MAINTAINING THE SOLUTION TO OPERATIONS AND MAINTENANCE EFFICIENCY IMPROVEMENT

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ABSTRACT

This paper discusses the emergence of a new, necessary philosophy for the successful implementation of advanced technologies to improve plant performance and longevity. This philosophy is necessary to ensure the expected return on the initial capital investment is realized. This paper defines the elements of an operations and maintenance (O&M) methodology that utilizes a holistic approach which considers all aspects of the supporting infrastructure (Operations, Maintenance, Engineering, Training, and Administration) as integral parts of the whole system. This paper also discusses a network structure that provides an intelligent integrated plant communication network for the measurement and management of plant performance goals.

INTRODUCTION

Increased fuel costs and environmental legislation have made the efficiency and emission controls of plant operations increasingly important. Significant advances in data collection, monitoring, and control systems to enhance the efficiency of plant operations are occurring at a fast rate. However, in many cases the installation of the latest system to improve efficiency has not resulted in the continuous improvement process that provides the long-term benefits of improved efficiency in O&M. Typical of optimization problems, the process of improving one area of performance causes another area to suffer. Thus, to improve total plant performance, efficiency enhancements must be approached from a global, as well as life-cycle perspective.

This holistic philosophy was developed and implemented during the installation of a Decision Support System for Operations and Maintenance (DSOM) developed by the Pacific Northwest Laboratory (PNL) at the Marine Corps Air Ground Combat Center, Twentynine Palms, California. The DSOM system is a Federal Energy Management Program-administrated research and development (R&D) project pioneered by a team of research engineers and scientists at PNL. This approach is unique in that it offers a permanent solution to O&M problems through the

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establishment of a computer enhanced plant infrastructure. This infrastructure is, in turn, capable of a self-supporting, program-improvement process that provides immediate improvement in the areas of operating efficiency, protection of plant capital equipment, and long term O&M life cycle cost reduction.

FEDERAL ENERGY CONSERVATION MANDATE

In 1992, Congress passed the National Energy Conservation Policy Act (NECPA). This legislation elevated the role that utilities conservation will play in the Federal government for years to come. One key aspect of NECPA is the mandate that a 12% reduction in utilities consumption for all Federal activities by 1995 from a 1985 baseline. Energy conservation must continue beyond that to reach a mandated 20% reduction by the year 2000. Executive Order 12709 of March 8, 1994, increased this goal to 30% by the year 2005 and stipulates that all cost effective energy and water conservation projects be implemented, and includes a goal for Federal industrial sites of 20% savings. In light of the funding reduction in military base operations, these mandates place an ever-increasing premium on improved reliability, productivity, and efficiency of base facilities. This results in a daunting challenge to base facility managers; increase facility efficiency while under reduced budget constraints.

On a percentage basis, Federal O&M funding is significantly less than that found in commercial industry. As a consequence, the field performance of military facilities and their supporting infrastructure tend to deteriorate relatively quickly. Realistically, the O&M of base support facilities has led to very few promotions among senior military officers compared with combat or operational readiness and training. Now, with reduced budgets, many base maintenance officers are ill equipped to successfully meet the efficiency and environmental challenges that lie before them.

The goal of the DSOM project was to increase the safety and productivity of base heating plants for the U. S. Marine Corps (USMC). Using state of the art engineering practices applied via an artificial intelligence computer network, DSOM utilizes an integrated and carefully structured approach to productivity enhancement.

PRODUCTIVITY FROM A LIFE-CYCLE PERSPECTIVE

During the usual 3-year tenure of the Facilities Maintenance Officer (FMO), he views only a narrow portion of the life cycle of any given facility or system. Figure 1 depicts the performance level of a facility over its useful life. The design life of a base central heating plant, for example, is typically 25 years. Given careful O&M practices this can be extended to something more on the order of 40 years. Obviously, no one in the military chain has responsibility for the O&M of such a facility for anything but a small fraction of this period.

As depicted in the figure, the performance of any facility tends to decrease over time. The slope of this decline is referred to as the degradation characteristic and its variations are dependent on design adequacy, operating environment, and maintenance effectiveness. In the nominal scenario, a plant proceeds at a fairly constant rate of degradation, but is fully capable of fulfilling its design mission (Case A). At some point the end of the useful life is reached and the facility must either be refurbished or replaced.

