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Power Delivery Asset Management Decision Making Process

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PRODUCT DESCRIPTION

Asset management processes for electric utility fossil and nuclear generation were formalized and widely used during the 1990s. However, transmission and distribution asset management processes have been slower to evolve because of wide diversity in power delivery organizations, many dimensions of potential value, varying perceptions of value by various stakeholders, the need to accommodate uncertainty, and the need to align the actions of individuals with higher level corporate objectives.

Therefore, the successful implementation of power deliver asset management (PDAM) requires specialized analytical tools and processes. Of particular importance and value are those tools that can assist in dealing with asset maintenance, repair, and replacement decisions and planning for a large base of aging assets.

Results and Findings

This report reviews the PDAM decision process in order to assist in the identification and specification of the decision support tools and analytics required for best-practice power delivery asset management. The report documents the results of a preliminary effort to develop a decision support framework.

Challenges and Objectives

Operations, maintenance and asset managers are increasingly asked to develop quantifiable justifications for a multitude of complex decisions associated with power delivery. The rationale for such decisions can be improved with the development of appropriate decision support tools.

Applications, Value, and Use

The goal of this project is to provide decision support tools that help utilities improve their prioritization of capital and maintenance decisions and, therefore, their return on investment. A logical, data-driven decision support methodology would help to optimize the repair-versus-replacement decision process, ensure the use of consistent criteria throughout a power delivery organization, and make better use of limited utility resources.

EPRI Perspective

This work is part of a suite of asset management guides and equipment-specific analytics, developed by Electric Power Research Institute (EPRI), to assist in dealing with asset maintenance, repair, and replacement decisions and planning for a large base of aging assets. The work presented in this report is intended to complement earlier EPRI work that defines the principles and practices of PDAM and extend them to a broad discussion of the decision process.

Approach

This report reviews the PDAM decision process in order to assist in the identification and specification of the decision support tools and analytics required for best-practice PDAM. The report also documents the results of a preliminary effort to develop a decision support framework.

Keywords
Power delivery
Asset management
Decision processes

CONTENTS

1 THE PDAM DECISION PROCESS

This report reviews the PDAM decision process in order to assist in the identification and specification of the decision support tools and analytics required for best practice power delivery asset management. The report documents the results of a preliminary effort to develop a decision support framework.

Operations, maintenance and asset managers are increasingly asked to develop quantifiable justifications for a multitude of complex decisions associated with power delivery. The rationale for such decisions can be improved with the development of appropriate decision support tools. The ultimate goal is to provide decision support tools that help utilities improve prioritization of capital and maintenance decisions and thus the return on investment. A logical, data-driven decision support methodology would help to optimize the repair versus replacement decision process, assure the use of consistent criteria throughout a power delivery organization, and better utilize limited utility resources.

This work is part of a suite of asset management guides and equipment specific analytics developed by EPRI to assist in dealing with asset maintain, repair and replace decisions and planning for a large base of aging assets. The work presented in this report is intended to complement earlier EPRI work on defining the principles and practices of power delivery asset management and extend them to a broad discussion of the decision process.

Introduction

Many power delivery organizations have initiated the application of asset management practices to their business units. At its best, asset management provides the ability to understand and manage the trade-offs among risk, cost, and service levels in order to optimize both financial and service performance. Although proven and in wide use in many industries, including the power generation sector, effective asset management processes have been less widely applied in the power delivery sector.

EPRI has recognized that, in today's business environment, power delivery system owners and operators need strategic and tactical asset management tools and processes properly adapted to their requirements. As a result, EPRI has undertaken a series of projects to assist utilities in adapting broad asset management principles to power delivery asset management (PDAM) practices. One area key to PDAM success is the decision process. Obviously decisions are made at many levels in a power delivery organization and the decision's impact can range from trivial to monumental. Furthermore the issues and technical knowledge required could include any of the many aspects of system design, operation, maintenance, or replacement. Nonetheless, there are certain principals and process that should be uniformly applied to insure that PDAM decisions are made in accordance with best practice asset management. The work presented in this report is intended to complement earlier EPRI work on defining the principles and practices of power delivery asset management and extend them to a broad discussion of the decision process. Successful implementation of power deliver asset management (PDAM) requires specialized analytical tools and processes. Of particular importance and value are those tools that can assist in dealing with asset maintain, repair and replace decisions and planning for a large base of aging assets.

Utilization of consistent decision making processes across a power delivery organization, including all operating units can significantly improve the results of applying asset management. This report introduces the fundamental elements and concepts of a uniform PDAM decision process in a power delivery asset management context. The report builds on those concepts to establish the decision support tools and data requirements for PDAM implementation.

- Successful application of "best practices" asset management requires the consistent decision making processes described in this report. These guidelines present an introduction and explanation for those interested in improving their PDAM processes. Special attention and insights are provided for issues that may impact many power delivery organizations over the next three to ten years.

Scope

The contents of this report are tailored for use by those involved in the management of electric transmission and distribution organizations. Chapter 5, Special Considerations for Power Delivery Decision Processes, directs particular attention to addressing emerging issues that may have significant impact on some power delivery organizations. Such issues include:

- Power delivery project requirements for increasingly longer planning horizons and greater pre-planning due to environmental and other regulatory constraints lengthening the time from project initiation to completion.
- Approaching "asset walls" (significant concentrations of particular assets nearing the end of their service life) as the result of major grid expansion in the 1960's and 1970's.
- Long lead times for large power transformers and other assets because of reduced domestic manufacturing capacity and increased worldwide demand.
- New technologies that may affect future power delivery equipment and system design.

Most power delivery organizations or their parent companies have corporate groups that deal with issues such as regulatory relations, mergers and acquisitions, market positioning, and responses to shifting competitive forces similar concerns. In the language of asset management (reviewed in more detail in Chapter 2) these areas are the sole responsibilities of the asset owner. This report addresses issues that are a step below in the corporate hierarchy and that are concerned specifically with the specialized tasks of providing safe, reliable and economic power delivery services. Again, in the language of asset management, this report addresses decisions that occur at the intersection between the asset owner and the asset manager.

Power delivery equipment owners and operators have become aware of some of the limitations of conventional business approaches. Depending on circumstance and degree, these limitations often include preconceived budgets; emphasis on costs rather than stakeholder values; focus on shorter-term equipment issues rather than long-term global issues; inconsistent business cases; difficulty in compiling and up-dating asset data; inadequate horizons for long-term planning; reliance on projection of historical results for future performance; and insufficient attention to risk and vulnerabilities throughout the remaining asset operating life. Power delivery asset management incorporating well constructed decision processes can help address these limitations.

Decision Timeframe

In a power delivery asset management (PDAM) approach, resource allocation decisions are tightly linked to policy objectives, and based on a quantitative understanding of the results obtained for all expenditures. Many operations and maintenance decisions are relatively straight forward and require no additional formality. Other common power delivery decisions such as repair versus replace may benefit form a more consistent process grounded in asset management principals and uniformly applied across the organization.

Decisions beyond the normal O&M categories involve two areas of concern. The first is to make decisions about issues that are well defined and very likely to appear (e.g. the replacement of a circuit breaker due to increased short circuit availability) but do not impact current operations. This is a long-range decision with well defined objectives and alternatives. The second is to identify both possible future changes in goals and potential issues that may impact the achievement of current goals moving forward or any future goal and to decide what actions should be taken now or contingency plans developed to mitigate risks in archiving those future goals. This is the sort of PD decision where an established process can be most beneficial.

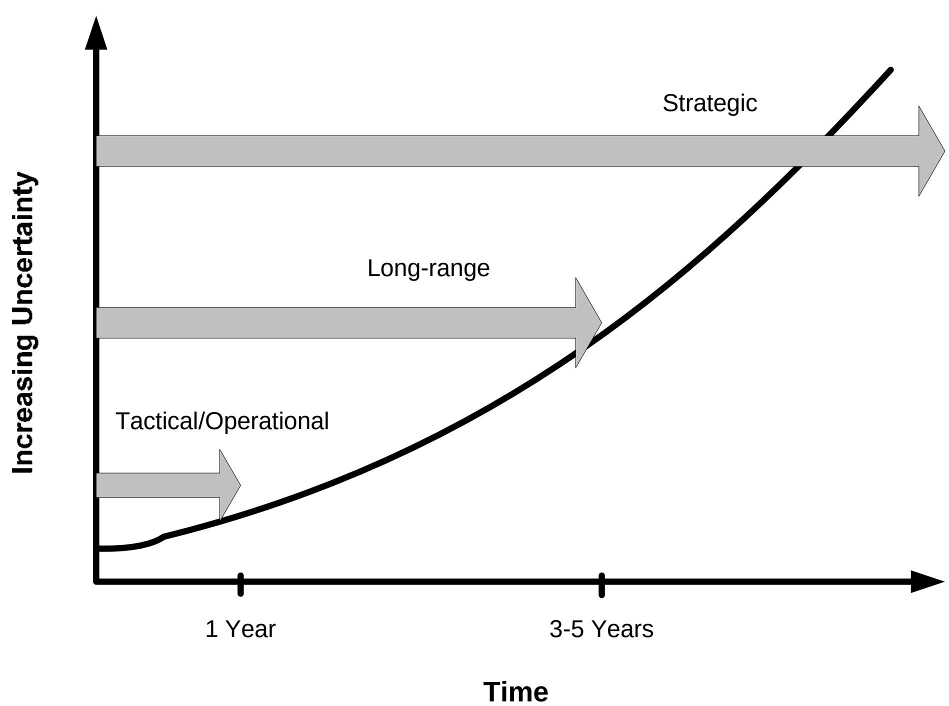

Figure 1-1.
The Relationship Among Decision Timeframes and Degree of Uncertainty. (Adapted from

***Guidelines for Power Delivery Asset Management Long-range and Strategic Planning:* EPRI, Palo Alto, CA: 2006 1012496)**

Traditionally, power delivery organizations have engaged in two broad classifications of long-range decisions. At the most senior level (Asset Owner level in PDAM terminology), decisions are generally directed at high level issues such as corporate growth and financial concerns, regulatory relations, mergers and acquisitions. At the operations level, utility System Planning departments have developed sophisticated load forecasting processes for planning capacity additions many years into the future. Both these areas deal with a level of uncertainty but are not the focus of this report. Other operating departments may engage in some forms of longer decisions but it is rare for such plans to have a horizon greater than the next capital budget cycle.

In general, power delivery system planning and power delivery system operations and maintenance activities have been relatively independent with different criteria and different cultures but focused mainly on current problems and issues. Successful implementation of PDAM requires development of another form of decision process grounded on asset management principles with a sufficiently integrated scope and adequate time horizon. This report will assist utilities with this development by providing appropriate definitions and explanations.

Decision Classifications

There are three broad classifications of decisions that will be discussed throughout this report.

Operational (also called Tactical) decisions are concerned with how to get things done in the near term and with the resources needed (people, money, facilities, time, and information) to carry out identified tasks. Operating decisions deal with how to carry out programs for which resources have been allocated (that is budgeted, ideally through PDAM review and prioritization) to achieve some specific, well-defined objective. These are the decisions that drive day-to day activities.

Long-range decisions extend in time beyond the current budget cycle and concern expected activities for which resources have not been firmly assigned. Long-range decisions are largely an extrapolation of the present mission, issues, and opportunities for a future expected to be essentially similar to the present. Long-range decisions are often developed at the operational level in accordance with unchallenged assumptions and objectives based on reasonably predictable trends. Both operational and long-range decisions are based on current conditions and tend to be analysis driven, for example, decisions for a particular piece of equipment on a three year maintenance cycle. As long-range decisions extends out in time and future circumstances become less certain, the boundary between strategic and long-range considerations blurs. Similarly, assumptions that may have appeared almost certainties can change quickly. Consequently, the distinction between the two can be arbitrary and in fact misleading. This text will treat long-range decisions as a subset of strategic decisions.

Strategic decisions address what should be attempted and identifies what objectives the programs and activities of the organization should be striving to achieve in the long term. They tend to be more qualitative and idea driven than long-range decisions. Strategic decisions should be more anticipatory and exploratory. The difference between long-range and strategic is not just a matter of a longer horizon. Adding 10 years to an existing R&D budget by accounting for inflation may make it a long-range decision but not necessarily a strategic decision. Considerations and assessments of technology trends, among other issues, would be required in a strategic R&D decision. Another distinction between strategic and long-range decisions is that of breadth. Strategic decisions assumes changes; explores future alterations in missions and customers' needs; considers a variety of trends that may impact the organization; considers opportunities and threats both internal and external to the organization; and seeks possible new future issues and alternative strategies to resolve them. Also, while strategic decisions will attempt to identify future desired outcomes, they will not provide a detailed decision to achieve them. Strategic decisions offer basic directions or courses of action but not operating decisions.

