, etc.).
- Project addresses INPO / WANO Area for Improvement (AFI).
- Project results in significant improvement to regulatory margin.

- Project results in significant improvement to regulatory required program (e.g. maintenance rule, fire protection, emergency preparedness, etc.).
- Project addresses issue that has resulted in excessive unplanned technical specification entries or in significant technical specification improvement.

Human Performance

- Project results in reduction in likelihood for human error associated with critical activities (e.g. critical operator actions, elimination of error traps, alarm reduction, etc.).
- Project results in improved organizational effectiveness (e.g. productivity improvements, process enhancements, site facility upgrades, etc.).
- Project results in elimination of / reduced operator work-around.
- Project addresses programmatic deficiency in plant support program (e.g. radiation protection, emergency planning, security, chemistry, work management etc.).

Financial Impact

- Project results in significant financial payback (as measured by NPV, IRR, BCR, ROI etc.).
- Project results in reduced O&M costs.
- Required to meet generation targets.

Other Business Impacts

- Project results in significant reduction in outage costs / duration.

In addition to evaluation of the individual attributes listed above, the process of ranking individual projects needs to address two additional elements. In the survey of NPPs that supplied data for development of this guideline, these two areas were the least represented in existing processes. The first area is evaluating the degree to which a project will contribute to or achieve strategic objectives. This element is important to address because it presents opportunities to circumvent the process. For those processes that do not address this element of prioritization, it also requires significant management attention to ensure the prioritization outcomes are aligned with strategic objectives. Although in many instances this is achieved by direct management evaluation, application of a structured approach to align these strategic values and objectives with the attribute weightings and scoring would simplify the process and provide greater transparency to all stakeholders.

The second element that needs to be addressed is the need to evaluate project dependencies and risks. The most significant dependencies that should be addressed are timing and continuity dependencies for projects that are executed in multiple stages or over multiple budget cycles. However, other dependencies and risks also can have a significant impact on the likelihood that a project will be able to achieve the anticipated outcomes. As a positive example, the synergies between two projects may be such that although neither one, by itself, provides sufficient value to warrant funding, the combination of the two projects may result in enough additional value to increase the ranking of the combination. As a counter example, if a project represents a first of a kind application, its elevated risk level may make it sufficiently less desirable than another less valuable but more certain project. Similar to the case of ensuring alignment with strategic objectives, this element typically is addressed by direct management evaluation. As in the case of that issue, inclusion of these considerations within the structured approach would simplify the process and provide greater transparency of outcomes.

Finally, it should be noted that many plant issues are complex and solutions may be evaluated and implemented in phases and over multiple budget cycles. As these solutions are developed, it often is necessary to allocate resources to evaluate alternative solutions. To address this issue, it is recognized that a phased approach to prioritization that includes both initial screening and full evaluation criteria is warranted. It is recommended that the screening process evaluate the core attributes described in this section to ensure that outcomes of the screening process are compatible with and support the full prioritization process.

III. Secondary Attributes

This section provides a listing of attributes that are in use at one or more plants as specific additional items considered in their prioritization process. NPP operators should consider these optional attributes for inclusion in their prioritization process based upon organizational strategies, goals and objectives.

One should note that many of the attributes presented in this section represent a lower level of detail than the core attributes presented in Section II. As one example, the attribute “project results in improved plant heat rate or thermal efficiency” in the Plant Operation Impact category is similar to the core attribute “project addresses issue that has resulted in plant trip / derate or resulted in extended outage duration”. For these attributes of this type, NPPs can use this listing to verify they are included in the evaluations of the applicable respective core attribute; or they can be included as specific additional attributes to provide more explicit criteria or enhanced emphasis.

Nuclear Safety

- Project addresses issue associated with or improves metric that measures nuclear safety (e.g. nuclear safety index, core damage frequency, etc.).
- Project addresses identified issues associated with configuration management.

Personnel / Industrial Safety

- Project addresses issue associated with or improves metric that measures personnel / industrial / radiological safety (e.g. lost time accidents, radiation exposure index, radioactive waste processing, etc.)
- Project addresses issue identified with or improvement to safe work environment.
- Project addresses issue identified with or improvement to plant / corporate safety initiative.

- Project reduces off-site emissions.
- Project reduces the potential for environmental incidents.

Plant Operation Impact

- Project results in improved plant heat rate or thermal efficiency.
- Project results in improved plant material condition.
- Project results in removal of a temporary plant modification.
- Project addresses repeat equipment failures.
- Project results in reduced maintenance burden.
- Project results in reduced maintenance backlog, rework, replacement or refurbishments.
- Project will provide improved performance or enhanced monitoring / diagnostic capability for non-critical SSC(s).
- Project will address abandoned plant equipment.
- Project eliminates critical equipment failures.
- Project eliminates challenges to operations.