In many situations the degradation process has been hastened by unavoidable reductions in the funding necessary to perform the O&M functions in a cost effective manner (illustrated in Figure 1 as Case B). This is often compounded by the fact that this same funding deprivation frequently removes the facility's ability to make an accurate determination of its current performance level. Thus, the understanding of where the performance level is, and its rate of change, are both lost. This result renders the facility manager virtually blind - unable to anticipate or mitigate the impending loss of a major facility service.

A third and much more desirable alternative is reflected in the curve labeled Case C, where a slowing of the degradation rate is accomplished. Life extension is a very real possibility using advanced monitoring and predictive maintenance techniques now being developed in the Laboratory.

WHERE ARE WE NOW?

The question is, where is your facility on the performance curve, what is the rate of change, and how can these conditions be measured? An accurate method for assessing your plant's physical condition, and the real performance level of the facility and its O&M infrastructure has been developed and tested by PNL. Borrowing on extensive Naval and commercial nuclear power experience, the nature of, and interdependencies of all of the areas necessary for effective process operations have been defined and the criteria formalized. These criteria are organized into the functional areas of Operations, Maintenance, Engineering, Training, and Administration (OMETA - see Figure 2). From both a performance and a programmatic perspective, these criteria allow us to define how well the subject plant functions relative to a "perfect plant." A uniform, reproducible measurement basis has thereby been established. The collection of these criteria is termed the Standard Plant Metric (SPM), and forms a yardstick for measuring potential plant improvement opportunities.

Some of the aspects of OMETA that are addressed and their functions are listed below.

Operations:

- Administration - to ensure effective implementation and control of operation activities,
- Conduct of Operations - to ensure efficient, safe, and reliable process operations,
- Plant Status Control - to be cognizant of status of plant systems and equipment,
- Operator Knowledge and Performance - to ensure that operator knowledge and performance will support safe and reliable plant operation, and
- Operations Procedures and Documentation - to provide appropriate procedural direction that can be effectively used to support efficient, safe, and reliable operation of the plant.

Maintenance:

- Administration - to ensure effective implementation and control of maintenance activities,
- Work Control System - to control the performance of maintenance in an efficient and safe manner such that economical, safe, and reliable plant operation is optimized,
- Plant Material Condition - to maintain the plant in a condition that supports efficient and reliable operation,
- Conduct of Maintenance - to conduct maintenance in a safe and efficient manner,
- Preventive Maintenance - to contribute to optimum performance and reliability of plant systems and equipment,
- Maintenance Procedures and Documentation - to provide directions when appropriate for the performance of work and to ensure that maintenance is performed safely and efficiently,
- Maintenance History - to support maintenance activities, adjust maintenance programs, optimize equipment performance, and improve equipment reliability,
- Maintenance Facilities and Equipment - to effectively support the performance of maintenance by providing adequate facilities and equipment,
- Materials Management - to ensure that necessary parts and materials meeting quality and design requirements are available when needed, and
- Maintenance Personnel Knowledge and Performance - to keep maintenance personnel knowledge and performance at a level that effectively supports efficient, safe, and reliable operation.

Engineering Support:

- Engineering Support Organization and Administration - to ensure effective implementation and control of technical support,
- Plant Modifications - to ensure proper design, review, control, implementation, and documentation of plant design changes in a timely manner,
- Plant Performance Monitoring - to perform monitoring activities that optimize plant reliability and efficiency,
- Engineering Support Procedures and Documentation - to ensure that engineer support procedures and documents provide appropriate direction and that they support the efficiency and safe operations of the plant,
- Document Control - document control systems should provide accurate, legible, and readily accessible information to support station requirements.

Training:

- Administration - to ensure effective implementation and control of training activities,
- General Employee Training - to ensure that plant personnel have a basic understanding of their responsibilities and safe work practices and have the knowledge and practical abilities necessary to operate the plant safely and reliably,
- Training Facilities and Equipment - the training facilities, equipment, and materials effectively support training activities,
- Operator Training - to develop and improve the knowledge and skills necessary to perform assigned job functions,

- Maintenance Training - to develop and improve the knowledge and skills necessary to perform assigned job functions,
- Chemistry Training - to develop and improve the knowledge and skills necessary to perform assigned job functions, and
- Emergency Response Training - to develop and improve the knowledge and skills of emergency response personnel to mitigate an emergency.