Over time strategic decisions, or parts of a multiyear decision process, may evolve into long-range or tactical decisions and long-range decisions, or parts of a multiyear decision, may become tactical decisions. All decisions that reach the implementation phase are, by definition, tactical (operational) decisions. It is at this phase where priorities are established and resources committed. This evolution is illustrated in Figure 2-1.

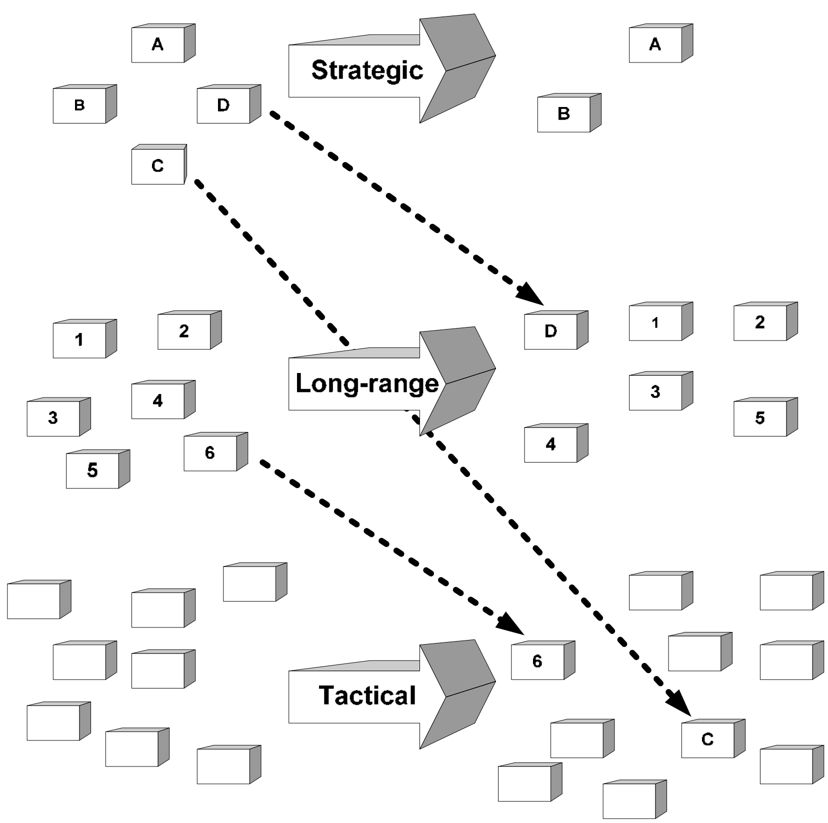

Figure 1-2
Over Time Strategic and Long-Range Decisions May Become Tactical Decisions for Execution.
(Adapted from *Guidelines for Power Delivery Asset Management Long-range and Strategic Planning:* EPRI, Palo Alto, CA: 2006 1012496)

Well executed decision processes can have broad implications for the organization's management and ultimate success. Of course, these three classifications of decisions – operational, long-range and strategic - do not stand alone. A well-managed organization has a continuum of processes developed in an integrated, iterative structure.

Report Organization

These Guidelines include the following topics:

- Introduction
- PDAM principles
- The decision process
- Application issues
- Special consideration for power delivery planning
- Conclusions and recommendations

References

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

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INTRODUCTION TO POWER DELIVERY ASSET MANAGEMENT PRINCIPALS

For the foreseeable future, utilities will need to manage an array of potentially conflicting business objectives, including the needs to maintain competitive economic performance, improve customer satisfaction, maintain high reliability, address regulatory uncertainty, and comply with increased environmental regulation. The result is that many utilities are considering or have moved towards implementing formal asset management concepts and driving decision-making based on minimizing equipment life-cycle cost and maximizing benefits. A structured asset management approach has been successful in many other industries and, when properly adapted to utility needs, can provide the processes and tools to develop the most effective programs for building, operating and maintaining today's power delivery infrastructure.

Power Delivery Asset Management begins with the fundamental premise that all asset management decisions made by utilities should contribute to stakeholder values, as set forth in the organization's goals and policies. PDAM applies this premise in decision processes at every level of the organization. The resulting alignment of decisions with criteria and value measures derived from the asset owner's or senior management's direction ensures that every asset management and resource allocation decision consistently supports the organization's strategic objectives and delivers value to the stakeholders.

This chapter describes the principles and fundamental process of Power Delivery Asset Management in order to provide the background and perspective for understanding PDAM Long-Range and Strategic Planning. Much of the material in this chapter is derived from *Guidelines for Power Delivery Asset Management*[1] (EPRI Report 1010728) and those interested in more detail are referred to that document.

The concept of asset management has been fundamental to the business of electric utilities throughout their history. Companies have always endeavored to manage their assets, employees, capital, and equipment to deliver as much perceived value as possible, and these efforts have been highly successful. However, several aspects of the traditional ways of conducting business in the electric power industry have changed. Many organizations have unbundled traditional vertically integrated utility functions via the sale of assets or entire operations, or by redefining roles and responsibilities (see Figure 2-1). In some circumstances, the roles are assigned to different enterprises, while in others; organizations within the same enterprise now perform these functions. Formal service level agreements have been established to define the roles and obligations of the three parties. Even where no separation has occurred, recognizing these distinct roles is helpful when exploring asset management concepts.

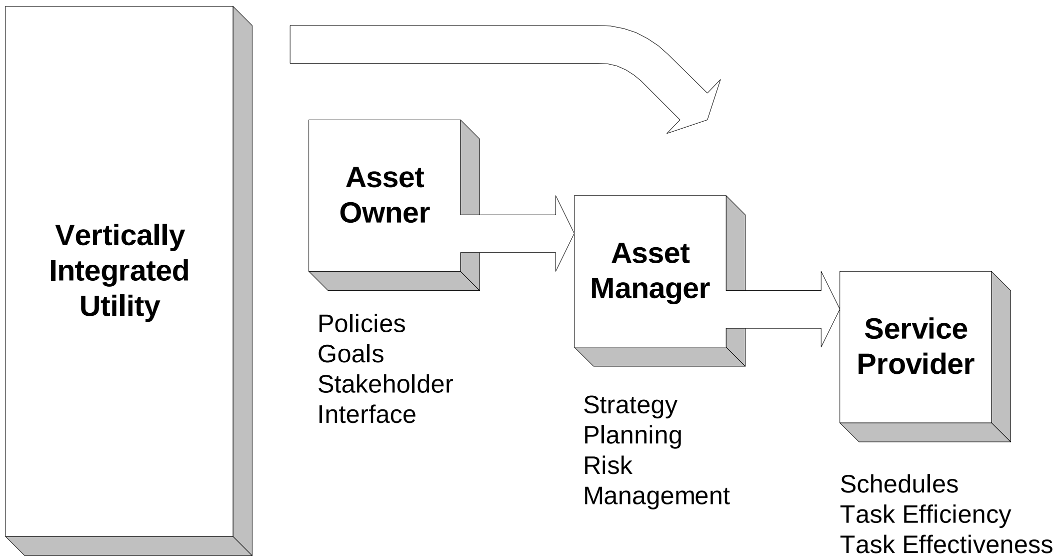

Figure 2-1
Unbundling of Utility Management Roles

Each of the distinct functions in Figure 2-1 has a well-defined role. The "asset owner" is the regulatory license-holder represented by the highest levels of management within the organization that owns or, in the case of governmental agencies, directly controls the assets. The asset owner may or may not be a part of the organization that operates and maintains the assets. Owners directly interact with key stakeholders (e.g., customers, shareholders, regulators, employees and financial agencies) and asset managers. The asset owner sets the business goals and policies, parameters of risk, cost and performance, and the budget for the organization. For example, the asset owner sets annual capital and operating budgets, customer satisfaction measures, and fuel mix risks. When asset management practices are applied in an organization below the enterprise level – an operating unit for example, the senior management to which the organization reports carries out the role of asset owner. (For convenience, this report applies the term "asset owner" to both cases.) The asset owner determines the operating context for the asset manager, focusing on corporate governance and goals, regulatory issues, and other stakeholder relationships.

The "asset manager" develops asset strategy and policy and directs risk management, investment and maintenance planning (not work scheduling), and contract management. The asset manager sets the policies and procedures for the service provider(s) and decides how and where money is to be spent for both capital and maintenance. For example, the asset manager sets feeder outage goals, equipment maintenance intervals, and replacement criteria. In short, the asset manager decides what to do and in which budget cycle to do it.

The "service providers" are then able to focus on core skills of scheduling personnel to deliver programs efficiently and effectively to meet defined service levels. They provide and schedule resources to perform work on the assets. For example, service providers set maintenance staffing levels, tool requirements, and work schedules. Rather than decide where or how to invest budgets, the service provider decides *how* to do work.

As utilities develop these new business models and the technology to support their engineering expertise to meet the emerging challenges, there has been a gradual change in focus towards power delivery asset management practices. However, asset management is about more than the maintenance or capital investment issues that are usually the first centers of attention. At its best, asset management represents the ability to understand and manage the trade-offs between risk, cost, and performance in order to optimize the financial and service performance of the three distinct roles – asset owner, asset manager, and service provider – that result from a fundamental approach to managing assets.

What is an Asset?

An asset is any resource that is important to an organization's functions and requires management. The organization's assets are used to service and supply end users or to facilitate performing such services. Asset owners acquire, operate, and maintain assets to support service delivery. Therefore, an asset possesses service potential or future economic benefit. In the power delivery industry, physical assets such as transmission and distribution system equipment are the most commonly considered. However, the more comprehensive application of asset management principles might also consider time, people, data and knowledge, and know-how to be assets. Fundamentally, an asset has value that persists, and often changes, over time. This implies that assets have both a useful and an economic life, which may not coincide in length. For practical purposes, only assets with significant value are considered in the asset management process. The management of financial assets is not within the scope of PDAM.

What is Asset Management?

Many formal definitions and approaches to asset management have been developed. At its most basic level, asset management is a fundamental business activity that involves the effective use of resources to create value. However, such a description is not particularly helpful in understanding PDAM. Asset management is difficult to define comprehensively simply because it has so many dimensions. Asset management is simultaneously a business philosophy, a process, and a set of technical tools.

As a business philosophy, asset management:

- Represents a performance-based approach to managing infrastructure that is strategic and proactive
- Places a premium on collecting and understanding information from all aspects and all departments dealing with assets
- Is holistic and may be applied broadly to all functional areas of an organization, or may be targeted to particular areas
- Is driven by policy goals and objectives based upon performance measured objectively
- Assumes a long-term view of infrastructure performance and cost
- Is forward looking and seeks to predict and anticipate

- Is pervasive, affecting the business practices of every organizational element involved in the functions to which it is applied

As a process, effective asset management:

- Has executive support
- Translates policies and plans into optimized investment strategies, and translates investment strategies into optimized program delivery and procedures
- Requires policy-driven, performance-driven choices and decisions on allocating and applying resources
- Requires that investment and decisions on allocating resources are based on explicit tradeoffs between projects, programs, or strategies
- Requires that risks are fully assessed and managed
- Develops organizational roles and responsibilities regarding asset management
- Promotes consistent practices across various organizations within an enterprise
- Documents plans (for normal operations and responds to unexpected events and changing circumstances) that maintain focus on goals and objectives)
- Is interdisciplinary, combining both engineering and economic tools and processes so that business functions become an integral element of operations
- Requires effective communication within and outside the organization, and established mechanisms for performance review and adjustments to correct for deviation from desired results

As a set of technical tools, asset management:

- Requires effective management systems
- Requires the best available, current, and accurate information on assets and asset performance
- Requires well-developed decision support analyses for evaluating tradeoffs and prioritizing actions

Formal Definitions

Numerous organizations have published formal definitions for the asset management process. Following the recent development and adoption of infrastructure asset management, most definitions originate from overseas organizations concerned with public service oversight.

Definitions include the following:

- "Systematic & coordinated activities and practices through which an organization optimally manages its physical assets and their associated performance, risks and expenditures over their lifecycles for the purpose of achieving its organizational strategic plan." – The Institute of Asset Management[2]

- "Asset management is a systematic process to guide the planning, acquisition, operation and maintenance, renewal and disposal of assets. Its objective is to maximize asset service delivery potential and manage related risks and costs over their entire lives." – The Government of Victoria[3]
- "A comprehensive and structured approach to the long-term management of assets as tools for the efficient and effective delivery of community benefits." AUSTROADS[4]

Other definitions abound but these are particularly interesting because civil infrastructure, for example roads, represents a large investment, distributed over large areas, and are long lived. They have many similar characteristics to the power delivery infrastructure.