Regulatory Impact

- Project addresses NRC significance determination process (SDP) greater than green or cross-cutting finding.
- Project addresses resolution of longer-term regulatory concern (e.g. adverse maintenance rule (a)(2) SSC performance trend).
- Project results in significant improvement to the corrective action program (CAP).
- Project addresses insurance issue.
- Project addresses actions to address company stop work orders.
- Project addresses internal company commitment.

Human Performance

- Project results in improvement in plant staff skills.
- Project results in improved plant staff morale.
- Project results in improved work environment.
- Project results in software / hardware improvements.

Financial Impact

- Project results in reduction in avoided or incremental costs (including overhead costs).

Other Business Impacts

- Project results in reduced radioactive waste generation.
- Project results in reduced personnel radiation exposure (ALARA).

IV. Guidance for Selecting Attribute Weighting and Scoring

In evaluating investment alternatives, NPP decision-makers must evaluate the benefit – cost tradeoffs against a wide variety of different criteria that involve numerous stakeholders. Many of these decision attributes are highly qualitative in nature. To provide maximal value to all of the stakeholders, corporate executives develop a set of strategic goals and objectives that are intended to govern decision-making. In the prioritization of projects at NPPs, these corporate strategic objectives should be used to develop the attribute weightings and scorings used to characterize the candidate projects.

For a ranking method to be effective and achieve broad acceptance by all stakeholders, it should possess the following characteristics:

- demonstrable alignment with corporate values and strategic objectives,
- clear and concise guidance on input data required,
- straightforward execution of analysis so that outcomes are repeatable and understandable,
- flexibility to account for changing conditions (e.g. changes in regulatory requirements, corporate strategies, etc.).

The goal is to provide a ranking method that can be applied in a straightforward and consistent manner to evaluate proposed projects and yield ranking results that support ensure plant resources are allocated in a manner that supports achieving corporate objectives as effectively and efficiently as possible.

In the literature, several structured methods to develop ranking systems to achieve these objectives are described. However, most of these methods have the following items in common:

- employment of a tree or hierarchy of company-specific value attributes,
- use of measurable anchored scales to provide a numerical value for each attribute,
- development of numerical weights that reflect the relative importance of each attribute for achieving the enterprise's goals,
- a straightforward mathematical technique for calculating overall project scores that are used to rank the set of projects.

One such structured process that has been found useful to achieve these objectives in a wide variety of applications in many different industries is the Analytic Hierarchy Process (AHP). Additional information on this approach and its application to utility / NPP decision processes is presented in the following EPRI reports:

- 1007385, "Project Ranking Method for Nuclear Power Plants: Prioritizing Proposed Capital and O&M Projects", (2003),

- 1012954, “Pilot Application of Enterprise Project Prioritization Process at Nebraska Public Power District”, (2006)

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EPRI PROJECT PRIORITIZATION REPORTS

The following describes EPRI reports that provide direct guidance or contributing technology for project prioritization. Nuclear reports are organized by topic areas and the remaining reports are organized by business area.

Nuclear Asset Management

1000636 EPRI Nuclear Asset and Project Evaluators Motivation, Concepts and Way Forward

1001877 Project Prioritization System - Methodology Summary

1002932 Guideline for Assessing Maintenance Effectiveness – A Self Assessment Guideline for Nuclear Power Plants

1003050 Nuclear Power Financial Indicators for a Competitive Market

1006268 Risk Informed Asset Management (RIAM) Development Plan

1007071 Technology Management Benchmark Study – Phase 2 Volume 1 Executive Summary

1007385 Project Ranking Method for Nuclear Power Plants – Prioritizing Proposed Capital and O&M Projects

1009615 Equipment Reliability Implementation Strategy – A Strategy for Identifying and Prioritizing Nuclear Power Plant Equipment Reliability Improvement Opportunities and Actions

1009632 Risk Informed Asset Management (RIAM) – Method, Process, and Business Requirements

1011925 2005 EDF/EPRI Collaboration on Life Cycle Management and Nuclear Asset Management