Power Delivery Asset Management

Although certainly accurate, the above definitions may be limiting for the purposes of power delivery asset management. Therefore in the context of this report, power delivery asset management is defined as:

> *A structured, integrated series of processes to align all decisions with business goals and values and designed to maximize the life cycle benefits of power delivery asset ownership, while providing the required service performance and risk exposure levels and sustaining the system forward*

- This definition includes assets of any form and services of any type.
- PDAM is "structured" because asset management is accomplished with documented and consistent processes and procedures. All decisions can be related to and support the organization's goals and policies.
- PDAM "maximizes the life cycle benefits of power delivery asset ownership" because the purpose of asset ownership is to produce benefits for all stakeholders. Examining costs and benefits over an asset's lifetime assures that all contributions are taken into account.
- PDAM "provides required service levels" because minimizing costs and maximizing benefits are not the only considerations. Service levels also must be considered. Even though asset management can reduce costs, it can improve reliability and performance because it emphasizes detailed attention to both assets and system service levels. With an emphasis on monitoring the condition of assets and their performance, resources can be better allocated to where they provide the greatest benefits.
- PDAM "provides required risk exposure levels" because resource allocations are to be made with an explicit understanding of the associated risks for achieving the desired benefits and service levels.
- PDAM "sustains the infrastructure" because a sound asset management program is both near-term (maintenance oriented) and long-term (refurbishment and replacement oriented). Its planning horizon should be very long – typically, five to ten years or more and with asset service lives of 40 years or more. Planning within this time frame yields the information required for utility management to understand infrastructure needs and to fund them

properly, considering all potential costs and benefits. This is an important linkage point between PDAM and PD long-range and strategic planning.

Note that the above definition differs somewhat from that given in *Guidelines for Power Delivery Asset Management.*

Asset Management Premise

Power Delivery Asset Management begins with the fundamental premise that all asset management decisions made by utilities should contribute to stakeholder values, as set forth in the organization's goals and policies. PDAM applies this premise in decision processes at every level of the organization. The resulting alignment of decisions with criteria and value measures derived from the asset owner's or senior management's direction ensures that every asset management and resource allocation decision consistently supports the organization's strategic objectives and delivers value to the stakeholders.

Consequently, PDAM should begin with a comprehensive process for defining organizational values (e.g., financial considerations and non-financial considerations, customer satisfaction, environmental stewardship, and risk). PDAM then provides a way of linking asset management decisions to higher organizational objectives. The explicit and quantitative consideration of uncertainty should be included in this process of decision-making. Properly applied PDAM assures consistency across time and across the organization. As will be shown in Chapter 4, the strategic planning process is important for articulating values to drive both tactical asset management and long term direction.

PDAM integrates these features into a decision-making approach that relies on analysis methods and good data. The result is a systematic approach to business decisions that helps utility managers organize, structure, and evaluate the functions they perform, while managing the assets required to support those functions.

Best-practice asset management is about aligning key processes across the entire asset lifecycle to higher-level strategies and values. The core competencies lie in the decision-making processes. The key is to optimize tradeoffs across a variety of financial and non-financial metrics, rather than simply attempting to manage lifecycle cost or risk. An asset management decision-making framework is guided by performance goals, covers an extended time horizon, draws from economics as well as engineering, and considers a broad range of assets. PDAM provides for the economic assessment of tradeoffs between alternative actions and investment strategies from the network - or system - level perspective. At the same time, it allows for the more complete comparative analysis of options for individual projects.

Implications of an Asset Management Approach

Utilities considering asset management are attempting to move toward risk-informed, performance-focused decision-making that minimizes equipment lifecycle cost and maximizes lifecycle benefits. A structured asset management approach has been successful in many other industries. When properly adapted to power delivery, such an approach can provide the processes and tools to operate and maintain the power delivery infrastructure. Within an asset management framework, the contribution and support of a higher level, over-arching strategy drives all risk management and asset capital and O&M decisions. The major challenge for power delivery asset owners, managers, service providers, and operators is to align their decisions with these goals and objectives through the use of asset management tools and processes. Within an asset management framework, all performance criteria are derived from goals and policies set down by the asset owner, and all decisions are developed to support those goals. Strategic planning is a well regarded method for validating and reviewing an over-arching strategy.

The core PDAM competencies lie in the decision-making processes. In optimizing performance across the entire asset lifecycle, the asset manager should be supported by an integrated set of business processes and decision support tools, which have interfaces with the asset manager's key stakeholders (especially the asset owner and service providers). The asset manager uses these processes and tools to manage asset lifecycles, as well as to manage the key interfaces and workload of the various internal and external service providers. These processes and tools and their elements can be summarized under the groupings listed below.

- Communications
  - Accurate and timely information flows to both owner and service provider
  - Documented, consistent decision-making
  - Performance measures, standards, and benchmarks
  - Useful outputs, effectively presented
- Data Collection and Analysis
  - Inventory of all assets
  - Valuation of assets
  - Quantitative condition and performance measures
  - Measures of how well strategic goals are being met
  - Usage information
- Strategy
  - Evaluation of asset performance and influencing factors
  - Risk goals and measures
  - Evaluation of lifecycle costs and benefits
  - Performance-prediction capabilities
- Planning
  - Engineering and economic analysis tools
  - Alternative analyses procedures
  - Project prioritization procedures

    - Evaluation to balance short- and long-term objectives
- Implementation
    - Contract management
    - Results monitoring and reporting
    - Continuous feedback procedures

Benefits of Asset Management

Asset management can touch nearly every aspect of the power delivery business, including planning, engineering, finance, construction, maintenance, and information systems. However, asset management should not be viewed as another management "flavor of the month," requiring new terms and workshops. Rather, asset management is a way of doing business. It brings a particular perspective to the manner in which an organization conducts its existing procedures and develops new ones, reaches decisions, and applies its expertise. PDAM suggests principles and techniques to apply in policy-making, planning, project selection, program tradeoffs, data gathering, and management system application, each of which is aligned with the organization's higher-level goals.

The benefits of asset management include the following:

- Assure that all asset decisions are policy driven
- Build, maintain, and operate facilities most cost-effectively
- Achieve desired performance levels
- Optimize long-term benefit/cost ratios
- Allocate available resources efficiently to support the organizations overall goals and policies
- Measure and focus on performance and outcomes
- Improved repeatability, credibility, and accountability for decisions

Asset management links customer and regulator expectations for system condition, performance, and availability with system management and investment strategies. A complete asset management process reports on progress made in achieving performance measures derived from asset owner goals and also evaluates the business processes used relative to the goals and performance criteria. Furthermore, the impact of alternative actions and investment strategies on the ability to realize expressed goals may be readily determined and evaluated. The focus is on assets (i.e., data, people, and physical resources) and system performance, including return on investment, economic efficiency, accountability, opportunity costs, risk exposure and future requirements. This broad approach to resource allocation and decisions can provide greater benefits to the organization and all stakeholders.

Asset management not only aids in the decision-making process, but also provides for a fact-based dialogue between asset managers and other stakeholders, government officials, and customers concerned with day-to-day operations. This results from the accessibility of relevant, objective, and credible information to all participants in the decision-making process. As such, decisions can be based on detailed input regarding available resources, current system condition and performance, and estimates of future performance. The information underlying the asset management processes – raw data and results generated from analysis – ensures an improved understanding of the economic tradeoffs, return on investment, performance impacts, and accountability.

Asset management provides ready access to quantitative and qualitative data and allows decision makers to more readily identify and focus on key issues. Furthermore, the ability to weigh and articulate the impact of choosing one alternative over another through "what if" analyses is enhanced. The documentation explaining the selection of a particular strategy is also improved. A documented, reproducible, systematic approach can enhance communication between stakeholders and provide the asset manager a defensible rationale for capital investments and other actions.

Requirements for Asset Management

Establishing effective PDAM systems and procedures requires effort, investment, and a business commitment to developing, implementing, and maintaining an asset management approach and the elements needed to support it. Although PDAM can be accomplished in a phased implementation, the ultimate goal is to implement most or all of the following components:

- Developed and documented policies and business practices, with assigned responsibilities
- Developed and consistently applied procedures, performance criteria, and measures
- Inventory of assets
- Quantitative condition and performance measurements
- Performance prediction capabilities
- A lifecycle view of costs and benefits
- A suite of engineering and economic analysis tools
- Performance monitoring systems
- Processes for review and adjustments

A key to effective asset management is good information – timely, reliable, and accurate data to support the PDAM processes. Information technology, including relational databases to integrate individual management systems, monitoring systems, databases, and other analytic tools, should complement PDAM decision-making processes, as well as organizational roles and responsibilities.

A Power Delivery Asset Management Diagram

A brief description of some key aspects of the PDAM process will aid in putting the LRSP process in perspective. A generic power delivery asset management diagram is depicted in

Figure 2-2. This diagram clearly shows the responsibilities of the three parties. As depicted, all asset-related decisions should be guided by the goals of the asset owner and other key stakeholders. The asset manager's responsibility is to direct resources to their optimal uses, as defined by the organization and its stakeholders. The service provider carries out the actions requested by the asset manager. Ideally, asset management applies at all levels, in all time frames, for capital investments as well as ongoing operations, continually balancing different and often conflicting goals.

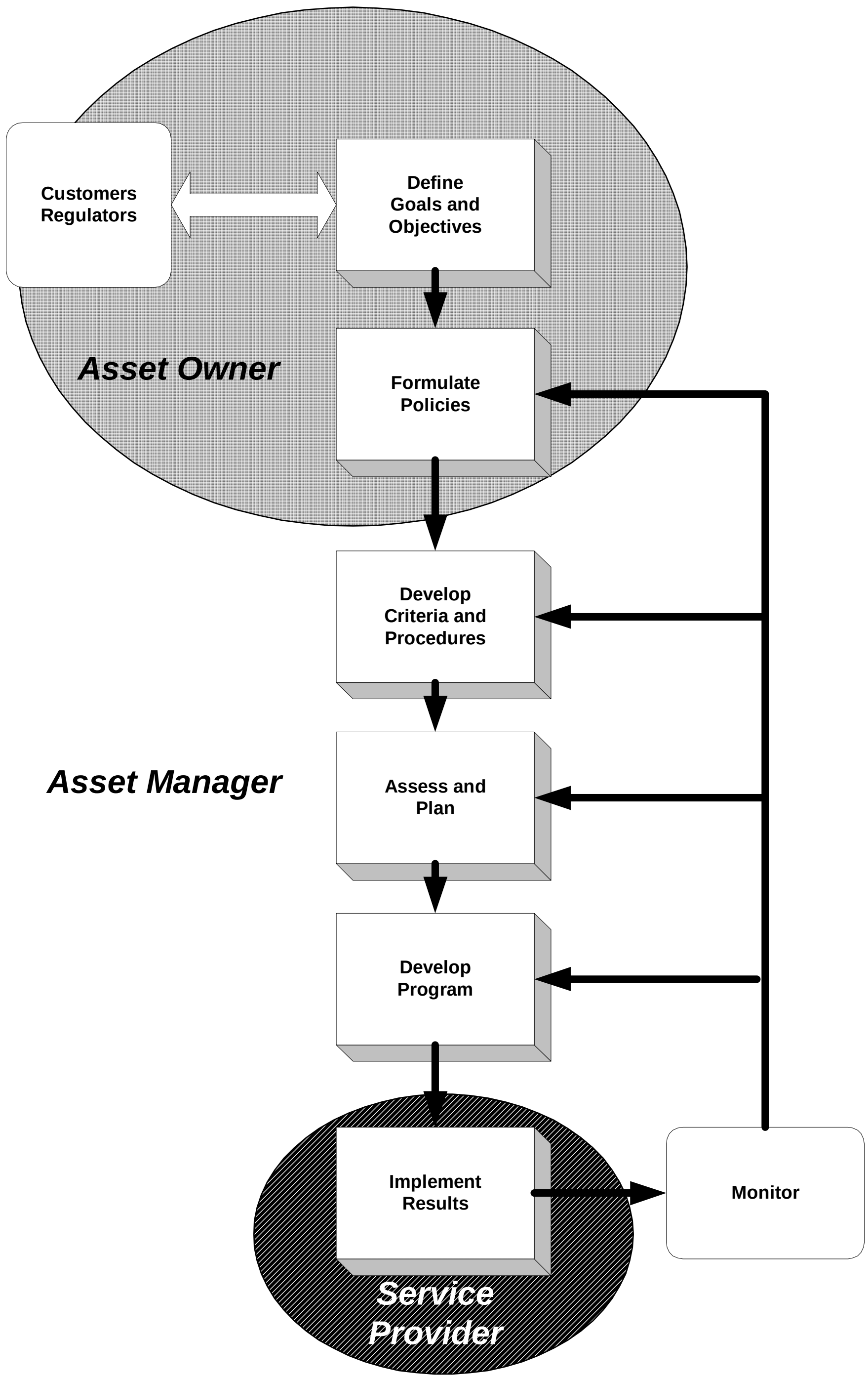

Figure 2-2
Power Delivery Asset Management Framework

Adding some detail to Figure 2-2 yields the power delivery asset management model shown in Figure 2-3. Its blocks can be readily correlated with the preceding Figure and the boundaries of the three party's responsibilities can be deduced. Performance criteria and assessments are the key to determining future actions. Processes for monitoring how well expectations are met are evident. This model fits most aspects of the power delivery business.

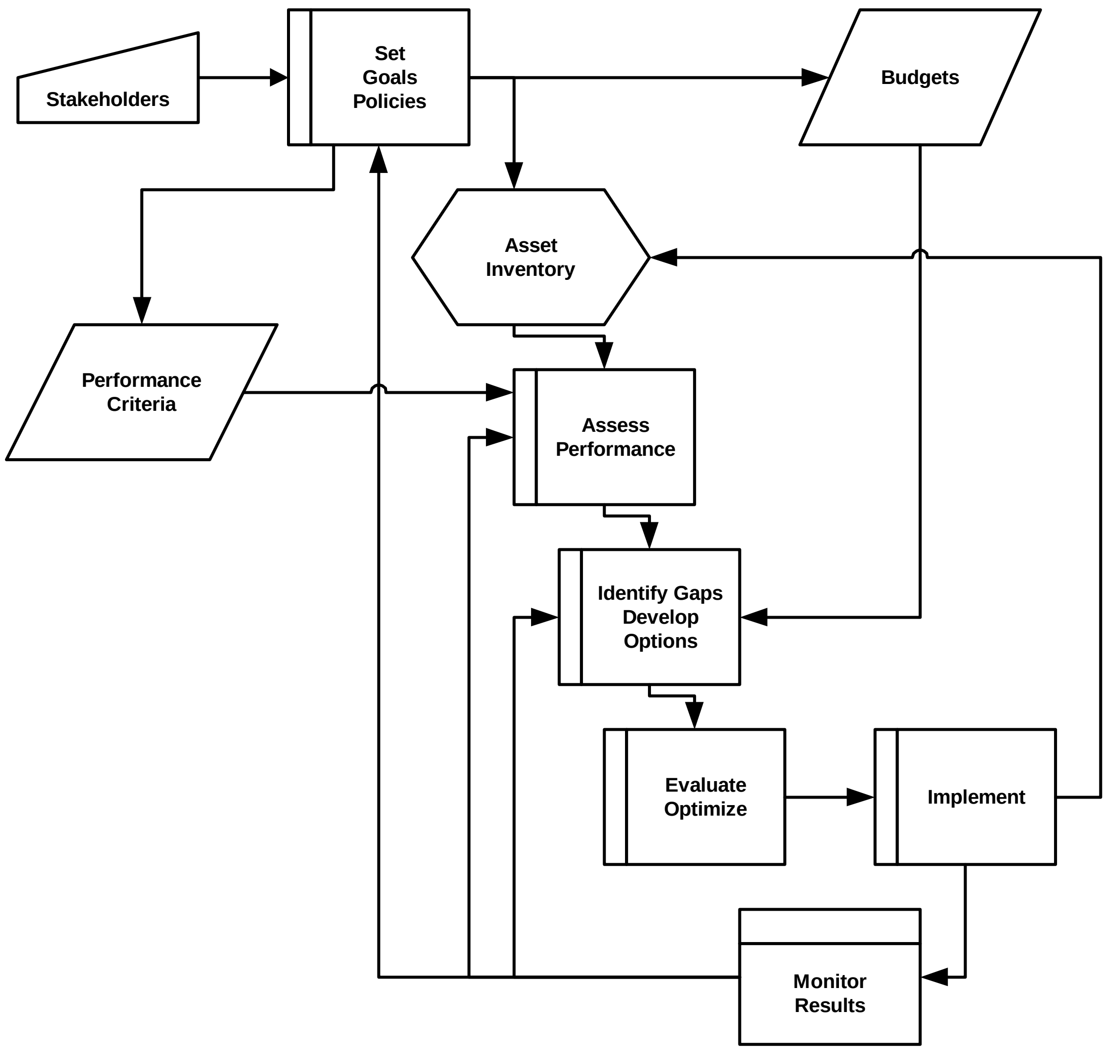

Figure 2-3
Generic Power Delivery Asset Management Model

Goals and Policies

The asset owner is the initiator for PDAM and for PD LRSP. The owner sets the business parameters, risk boundaries, and operating context for its assets for the operational and longer term horizons. The asset owner also sets the operating context for the asset manager and, for power delivery, focuses on corporate governance as the regulatory license-holder. In general, the owner is represented by the highest levels of management within the organization that owns or, in the case of governmental agencies, directly controls the assets. The asset owner may or may not be a part of the organization that operates and maintains the assets. Owners directly interact with key stakeholders (e.g., customers, shareholders, regulators, employees and financial agencies), as well as asset managers. The asset owner sets the **Goals and Policies** (see Figure 3-3) and the **Budget** for the organization.

The asset owner should develop and clearly communicate well-defined high-level **Goals and Policies** and a strategic framework for operating the organization. These goals should be translatable to clear business objectives and measures of performance. Some goals, such as desired internal rates of return, might be very specific and quantifiable. Other goals, such as improving customer perception, may be less specific and incorporated in a long-range plan resulting from a strategic planning process. It is the asset manager's responsibility to translate these goals and policies into measurable objectives. Included here may be an outline of organizational roles and responsibilities and business processes that reflect the asset owner's policies and philosophies. These goals and policies often start with a mission statement as will be discussed in the next chapter and are used to set performance metrics for subsequent processes.

Policy formulation seeks input from various stakeholders, and reflects customer priorities and concerns. Stakeholders can include the asset owner's parent company, shareholders, regional operating organizations, state and federal utility, safety and environmental regulators, local governments and the public at large. Each of these groups may have different goals and metrics. Some may be very specific and short term, such as specific earnings per share target or an availability factor. Other goals and metrics may be less well-defined or longer term. These stakeholders (particularly regulators) also may have different constraints on actions that can be taken. These are "must do" or "must not do" types of inputs. The asset owner relies on the leadership, vision, values, business objectives, and judgment of the organization and its senior management to establish how to weigh tradeoffs between competing goals and produce a consolidated set of goals and operating policies.

Performance Assessment

Assessment of asset and system condition and performance provides factual and quantitative information on the performance of the **Asset Inventory** in meeting established **Performance Criteria** and information that can be used in subsequent analyses to predict their ability to meet these requirements in the future (an important input for long-range and strategic planning). Condition assessment and performance monitoring form the basis for management of an asset throughout its life. They provide a basis for adjustments to the various outputs of subsequent processes, ensuring that expected performance goals are met and providing indications where changes are required. Effective asset condition assessment in relation to its service performance is needed to understand and predict the deterioration that leads to reduced asset performance in the future. Assessments of system performance and implementation also may be conducted by external stakeholders (e.g., customer perceptions of the quality of infrastructure condition, or regulator assessment of the provision of services), and these are valid inputs for analysis as well. These evaluations are a key process of PDAM. Understanding the current condition of an asset or the current level of performance provided by a system provides vital information for a series of asset management decisions and a starting point for predicting future performance.

Determining the current level of system performance usually entails straightforward calculations, such as summing the number of customer interruptions. Tracking equipment condition parameters has a number of uses. The most obvious use is for deciding whether some immediate corrective action is indicated. For equipment, many of these evaluations are part of normal maintenance activities. However, it is important that the history of these activities not be "islanded" in the maintenance system. Rather, this information should be available to the larger PDAM process, of which maintenance is just a part. In addition to triggering maintenance, such information should be used to determine how well past asset management decisions have been implemented and whether the expected improvements have resulted. This assessment information also can provide a starting point for projecting future asset or system condition through the use of deterioration models and also to refine existing models. This linkage, and others, will be further explored in the development of the LRSP process.

Summary of Asset Management Concepts

- Decisions on asset acquisition or replacement, use, maintenance, and disposal should be integrated with strategic planning. This is achieved by linking assets with program delivery standards and strategies derived from the asset owner's goals.
- Effective asset planning processes incorporating evaluation of alternatives to the acquisition of new assets and the maintenance of existing assets should be driven by performance requirements. The evaluations should include a comparison of lifecycle costs, benefits, and risks of ownership.
- Effective organizational frameworks that identify responsible parties for assets should be established. This responsibility encompasses all phases of the asset lifecycle. Mechanisms should specify clear ownership, control and responsibility for use, security, condition and performance of assets.
- Performance monitoring and measurement against meaningful standards should be established and maintained.

References

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3. "Sustaining Local Assets": Government of Victoria December 2003
4. "Strategy for Improving Asset Management Practice", AUSTROADS 2002 Sydney

3
DECISION PROCESS CONSIDERATIONS

Performance Metrics

All PDAM decision should have the goal of ensuring performance objectives. All properly defined Performance Indicators (PI's) are strategic in the sense that they should be identified and linked with a component of the corporate strategy. The corporate strategy is the plan to achieve the corporate objectives determined by stakeholders. Therefore, there should be a direct link from properly defined PI's to goals, from goals to objectives and from objectives to corporate values and mission. Consequently, it should be possible to show a connection through an organizational hierarchy from any PI to a goal and then to an objective, whether strategic or operational. There will be a number of Performance Indicators for the company at the highest level and all the units below will also have a number of PI's of their own that support the overall company goals and can be "rolled up" into them. One could define the highest-level PI's as the "Strategic Key Performance Indicators" but there is no common definition or usage of this term.

All asset management decisions made by utilities should contribute to stakeholder values, as set forth in the organization's mission, goals and policies and this premise should apply to decision processes at every level of the organization. The resulting alignment of decisions with criteria and value measures derived from senior management's direction ensures that every asset management decision consistently supports the organization's strategic objectives and delivers value to stakeholders.

Performance measures are observable, quantifiable measures that align with project and process objectives. They provide the means to track progress toward meeting the objectives. Performance targets are specific values of performance measures that define the levels desired to be attained. They provide the bar against which actual performance data will be compared. For example, SAIFI is not only a natural unit for measuring a component of corporate value but also a way to measure performance.

There are, in fact, two general classifications of performance metrics of interest in a PDAM decision process. Results metrics measure what has been accomplished. Process metrics measure how the results were achieved. These same metrics are of interest in strategic planning decisions for the situational analysis, understanding the "as is," and for tracking the implementation of action plans resulting from the decision process. As for the example above, results metrics are usually closely related to attribute value metrics. One conceptual approach to developing a list of performance metrics is to use a process model formulation. All natural units defined in the development of the corporate value model can be considered as the outputs of various processes and can be measured by their natural units. The inputs to the process that produce the result are measured by process metrics. Going back to the SAIFI example, the index is the result of a process with many inputs that can be measured such as vegetation management and equipment maintenance, each of which can be considered as a sub-process with its own process metrics (e.g. maintenance backlog). One can see that the approach to developing a set of performance metrics is similar to the hierarchal corporate value model development with attributes and sub-attributes described above.

Defining and measuring performance metrics of both classifications is important for good asset management and strategic planning. It is important not only to direct resources properly to maximize value but also to utilize the resources efficiently and effectively in attaining that value. In addition, good asset managers want to respond to deviations in results metrics quickly. To do this, it is important to know what influences the result metric. Process metrics provide this information. Furthermore, most results metrics are lagging indicators. This is to be expected since they are the output of a process. A distribution manager only knows that the SAIFI metric has gone below target or has not been reached after the fact. Process metrics can be leading indicators (e.g. maintenance backlog). Tracking and managing them can improve the performance of the result measure.

Key Performance Indicators

Key performance indicators (KPI's) are, in a general sense, the same as the performance metrics discussed above. However, the term has come to be associated with metrics that are tracked and reported to a higher level of authority. For this reason, KPI's usually focus on measuring accomplishments or results. The commonly used reliability indices are an example. They directly measure a dimension of customer service level that is the result of many factors – design, maintenance, capital investments, etc. Trigger parameters in performance-based rates can be considered as KPI's and they too are the result of many separate activities. Because so many factors can influence a high level KPI, it can be difficult to gain insight when some corrective action is required. For this reason, many organizations develop lower level KPI, for example maintenance metrics such as number of backlog maintenance orders.

In fact, KPI's can be useful at any level of the organization if they are properly chosen. Good KPI's should:

- Focus on accomplishments rather than activities
- Utilize readily available metrics
- Provide meaningful indication of performance to all levels of the organization
- Promote improvement
- Allow external comparison (benchmarking)
- Communicate progress

Selection of KPIs is ultimately a company-specific decision but there is similarity among power delivery organization for the higher-level KPI's.