1012527 Information Technology for Enterprise Asset Management An Assessment Guide

1012954 Pilot Application of Enterprise Project Prioritization Process at Nebraska Public Power District (NPPD)

1013488 Leading Business Performance Indicators for Nuclear Power Enterprises

1013576 Nuclear Asset Management (NAM) Toolkit – Definition and Industry Survey

1015091 Nuclear Asset Management (NAM) Process Model

1015092 Program on Technology Innovation – Project Prioritization Optimization Under Budget Uncertainty

1015306 Proceedings of the 2007 Nuclear Asset Management Community of Practice Annual Meeting

1015385 Program on Technology Innovation – Enterprise Asset Management Executive Primer

Generation Risk Assessment

1011924 Generation Risk Assessment (GRA) at Cooper Nuclear Station

1007386 Introduction to Simplified Generation Risk Assessment Modeling

1008121 Generation Risk Assessment (GRA) Plant Implementation Guide

1013575 Comparison of Qualitative (AP-913) and Quantitative (Generation Risk Assessment) Equipment Reliability Assessment Technique

Strategic and Long-Range Planning and Life Cycle Management

LcmVALUE Version 1.5 – LCM Planning for SSC-LCM Planning Tool, EPRI Software 1003455, August 2002.

Life Cycle Management Economic Tools Demonstration, EPRI Report 1007931, March 2004.

EPRI Nuclear Asset and Project Evaluators, Motivations, Assets and a Way Forward, EPRI Report 1000636, 2000.

EPRI TR-101162: Long-Term Capital Planning Considering Nuclear Plant Life-Cycle Management. September 1992.

EPRI TR-103054: A Resource Guide to Nuclear Plant Life-Cycle Management. November 1993.

EPRI TR-104326: Nuclear Plant Life Cycle Management Economics. April 1995.

EPRI TR-104751: Utility Activities for Nuclear Power Plant Life Cycle Management and License Renewal. May 1995.

EPRI TR-106109: Nuclear Plant Life Cycle Management Implementation Guide. November 1998.

EPRI TR-108984: Product Life Cycle Management – Adapting the Best Practices of Other Industries. November 1997.

EPRI TR-110676-V1: Life-Cycle Decision Making – Volume 1: Getting Started. September 1998.

Generation Asset Management

Five Essays on Modern Asset Management Practice. EPRI, Palo Alto, CA. 1997. TR-108818.

From Regulation to Competition: Managing the Corporate Portfolio for Maximum Value Creation. 1996. EPRI, Palo Alto, CA. TR-106216.

Strategic Asset Management: Helping Electric Utilities Translate Vision into Value. EPRI, Palo Alto, CA. 1994. TR-102730.

Power Delivery Asset Management

The tools and methodologies described in the following EPRI reports can be used to help develop a PDAM implementation:

Summary of Asset Management Tools Currently Available for T&S Application. EPRI, Palo Alto, CA. 2003. 1002132.

Pilot Application of Enterprise Project Prioritization Process at Nebraska Public Power District (NPPD). EPRI, Palo Alto, CA. 2006. 1012954.

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

P2: Project Prioritization System, Version 3.0. EPRI, Palo Alto, CA. 2005. 1010741.

Value Modeling and Measuring Key Performance Indices for Power Delivery. EPRI, Palo Alto, CA. 2007. 1012502.

Value Modeling for Reliability of Distribution and Transmission Systems. EPRI, Palo Alto, CA. 2006. 1012501.

Asset Management Toolkit Modules: An Approach for Risk-Informed Performance-Focused Asset Management in the Power Delivery Industry, Report 1011365 – June 2005

Guidelines for Power Delivery Asset Management: A Business Model for Program Implementations," Report 1008550 – November 2004

Project Prioritization System, Methodology Summary, Report 1001877, December 2001

EPRI TR-106216: From Regulation to Competition – Managing the Corporate Portfolio For Maximum Value. March 1996.

EPRI TR-104917: Investing Resources to Create Value – The Portfolio Approach to Capital and O&M Budgeting. March 1996.

Guidelines for Power Delivery Asset Management. EPRI, Palo Alto, CA. 2005. 1010728.

Guidelines for Power Delivery Asset Management: Long-Range and Strategic Planning. EPRI, Palo Alto, CA. 2006. 1012496.

Asset Management Practices Survey, 1013813, EPRI, Palo Alto, CA: 2008.

Enterprise Asset Management

Information Technology for Enterprise Asset Management, An Assessment Guide, 1012527, EPRI, Palo Alto, CA: 2007.

Information Technology for Enterprise Asset Management, Utility Examples and Lessons Learned, 1013860, EPRI, Palo Alto, CA: 2008.

Program on Technology Innovation: Enterprise Asset Management – Executive Primer, 1015385, EPRI, Palo Alto, CA: 2007.

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Electric Power Research Institute
3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com