It is important to note that the terms "KPI" and "metric" are often used interchangeably. This is incorrect and can lead to confusion. A KPI is a metric, but a metric is not always a KPI. The key difference is that KPI's always reflect strategic value drivers whereas metrics may represent the measurement of any aspect or activity of the business. As an example, "average equipment age" may be an interesting metric but would not necessarily make a good KPI. As for any KPI, good equipment KPI's should be accurately defined and measurable.

Risk Boundaries

As in operational asset management, strategic planners must set some boundaries on how much the organization is ready to risk achieving its strategic goals. Risk can be considered as a measure of the uncertainty of business performance and as such is closely tied to corporate goals. There are several definitions of risk centered on whether unexpected positive or negative or both outcomes are included. For power delivery, defining risk at the asset owner level as a loss or negative result is more appropriate. Because power delivery is a regulated activity, there are few opportunities to achieve unexpected, materially positive outcomes. Utility managers in power delivery are risk adverse in the sense that they concentrate on minimizing negative results. Formally risk is defined as the product of the probability of a hazard causing loss occurring and the consequences of that loss.

The subject of risk has been extensively studied for financial assets and is generally considered to be the risk of not achieving the expected financial return. Risk has also been studied in detail for the power generation and energy trading side of the utility business. Here the desire is to assess energy portfolio exposures to commodity markets and customer loads, evaluate overall portfolio risk in terms of cash-flow-at-risk or value-at-risk, and assist in designing portfolio risk management programs. EPRI has developed tools to assist utilities to manage price and load risk in this area[7] and a more detailed discussion of the theory of risk assessment for power generation can be found in Introduction to Simplified Generation Risk Assessment Modeling[8].

For power delivery, risk management is not so well formalized at the asset owner level. However, there has been much discussion and work done at the level of individual power delivery component assets. Both can have impact on the selection of strategic goals. It is important to clarify the distinction between the two and an example will help to illustrate the differences. An illustration of risk management that requires an asset owner perspective would be the evaluation of the risk exposure of not doing something. One example would be investing whether to replace functioning units on a scheduled basis versus the unanticipated need for a large capital investment over a short time to replace a significant population of aging equipment, which may require unplanned financing.

There is another kind of asset level risk and that is expressed as the probability that a particular asset investment will achieve the expected benefits over the time frame of interest. Will the new monitoring system provide the information necessary to implement condition based maintenance and reduce preventive maintenance? This type of risk is similar in form to that used to quantify financial portfolio risk, and its management is the responsibility of the asset manager.

Setting risk boundaries at the asset owner level is now a normal part of the deregulated power generation business but is not often explicitly treated in the power delivery sector. One exception is in the area of performance-based rates. In such cases, the asset owner has directly expressed a risk valuation through the acceptance of performance standards and associated monetary adjustments for deviations. In order for the asset manager to manage asset level risk in accordance with the asset owner's wishes, he needs to understand the owner's risk boundaries.

Consequently, LRSP goals and objectives should include some measure of tolerable risk along with other performance measures. This information is necessary to properly manage asset-level risks whenever the outcome has the potential to impact an area not in the asset manager's area of responsibility (e.g. corporate finance, regulatory relations). At the very least, for communicating a relative sense of risk tolerance, qualitative statements can suffice if they are informative and meaningful, that is give a sense of relative priority, if quantitative statements are not possible.

Implementing the Link between Goals, Policies, and Performance Criteria

Developing the corporate value model and performance and risk metrics are the cornerstone activities of decision process implementation and provide a tight linkage with PDAM implementation. The results of this effort influence all other decisions and the subsequent operation of the asset management processes. It is also the step that requires the most interaction with the asset owner. To achieve success, sufficient attention, resources, time, and expertise, must be made available to accomplish these task.

Because so much stakeholder interaction can be required, this portion of the process establishment often is separate from the general decision making. Typically, this step starts with a workshop that includes experts from all of the functional areas included in the decision scope as well as the internal customers of those functions and representatives of the asset owner. A broad representation is required to capture all values and to promote buy-in and ownership of the results.

4
THE DECISION PROCESS

As previously discussed, the range and complexity of PDAM decisions is vast. Nonetheless, there are common attributes to a well constructed decision process. The reader may be aware that decision theory is an established field of study. Most of decision theory is normative or prescriptive, that is, it is concerned with identifying the best decision to take, assuming an ideal decision maker who is fully informed, able to compute with perfect accuracy, and fully rational. This is very rarely the case in any PDAM decision of interest. The practical application of a prescriptive approach, that is, how people should make decisions, is called decision analysis. Such analysis is the focus of this report because it is aimed at finding tools, methodologies and software to help make better decisions. The most systematic and comprehensive software tools developed in this way are called decision support systems and this is an area of particular EPRI development.

Steps of the Decision Process

The general steps in making a decision are:

- Define the problem
- Identify available alternative solutions
- Evaluate the identified alternatives
- Make the decision
- Implement the decision
- Evaluate the decision

Each of these can be further described. Some of the more important sub-steps are listed below.

Problem definition:
- Situational assessment
- Boundary definitions
- Data and information collection

Identify alternatives:
- Gather facts
- Set limits
- Determine unknowns

Evaluate the identified alternatives:

- Establish evaluation criteria
- Establish weighting factors
- Assess risks associated with each

Note that the final step in the decision process entails evaluating the decision. This is an essential task in the larger PDAM scheme and is an important mechanism for process improvement. This evaluation can provide feedback and establish for example:

- Were the assumptions were valid?
- Were the criteria appropriate?
- Was the available data accurate and sufficient?

Best-practice PDAM Decisions

Best-practice PDAM decisions should be based upon risks associated with actual equipment condition and performance.

There are four key steps required:

- Understanding existing performance
- Understanding required performance
- Projecting future performance
- Understanding how to bridge gaps

In turn these key steps have there own requirements including:

- Equipment failure models
- Failure rates
- Equipment Performance data

Strategic decisions revolve around determining when and where to make new investments. These decisions depend on whether or not, given the present state of the equipment, there is unacceptable risk of a current or future shortfall in performance. To make or plan for such decisions quantitatively requires processes to predict future condition of an asset and how it may respond to future demands or stresses. The ability to predict future performance starts with developing the proper reliability models. Strategic planning for aging infrastructure makes it critical to identify equipment hazard functions and understand risks and influence of critical variables on equipment failure rates.

These requirements suggest a need for mathematical modeling of aging and failure behavior of power equipment to estimate current reliability and predict future failure behavior. No such models are available for the major power delivery components. However, EPRI has several initiatives to address these gaps. With better failure rate predictions, risk based models of each asset type could be developed to allow optimizing the risk-cost function for inclusion in the decision process.

The models described above require identification of mechanisms of deterioration for asset and evaluation of rate of deterioration as a function of various stresses (time, loading, etc.). Stress/aging models would represent dynamic deterioration process with a set of equations that could be used to perform trending and failure prediction to provide forecast of future deterioration.

Implementation into the PDAM Process

Some of the most important decisions that must be made revolve around whether the current and future performance of installed assets is and will continue to be acceptable. The following, adapted from *Guidelines for Power Delivery Asset Management,* EPRI, Palo Alto, CA: 2005, 1010728, illustrates the implementation of a complex decision process into the larger PDAM framework. Figure 4-1 diagrams the process.

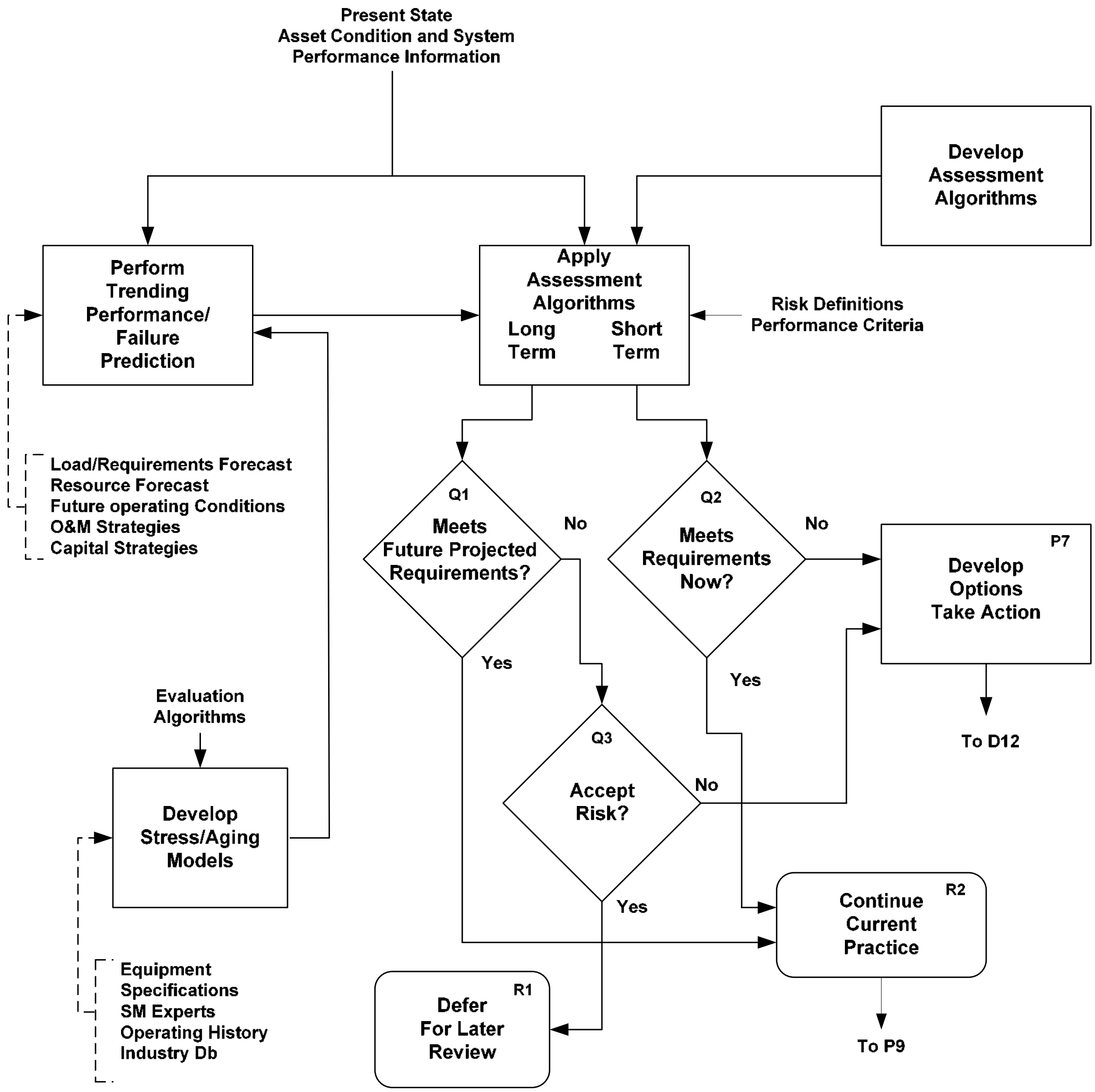

Figure 4-1
Diagram of Conduct Analysis Performance Modeling and Prediction

Conduct Analysis Performance Modeling and Prediction entails analyzing performance data and asset information from the **Evaluate Asset Condition and System Performance** process in order to predict the future condition of an asset, subsystem, or the complete system and how it may respond to future demands or stresses. This process is concerned with deriving, calculating, and analyzing direct and indirect performance metrics and values. It works by identifying and understanding the causes of performance gaps, current risks and trending, and predicting future performance and risk. The general objective here is to predict future asset condition or system performance levels.

Modeling performance generally requires data on past performance of similar facilities or equipment and some understanding of the mechanisms of aging and wear that contribute to a decline in performance over time. Knowledge of how operating stresses may influence asset degradation over time (i.e., aging models) is useful in this process. Expected future operating conditions are also required, including **New Business** (load growth for example). Specific, directed analysis may also be required to identify the underlying causes of performance gaps or an unexpected asset condition through root cause analysis and other forensic investigations. Using various analytical, statistical, and simulation tools, this process also determines such information as statistical failure data derived hazard curves, predicted end of life, condition-based triggers to support proactive asset maintenance or replacement, the implications of deferred maintenance, probability and consequences of failures and other risks, and future rating limitations.

There are two decisions in this process that the asset manager would like to make based on the present condition of the assets and levels of performance. The first is to determine whether the current state of either warrants taking some action now because of a current shortfall in meeting a desired performance level. The second is to determine, given the present state, whether there is sufficient concern about a future shortfall in performance to initiate an ameliorating action now.

Information comes from the **Evaluate Asset Condition and System Performance** processes to the **Apply Assessment Algorithms** process. In the simplest case, this could consist of merely determining whether a threshold level has been crossed. For example, a reliability index for a particular feeder circuit has exceeded a target level and design options for reconfiguration are initiated. Another example would be if the incurred maintenance costs for an individual piece of equipment exceed some percentage of its replacement cost, then options for replacement are explored. Other short-term assessments may be more complex and could include some risk assessment.

Long-term assessment algorithms may also be as simple as detecting a threshold level crossing. However, here the parameter crossing the threshold is not the current state but rather the projected future state. Obviously, this requires an ability to predict future performance. Obtaining this ability starts with Develop Stress/Aging Models. Building these models requires an identification of the mechanisms of deterioration for the asset or system and an evaluation of the rate of deterioration as a function of the various stresses (time, loading, etc.).

Work on component aging models has been underway in the nuclear industry for several years and some of it deals with equipment used for power delivery, namely circuit breakers [3] and control equipment[4]. Work specifically directed at T&D equipment has mostly focused on transmission cable [5] and distribution cable. [6] More recently work has been done for wood poles.[7] For power delivery, aging model work has been focused on insulation aging in transformers [8] and is also addressed in EPRI's Power Transformer On-line Monitoring and Loading Software[9]. Significant work remains to be done in developing comprehensive aging models for the wide range of power delivery components and systems.

Ideally the stress/aging models would represent the dynamic deterioration process with a set of equations that could be used in **Perform Trending Performance/Failure Prediction** to provide a forecast of future deterioration and the asset or system state for a future time. To be most useful for PDAM decision support, the deterioration processes should be described probabilistically. With such models, future states or performance levels could be represented as a probability distribution of states going forward. In some cases it may be possible to develop trending algorithms that can use data from condition monitoring to automatically update these deterioration models, make an assessment and provide an automatic notification of the need to consider taking action.

To predict future performance when the deterioration is not just a function of time but also of stress levels, the future stresses must also be predicted. If loading were one of the stress factors then a load forecast could be used for this purpose, for example. Future performance may also be affected by changes in operating or maintenance practices or by replacement of individual components within a system. Consequently, these factors may also have to be accounted for in projecting future performance. Not every asset decision warrants a detailed analytical approach. In some cases a simply extrapolation of past trends may be sufficient.

For some asset classes, the evaluation process could be automated. Others may be too complex or too infrequent to justify anything more than a manual analysis~~.~~, for example, deciding whether a feeder circuit needs to be upgraded to accommodate a new industrial customer connection. For some decisions, sufficient data may not be available to approach the problem mathematically and expert judgment may be the only solution. The generic models presented here describe the PDAM methodology for all of these situations and for good asset management the model should be applied across the organization. Developing the proper assessment algorithms is the responsibility of the asset manager and decision support tools for applying them are important requirements for PDAM.

For better understanding, the processes immediately following the **Apply Assessment Algorithms** are shown. If current requirements are being met, then current practices may continue. If there are no projected problems in meeting future requirements, current practices may continue also. If there is a projected shortfall in meeting requirements in the future, there are two choices. Accept the possible future risk and continue current practices, but catalogue the issue for future review, or decide on proactive action and develop options. Obviously, if current requirements are not being met, action must be taken also. Implicit in the **Develop Options** process is a determination of the causes of underperformance. It should be clear at this point in the description of PDAM concepts that proposed actions are not limited to asset investments alone but also may include changes in operations and maintenance practices, design standards, training, contracting and any other controllable action that impacts asset and system performance.

References

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

5
SPECIAL CONSIDERATIONS FOR PDAM DECISIONS PROCESSES

General Considerations

Accounting for long asset life cycles is crucial to effective asset management and multi-year replacement programs should be integrated into a power delivery organization's business planning process. Without the level of insight gained from a strategic review of asset management issues, it is difficult to anticipate the longer-term risks associated with managing a diverse power delivery asset bases. In order for power delivery organizations to avoid excessive asset deterioration and service reductions, they must develop a methodology for distributing limited capital funds to the appropriate asset replacement. To do this effectively, they must have a strategic vision of their infrastructure requirements.

Strategic planning processes have been successfully utilized by many organizations for over thirty years and have become a well-established business tool in many industries. However, it must be noted that strategic planning has most often been applied to traditional businesses competing in a commercial marketplace. The situation of a power delivery organization is different. Not only are most power delivery organizations regulated monopolies or government entities with little traditional competition but they are also highly asset intensive. To ensure success of the strategic planning effort, power delivery organizations need to adjust the "conventional business" strategy model to the utility business. As discussed below, utility-based strategic planning differs from the competitive, traditional business model in several specific ways. By recognizing these differences and adapting the traditional model accordingly, power delivery organizations can increase understanding of, and success in the strategy process. In addition to the obvious issue of regulatory oversight, listed here are some of the other unique aspects of strategic planning in power delivery.

Timeframe

In the conventional business world, a typical strategic planning model timeframe is 2 to 3 years; for power delivery, five to ten years is more appropriate because there are no rapidly moving competitors and changes take longer to implement.

Consensus

The conventional business model is generally top down. Because of the importance of political and regulatory influences, stakeholder involvement is key and building consensus essential for implementing power delivery strategic planning results.

Value system

Power delivery organizations' obligation to serve and guiding principles - long-term investment for reliable service - are different from conventional business' bottom line approach. Differences in the value system require different criteria and approaches to strategic planning.

Customers

Power delivery organizations do not have end-use customer who have chosen their service in the traditional sense. Rarely would a consumer have a choice of electric power delivery supplier and hence there is no voluntarily established customer relationship.

Context

The critical social and economic importance of electric service means that most power delivery organizations will have a very conservative approach and changes will usually be incremental.

Assets

The underlying assets for power delivery have long lives and their investment cycle might span several economic, political or market cycles. The basic technologies employed are mature.

Special Considerations

Many of the critical issues power delivery organizations will identify when performing a situational analysis will be unique to their circumstances. There are, however, several widespread issues that will be important for a number of utilities. Three issues that every power delivery organization should assess while planning a long-range strategy are:

- Aging Asset Base
- Aging Workforce
- Longer Project Cycle Times

These three issues will be discussed below.

Aging Assets

Probably the strategic issue most in common across the industry is that of an aging asset base. This issue is gaining wider attention both in the industry and with the public.

> *"Engineering experts now believe the nation is entering a period that could be marked by a dramatic increase in localized power outages unless considerably more is spent on replacing old and deteriorated lines. Replacing these old cables and equipment could add billions to utility spending."*[1]

Many in the industry believe that a significant percentage of the power delivery equipment base is at or close to the end of its useful life, the so-called design life. There is no formal definition of design life but the general usage is that it is the age beyond which risk of failure will become increasingly unacceptable. The concept arises from the fact that the original designers and purchasers did not expect the equipment to be in service much beyond that age. Equipment engineers commonly use an age of 40 years to estimate design life for power delivery equipment but there is no technical basis for this number and there are many examples of equipment functioning reliably well beyond that age. Nonetheless, it is accepted that the risk of equipment condition deterioration and wear out failures increases as equipment ages and approaches the end of its useful service life.

As will be discussed later, aging effects are not necessarily simply the result of the passage of time but more likely the accumulation of the results of a series of stress factors such as high temperatures, overloads, etc. As time in service increases, the total exposure to and the cumulative effects of these stressors also are likely to increase. However, since not all equipment will be subject to the same operating conditions and stresses, a given service age will not necessarily correspond to the same level of deterioration for all equipment. This variation across equipment complicates aging asset decisions.

Many of the power delivery systems in the United States experienced a rapid expansion in the 1960's and 1970's corresponding with significant national economic growth and increased electric consumption. Much of the equipment installed in that time frame is still in service and the equipment installed during that peak expansion is now 30 to 40 years old. A good deal of the recent literature concerning aging transmission assets deals with power transformers because they are usually the single most expensive component in the delivery system but the same situation exists for circuit breakers, and overhead and underground transmission. Foundations and ground mats are other important power delivery infrastructure components that clearly deteriorate with time. Replacing this significant population of older equipment will require a large capital investment and hence the interest in the aging asset problem. Clearly this is an issue for consideration in any strategic planning process since it can be expected that regulators would need to be convinced through detailed business case analysis of any large capital request and would expect a utility to manage the transition in a business-like way.

The general situation is depicted in Figure 6-1. A histogram showing the number of units of a particular equipment type in several age brackets has been superimposed on a failure rate curve that shows an increasing failure rate with age for that type. The age profile of the units reflects previous investment patterns. As time progresses, an increasingly larger percentage of the equipment population will move into the range of higher failure rates. This type of histogram gives rise to the term "asset walls." A significant concentration of a particular asset in a group of adjoining age brackets looks similar to a wall moving forward in time.

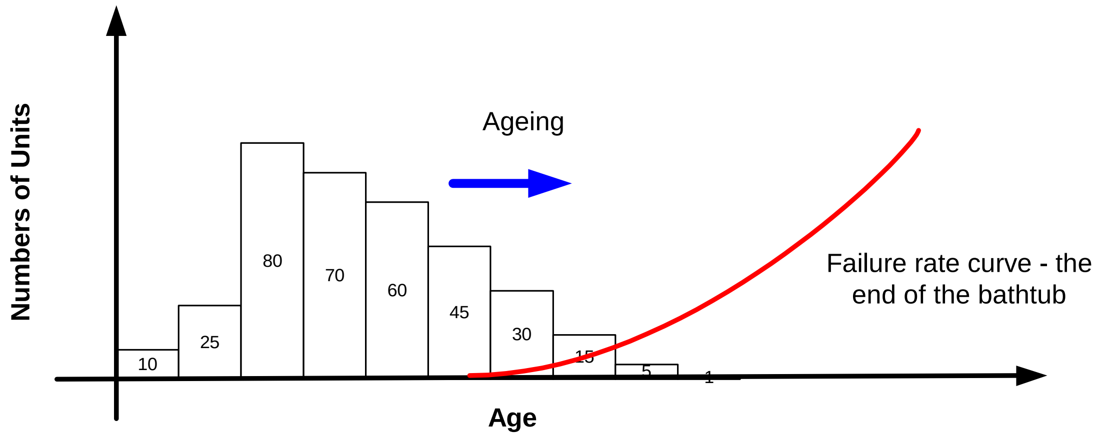

Figure 5-1
Combining Demographic Data with a Failure Rate Curve.

Age alone is not the only infrastructure factor contributing to the potential problem. The situation has been compounded by the increased utilization of many power delivery circuits. In the period between 1960 and 1985 an average $7 billion was invested annually in the power transmission system but during 1985 to 2003 the annual average dropped to only $2.5 billion[2]. However, electric usage continued to grow during this later time period. The result is that the loading, the utilization factor of the circuits, has increased for many transmission components even as they moved closer to the end of their service life. Aging electrical infrastructure has caught the attention of the general public and the regulators. A recent quote from the New York Times attributed to an industry executive illustrates the common perception.

> *“"We've been using equipment far beyond its original intended life because we've been concerned with the cost of replacement and the need to keep utility rates down," says Dean Oskvig, president and chief executive of B&V Energy, a unit of Black & Veatch, a global engineering firm based in St. Louis, Mo.”*[3]

Many utilities recognize the need to increase capital investment in their power delivery systems. A recent survey of utility executives ranked distribution-system spending as a higher priority than generation and environmental compliance[4].

Rate freezes and uncertainties about deregulation have discouraged power delivery investment and system redundancy has allowed for a “run to failure” approach for many equipment applications. The exact timing may be in doubt but it is obvious that many power delivery organizations will be faced with major capital requirement to replace aged assets during the typical strategic planning horizon of ten years. Some believe that these costs will be great enough to materially affect the rates and capital structure of some companies.

As an example of the possible repercussions, note the experience of a large west coast utility that requested regulatory approval to replace 800 miles of aging underground cable at a cost of $145 million. Approval was granted to replace only 300 miles of cable even though the parties acknowledged that reliability might be reduced. In response, the utility has decided to invest $250 million more than included in its rates to replace some older cables.

A specialized decision process and supporting tools involving aging assets could help power delivery organizations with better data and plans to support and prioritize capital investment requests and phase expenditures.

Aging Workforce

In parallel with the power delivery industry's rapid expansion of the equipment base in the 1960's and 1970's, a similar increase occurred in the size of the workforce. The economic pressures of deregulation and of a series of mergers have resulted in a significant reduction in the number of people employed in the utility workforce, both skilled craftsmen and engineers. The average age of those remaining is increasing. It has been estimated that over half of all electric utility workers are 45 or older.[5]

The workforce reductions coupled with the approaching retirement of those remaining, means that skilled technical, craft and engineering expertise will be in increasingly short supply. This increases the challenges of dealing with the aging asset base and the increasingly more complex issues of operating and maintaining power delivery systems operating closer to design limits and in unanticipated ways to accommodate the deregulated generation market. The lack of skilled personnel and loss of institutional knowledge could impact power delivery operations in a number of ways including:

- Increased maintenance costs
- Longer outages
- Lower reliability
- Inability to utilize new technologies

It will not simply be a matter if increasing hiring because the required skill sets are not available in the labor market and qualified replacements are increasingly difficult to recruit and train. There has been a decrease in the interest in technical careers at both the vocational and college levels. It takes many years to train a journeyman utility worker and power engineering has not been a strong choice for college studies in the United States for many years. For a variety of reasons, employing foreign engineers is not as attractive an option as it had been in the past.

Dealing with this approaching labor shortage requires some strategic thinking. Many utilities are aware of the situation and the details are company specific. Utilities in growing population centers, those with older systems, urban and rural will have different issues. New technologies, such as digital controls, require new skills. For some equipment, it is possible to trade off higher initial costs for reduced maintenance requirements. Establishing in-house training centers and changing salary structures are possible approaches at the personnel level but there may be broader solutions. Among possible approaches that would require a more strategic perspective are:

- Better monitoring and diagnostics to trigger preventive maintenance and efficiently direct corrective maintenance.
- Knowledge-capture systems to harvest the expertise of retiring employees.

- Different operating and maintenance practices that are less skills dependent.
- Increased application of artificial intelligence for operations and maintenance.
- Development of decision support tools.

Reliance on the availability of an adequately trained work force is another area where power delivery organizations cannot assume "business as usual" will suffice. A strategic approach, integrating operations, maintenance, human resources, research and other departments is the best way to address this issue.

Longer Project Cycle Times

Planning a major utility project has always required significant lead times because of the multiple approvals and permits required. Increased regulation and more determined opposition from independent organizations have lengthened the approval process even more. In addition, smaller projects have increasingly been subject to the same delays.

For many utilities, lengthen cycle times can be expected for:

- Site permitting
- Procurement
- Construction

Compounding the uncertainties in the approval process, are increased lead times for major components. Over the last decade, the domestic manufacturing base for power delivery equipment has diminished and many utilities have turned to offshore suppliers. Consequently, power delivery organizations find themselves in the same marketplace with rapidly expanding power systems such as those in China and India. The result has been significant increases in the manufacturing lead times for major components, most notably power transformers. Eventually, new manufacturing capabilities in the developing countries may reduce order cycles but obtaining critical equipment from new suppliers brings another set of problems.

As more utilities begin to address the aging asset issues, the demand for equipment and contractors for installation will increase. Purchasing and construction cycles will be further impacted and historical experiences may not be accurate for planning new installations. A longer-range approach will be required to anticipate and adjust for a lengthen implementation cycle and to assure successful project planning.

The Energy Policy Act

The Energy Policy Act of 2005 is expected to have a significant impact on the transmission area of the power delivery business but the extent is still uncertain. Much of the impact will be felt at the corporate level but there is considerable potential for changes at the operational level and strategic planning would be appropriate for assessing emerging possible strategic issues that could affect operations across the organization.

In particular, the act in conjunction with more active oversight from regional transmission operators will most likely lead to:

- Mandated investments in new and upgraded transmission circuits
- Common standards for transmission reliability
- Additional monitoring of the status of the transmission grid and the development of new systems and methods for performance comparison across existing control areas
- Penalties for non-compliance to new reliability standards

Specific regulations are still evolving but it is clear that there will be consequences for construction, operation and maintenance from the act's provisions. Already, maintenance outages for critical equipment are difficult to schedule. Developing strategies to improve transmission corridor reliability with aging equipment and restricted access will be a major challenge for many PD organizations and a well developed decision process can assist in addressing these issues and identifying appropriate solutions.

Data and Tools for PD Decision Processes

Analysis and decision support tools could assist in several phases of both the long-range and strategic decision processes. There are two broad categories of tools that can be useful. The first helps with the identification and quantification of risk for situational analysis and critical issue classification. The second helps with prioritization and trade-off studies and can assist in strategy selection. Some efforts to supply such tools for power delivery are described below.

System and Equipment Models

In general, modeling is an attempt to represent mathematically some physical process such as the rate of occurrence of failure. Models have been developed to measure, estimate and predict the reliability of many different kinds of components and systems. A model that predicts time-to-fail as a function of operating stresses is known formally as an acceleration model. Reliability models can be mathematically intense, incorporating stochastic processes, probability and statistics in their calculations, and relying on maximum likelihood estimates, numerical methods (which may or may not converge) and confidence intervals to model their assumptions. The most common objective is to model the failure behavior of systems to estimate the current reliability and to predict future failure behavior. Such models are not readily available for the major power delivery components.

Strategic asset management decisions often revolve around determining when and where to make new investments - e.g. when and which equipment to replace, when to upgrade the system. These decisions, in turn, depend on deciding whether or not, given the present state of the equipment or system, there is unacceptable risk of a current or future shortfall in performance to initiate an ameliorating action. To make or plan for such decisions quantitatively there should be a process in place to predict the future condition of an asset, subsystem, or the complete system and how it may respond to future demands or stresses. Obviously, this requires an ability to predict future performance. Obtaining this ability starts with developing the proper reliability models. Building these models requires an identification of the mechanisms of deterioration for the asset or system and an evaluation of the rate of deterioration as a function of the various stresses (time, loading, etc.).

Ideally the stress/aging models would represent the dynamic deterioration process with a set of equations that could be used in to perform trending and failure prediction to provide a forecast of future deterioration and the asset or system state for a future time. To be most useful, the deterioration processes should be described probabilistically. With such models, future states or performance levels could be represented as a probability distribution of states going forward.

To predict future performance when the deterioration is not just a function of time but also of stress levels, the future stresses must also be predicted. If loading were one of the stress factors then a load forecast could be used for this purpose, for example. Future performance may also be affected by changes in operating or maintenance practices or by replacement of individual components within a system. Consequently, these factors may also have to be accounted for in projecting future performance.

Fleet Management

One of the most pressing needs for new and better tools to support power delivery long-range and strategic planning is in the area of equipment asset management. Even for those utilities not faced with a large aging asset problem, quality long-range planning requires a good understanding of the current and projected future condition of the asset base.

As introduced earlier, it is well accepted that the risk of equipment condition deterioration and wear out failures increase as equipment approaches the end of its useful service life. The rationale and timing of investment decisions in anticipation of this increased risk have been traditionally left to historic patterns and engineering judgment. This may result in higher costs to the utility and its customers if investments are not optimally timed, i.e. if made too early, they may result in higher carrying costs; if made too late they may result in reduced service and higher failure costs. Strategic planning with an aging asset infrastructure makes it increasingly critical to identify equipment hazard functions of major asset classes and to understand the risks and influence of critical variables on equipment failure rates. With better failure rate information, risk based approach models of the underlying distribution of failures or “bath-tub” curve of each asset type can be developed to allow optimizing the risk-cost function in the planning and decision making processes.

Historically, projected equipment failure rates were computed by dividing the number of past failures by the equipment-years considered in the studies. These historical failure rates were assumed to be constant throughout the equipment life and used for replacement and spares planning. However, as illustrated in Figure 6-1, these assumptions only apply if the equipment in question is operating in the flat portion of the hazard rate curve. Furthermore, many factors can influence equipment performance causing variations in equipment failure rates with time and usage. These could include equipment age, loading, manufacturer and maintenance history. A better understanding of how these additional stress factors affect equipment performance is required to correlate the relationship of various parameters with the probability distribution of equipment time to failure and failure rate.

Approaching asset walls and new operating requirements make projections based on past history increasingly risky. Planning strategically, estimating future capital requirements and making the best effective capital funding decisions in the present requires a better understanding of asset performance projections over the long term. Understand individual asset performance is important for tactical planning but understanding the collective performance for groups of asset types, often called fleets, is important for PD LRSP. The key to sound strategic asset planning for a power delivery organization is obtaining and consolidating information on prioritizing and scheduling asset base renewal into a coherent plan that then can be integrated into an overall strategic plan.

Integration of asset base renewal into long range planning can be difficult for a number of reasons including:

- Poorly defined and inconsistent methodologies and approaches to asset management;
- Traditional focus on minimizing current capital costs
- Failure to recognize the impact of asset renewal on the organization's strategic plan;
- Lack of data and models to predict future equipment condition
- Lack of decision support tools to prioritize investments.

Asset Life Cycles

Power delivery assets follow a well-defined life cycle and different asset management disciplines must be applied at various stages in this cycle. Understanding these cycles is important for proper strategic planning. Power delivery assets' life cycle can be characterized by three major phases:

- Initial
    - Planning
    - Design
    - Procurement
    - Construction
- Operation
    - Normal operation and maintenance
    - Minor refurbishment
- End-of-life
    - Major repairs
    - Wear out
    - Retirement
    - Disposal

The first stage of an asset's life cycle most always gets sufficient attention. During this phase needs are defined, options are considered, capital budgets are established and schedules and expenses are tracked. In this phase a fundamental asset management approach produces operational plans and budgets. In the second phase, only normal maintenance is usually required. If there is some performance shortfall, then alternatives can be evaluated. In the third phase, maintenance costs increase and there may be major repair expenditures. Performance and condition begin to degrade. Ideally, this phase of an asset's life cycle should be anticipated and identified as soon as possible so that replacement can be integrated into a long-range plan.

As the equipment continues to age, it becomes increasingly important to understand the future costs and risks associated with operations. Eventually risk will become too great or performance too poor and the asset must be replaced. Understanding in which phase assets are is important so that replacement can be planned appropriately. This information exchange is an important interface between tactical asset management and long-range and strategic planning. A sound long-range planning process should integrate infrastructure condition data and performance predictions so that this information can be used beyond the tactical time frame. A series of projected capital needs based on current fleet condition, age profile and performance requirements should be available for inclusion for strategic planning situational analyses. There is a need for better tools to assess system and equipment risk and predict future performance for better fleet management.

Power Transformer Fleet Management

One of the approaching asset walls of most concern is that of power transformer. These are obviously critical operating components in the power system, are often the most expensive, and require long and disruptive repair and replacement procedures. Running all power transformers to failure may entail unacceptable financial and operating risks. Because of the skewed demographic distributions common in many utilities and the fact that significant numbers of transformers may be at the back end of the failure rate "bathtub curve", existing methods need improvement to provide informed long-range planning for effective management of this aging transformer generation. In response to this need, EPRI launched a project to help asset managers and planners deal with the problem of managing populations of aged transformers by formulating innovative methodologies to analyze transformer investment strategies. The results illustrate a successful application of the integration of equipment asset management with corporate, financial asset management. This work is reported in *Innovative Methods for Managing Aged Transformer Fleets*[7] and follow-on efforts are summarized below. The latter work was directed at practical applications of the methodology for a specific set of circumstances and included:

- Analysis of several possible power transformer maintenance and replacement strategies
- Projections of the numbers of failures going forward for a twenty year planning horizon,
- Net present value comparisons of these potential strategies,
- Budgetary requirements for each of these scenarios for the planning period.

The results discussed below draw from that work and demonstrate the types of methodologies and data that would be supportive of a PD LRSP process for transformers and other equipment types.

In the reported project several innovative methodologies were analyzed and formulated for the types of scenarios and business case studies that typical utility asset managers need to consider and that can support strategic planning. Integral to the development of such business case analyses is the ability to project the rate of failure of the transformer population at risk. In the basic case, this is calculated by convolving the hazard rate function with demographic data as previously illustrated in Figure 6-1. The convolution is the sum of the products of the number of transformer units in each age bin times the value of the hazard rate function for that specific age bin. The hazard rate function is fixed for a given population; however for each year or interval into the future, the demographic distribution moves to the right, causing more overlap and higher numbers of projected failures.

The key to successful application of this approach is to establish the proper hazard rate function. It is not a straight forward task to generate an accurate curve for the assets of interest. Quantitative data on the hazard rate function for transformers are sparse. The reliability performance of a transformer is first determined by the physical characteristic of the transformer as set by its design, manufacturer, and materials. Hazard rate is further modified by the stresses experienced by the transformer. Loading, switching transients and environmental factors all stress the unit. Finally, maintenance practices may influence the condition of the transformer and hence its ability to withstand stresses. The appropriate hazard rate function can be derived from actual failure data from the utility (if there is enough available) or, for the normal aging portion at least, from a model for aging based on standardized methods used in ANSI C57.91 or IEC standards. Such well-established models relate hot spot temperature to life expectancy as a function of oil condition. Based on such a model, the hazard rate function can be calculated for specific loading conditions and insulation system condition. Note though that this is only one of the contributing factors to the overall hazard rate. Described below in a later section is additional EPRI work to address the scarcity of data for constructing representative equipment hazard rate curves.

For the focus of the transformer study, sufficient utility failure data was available to construct a hazard curve for the transformer type of interest. A detailed analysis, graphical analysis of multiply censored data, which takes into account all of the data from a population - namely the failure data and as well as data associated with units in the population which have survived to date, was use and several conventional statistical distribution functions tested. The Normal distribution provided the best fit to the available data.

The transformer owner used an economic value added (EVA) model as a tool for evaluating company performance and investments. On an overall company assessment basis, EVA is a value-based financial measure, which reflects the amount of shareholder value created or lost on an annual basis. It has become a tool of choice for controlling operations in some companies and for evaluating alternative financial investments. This tool provides decision-makers a logical and convenient method to evaluate the benefits of deferring investments, as offset by the influence of inflation, and to provide management business case analyses which include projected budget variances, earnings measures such as ROI and EPS, and discounted cash flow measures such as projected NPV of the cash flow for selected discount rates. Other tools and methods are available to accomplish the same function. The financial fundamentals of EVA were adopted for the projections of the economic consequences of candidate fleet strategies in the study.

To consider business risk, probabilistically derived failure projections were developed as a function of the asset management strategy being considered. Consequential costs were then factored in to obtain the business risk for each strategy. Associated with each strategy is an investment cost. In theory, if investment costs are increased the business risk should decline. At some point, carrying out analyses for several asset management strategies could identify an optimum trade-off between business risk and investment.

The key process in the business case analysis was the ability to project the number of likely failures going forward, as a function of selected asset management strategies. In this study, the underlying cumulative and density distributions for the derived hazard rates were used in a Monte Carlo process was used to select the ages of the failed units. The process biases the random selection of failed units such that the units that are selected fit the distribution that corresponds with the hazard rate function. The demographic distribution is then adjusted appropriately to move ahead in time. Using this methodology, calculations were performed for each proposed strategy on a year by year basis whereby the number of units that will fail is determined for the first year, the demographic distribution is adjusted to compensate for the failed units, and then the new demographic distribution convolved with the hazard rate function to calculate the number of failures in year two. The process of projecting the number of future failures was continued for the number of years required for the associated business case analysis. Representative results are shown in Figure 6-3.

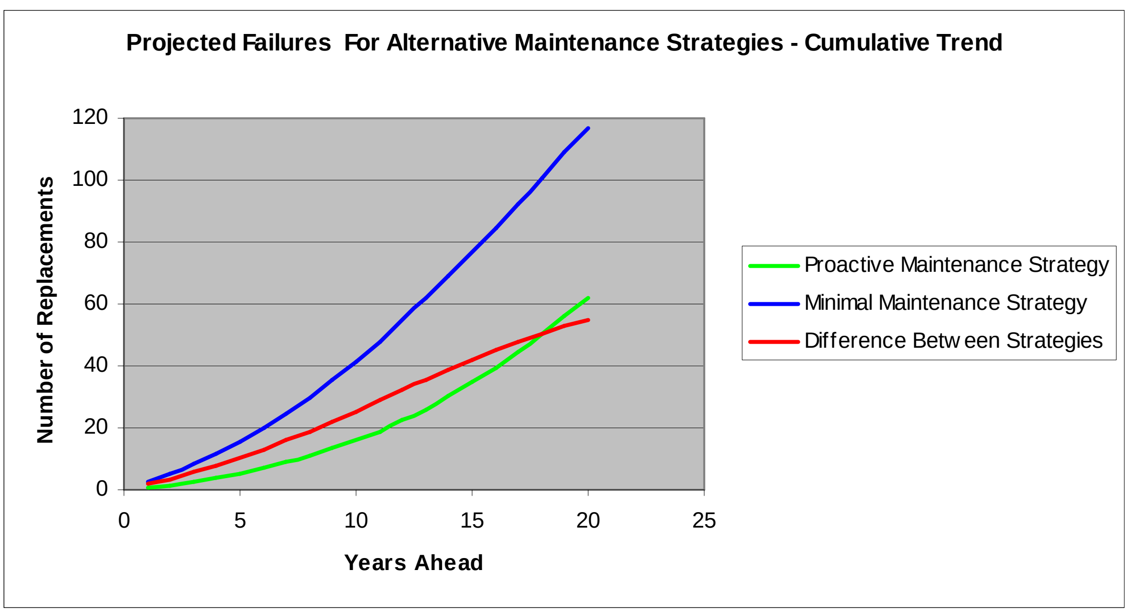

Figure 5-2
Combining Demographic Data with Estimated Failure Rate Curves for Alternative Strategies

While most of the required business case analysis in the study related to decisions about a whole fleet or a large group of assets, it should be noted that the hazard rate function can also be used in business cases related to single assets. If for example, there is an interest in a decision around a specific transformer, and it is known that this transformer is a member of a population for which a representative hazard rate function is known, then the hazard rate function can be used to project the probability of failure for that transformer in any given year in the future.

A typical case might relate to the assessment of the business risk associated with deferring investment in a transformer. In this case the business risk per year is the sum of the expected consequential costs of failure, the expected capital cost and the maintenance cost per year. The expected consequential cost is the product of the consequential cost if failure occurs times the probability that a failure occurs. Similarly the expected capital cost is the product of the probability of failure times the inflated capital cost in the year that failure might occur. The probabilities of failure may be obtained for the calculation from the hazard rate functions for transformers of interest as described above.

The primary objective for this project was to develop a methodology to address the problems presented by aging transformer populations with significant numbers of units nearing the end of their service life. The scope also included investigating the following:

- Longer-term view on maximizing return on operating and capital investment
- Relate the effect of available options on projected failure and replacement rates and their associated costs and impacts
- Identify emerging and "hidden" problems with specific segments of their transformer fleet
- Build credible business case studies

The project has identified and formulated a number of useful methodologies which have potential benefits for both tactical asset management and long-range and strategic planning including:

- Analysis of candidate asset management strategies using quantitative risk-based approaches that can reduce costs and improve other corporate performance measures
- Improved replacement needs projections that can facilitate savings through improved strategic procurement arrangements and spares assignment
- Improved credibility of capital requirement projections for senior management and regulatory scrutiny

The project demonstrated that application of advanced decision-making methodologies is practical for some studies in terms of the quality and extent of data required, and feasible in terms of the formulation of appropriate methodologies. The underlying probabilistic and financial techniques used in this work are well founded and primarily generic. The primary challenge is to establish acceptably accurate hazard rate curves for the populations of interest.

Lastly, several innovative methodologies were developed and formulated for extension to the types of scenarios and business case studies that typical utility asset managers and planners need to analyze. These include:

- Improved spares projection based on transformer fleet condition

- Forward looking failure rate projection
- More versus less proactive transformer replacement
- Tradeoffs in rating and loading capability versus maintenance and
- Analysis of solution options for generic transformer failures.

Even though this work was primarily motivated by operational issues, the methods developed and demonstrated are applicable to long-range and strategic planning, both for situational analysis – especially risk analysis – and strategy selection.

Although this study was limited in scope, focusing on one particular transformer type and application, it clearly demonstrated the power of combining equipment expertise and economic analysis. The project sets the stage for further integration of equipment asset management with corporate asset management. A fundamental principal of PDAM is that investments can be fully justified only where benefits clearly outweigh costs. Aging assets is no exception and methodologies such as those described above are required to provide the basis for planning replacement strategies.

Equipment Performance Data Base

The discussion above showed the usefulness and importance of having accurate equipment hazard rate curves. For the example presented, the utility had sufficient historical data for the transformer type studied but that is often not the case. Another EPRI effort is underway to gather the data needed for the methodology discussed and other PDAM and LRSP applications. This project, Equipment Performance Database for Transformers (IDB)[8] can help provide important information to support the planning process.

The previous section illustrated how effective planning, maintenance, refurbishment, and replacement decisions require knowledge about asset performance and the ability to project future performance and apply the concepts of risk management to power transformers. Risk management expresses the relationship between the consequence of failure to all stakeholders and their acceptance of a failure in terms of probability of occurrence. The translation from accepted risk into performance and maintenance requirements is of great importance to power delivery organizations for both planning and operations.

To be well informed about a power transformers expected performance, one must analyze both the asset's individual historical performance data and that of other assets of similar characteristics or type. Similarly, as described in the preceding section, fleet management decisions are best made with an understanding of expected performance of the group. Transformer performance varies considerably because of differences in design, manufacturing, and application. Therefore, risk identification using generic transformer failure rates is not sufficient to meet the current business and technical demands for risk management placed on power delivery planners, asset and maintenance managers. Required is statistically valid information identified by:

- Failure type

- Operational history
- Maintenance history

Design Based on specific:

- Family
- Make
- Model
- Application
- Age

To this end, EPRI has undertaken work to collect the needed data. By including data from numerous utilities, meaningful reliability, maintenance, and operating statistics can be generated. Some of the uses include:

- Population age distribution
- Failure mode distribution
- Lifetime distributions or probability density function (hazard rates)

EPRI's Transformer IDB[9] is a collaborative effort to pool appropriate transformer operating and failure data in order to assemble a statistically valid population of many types of transformers. With sufficient data, it will be possible to develop hazard rate curves for various PDAM and decision process applications, including that described above.

Power Delivery Technology

Most of the technologies used for power delivery equipment are mature and consequently new equipment designs evolve slowly. "Cutting edge" technologies that may impact the power delivery business in the future, such as fuel cells for distributed generation or super conducting energy storage, are tracked by various research and government agencies. However, technology changes that may occur over the next five to ten years are less well assessed. These would most likely be the result of equipment suppliers' efforts and, although evolutionary, may have potential strategic impact.

Usually power delivery subject matter experts are too involved in operational issues to have the time to evaluate potential technology changes in this five to ten year horizon. Therefore it is important for the planning team to include this subject in the situational analysis. As an example, new developments in integrating high voltage circuit breakers, disconnect switches and gas insulated bus into one device could reduce the required substation footprint and allow construction on a site otherwise not practical. Of course, strategic planners need to take advantage of the information EPRI, The Department of Energy and others collect on the more advanced innovations that may offer opportunities or pose threats within the strategic planning horizon.

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10.

6
CONCLUSIONS AND RECOMMENDATIONS

This report reviews the PDAM decision process in order to assist in the identification and specification of the decision support tools and analytics required for best practice power delivery asset management. The report documents the results of a preliminary effort to develop a decision support framework.

Operations, maintenance and asset managers are increasingly asked to develop quantifiable justifications for a multitude of complex decisions associated with power delivery. The rationale for such decisions can be improved with the development of appropriate decision support tools. The ultimate goal is to provide decision support tools that help utilities improve prioritization of capital and maintenance decisions and thus the return on investment. A logical, data-driven decision support methodology would help to optimize the repair versus replacement decision process, assure the use of consistent criteria throughout a power delivery organization, and better utilize limited utility resources.

This work is part of a suite of asset management guides and equipment specific analytics developed by EPRI to assist in dealing with asset maintain, repair and replace decisions and planning for a large base of aging assets. The work presented in this report is intended to complement earlier EPRI work on defining the principles and practices of power delivery asset management and extend them to a broad discussion of the decision process.

This report has presented the basic outline of the PDAM decision process and shown how it may be applied to power delivery organizations. Presented was an integrated approach that was linked from the asset owner level to business units and then to the basic power delivery asset management processes. Implementation issues and particular power delivery considerations were explored.

The power delivery industry is good at reacting to changes or performance deficits but less adept at foreseeing coming changes or performance issues. Formalized decision processes and supporting methodologies can help power delivery organizations adapt to and succeed in a shifting business environment. Accounting for long asset life cycles is crucial to effective asset management and multi-year replacement programs should be integrated into a power delivery organization's long-range business planning process. Without the level of insight gained from a strategic review of asset management issues and a well constructed decision process, it is not possible to anticipate the longer-term risks associated with managing a diverse, aging power delivery asset bases.

Future Work

Corporate decision processes are the subject of many texts, and power delivery decision making is a complex endeavor. The modest scope of this report can serve only as an introduction to the concepts and highlight some important issues. Nonetheless, the work presented here can provide insight and guidance for the direction of future efforts. EPRI has established a broad set of programs in asset management and this guide complements and supports that work. Some areas for additional investigation that would provide value include:

- Further development of the Corporate Value Model Methodology for power delivery. This would be beneficial for the entire asset management program.
- Further development of a risk management process tailored to power delivery and including risk and economic quantification to identify critical issues.
- Additional development of fleet management analysis methodologies and linkage of technical and economic decision support tools.
- Development of decision support tools and analytics for integrated power delivery asset performance and risk assessment applications.
- Development of better condition assessment algorithms for a full range of power delivery equipment.
- Development of aging models for power delivery equipment.
- Automated decision support tools

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