Administration:

- Station Organization and Administration - to establish and ensure effective implementation of policies and the planning and control of station activities,
- Management Objectives - to formulate and utilize formal management objectives to improve station performance,
- Management Assessment - to monitor and assess station activities to improve all aspects of station performance,
- Personnel Planning and Qualification - to ensure that station positions are filled with highly qualified individuals, and
- Industrial Safety - to achieve a high degree of personnel and public safety.

The process plan for accomplishing a site characterization that leads to an integrated facilities improvement strategy is depicted in Figure 3.

- An OMETA trained and experienced team is first assembled. Each of the five areas has its own expert, who coordinates and organizes the information from all team members for that area. Following a review of the plant design and operating states, a discussion of any available plant information prepares the team for the site visit.

- At the site, the team uses a criteria protocol and systematically gathers information on each of the functional areas. The team also establishes an efficiency baseline at both the component and plant performance levels.

- A master list of observations is used to derive the full set of improvement opportunities for the plant. Next a critical systems analysis is performed to narrow the field to areas that are truly necessary to the safety, reliability, and efficiency of the plant.

- A solution to each of the critical improvement opportunities is now formulated based on plant experience and sound engineering practices. As the DSOM project domain deals only with the analysis and management of information, solutions that involve upgrading infrastructure elements must be supplied by either site or project resources.

- A value/impact ratio for each critical solution is derived based on the projected cost of a given improvement and the likely return in terms of plant O&M savings.

The final rankings of improvement solutions are sorted from highest to lowest benefit/cost ratio, but maintain their functional area identity. This presents plant managers with a prioritized list of improvements that can be implemented using a focused improvement strategy. Because these improvements are derived from an integrated infrastructure perspective, they inherently contain the elements that are necessary to produce an effective and therefore efficient plant operation.

FOCUSING FACILITIES RESOURCES

A look at the administrative area of the SPM reveals that one of the principal responsibilities of the managerial function is the assignment of resource priorities. An earlier paragraph of this article points out a new management priority: a mandate for improving efficiency and thereby reducing energy consumption. Let's continue a bit further with the central power plant example, and assume that the characterization described above has been performed and we have a concise cost/impact ordered listing of improvements. How do we identify the minimum resource level that must be obligated to attain the required improvement goal? The nature of the improvements and their cost/impact ratios help to answer this question.

Summing up our collective experiences with power plant operational infrastructure conditions, we find that a wide range of productivity levels can be found. The upper curve of Figure 4 illustrates how the population of plants might be distributed based on how well they perform in terms of productivity level.

> In a low productivity environment the goal is survival for one more day. Complaints, confusion, and apprehension of impending catastrophe pervade the operator attitudes. These plants usually have chronic O&M problems and don't have a clue as to how to go about fixing them. Low reliability and even total plant failure characterize this segment of the population.
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> One notch up the ladder, the by-word is adequacy. They're keeping it together, but a current of uncertainty and uneasiness can be found. These plants typically are in the lower 1/3 of the reported efficiency ratings, and frequently represent older plant population.
>
> Many of today's better performers are striving for operational accuracy. They are secure in their knowledge of how to operate and maintain their plant, but would like a better grip on the exact performance level, and how their O&M changes affect the plant processes.
>
> At the top of the ladder are those plants that know both the level and slope of their plant performance curve. They search for better ways to optimize the state of an already effective O&M process.

While these characteristics are obviously very general, they should serve to provide some idea of your relative position on the O&M spectrum. Once you have identified approximately where your plant resides on the upper curve, the lower curve in Figure 4 tries to translate that position into an immediate improvement focus area.

Safety - Chronic problems provide a condition conducive to accidents. At this level, the focus is clearly on personnel safety and the preservation of your capital equipment.

Infrastructure - Effective and efficient O&M requires that all the OMETA elements are fully functional. While the format of these elements is quite flexible, the plant cannot move toward a higher productivity rating without a well-understood responsibility and communications pathway.

Information - Accurate and complete information set is essential to making logical cost/benefit decisions regarding operation and maintenance of any facility process. This provides the footing necessary to reaching the top rung of the O&M ladder.

Analysis - Given an accurate information basis, advances in technology allow predictive diagnosis and mechanistic root cause to be determined. This gives the plant the ability to assess the remaining useful life of critical components and to plan maintenance around the prevention of failure rather than reaction to failure.

These are difficult, but feasible transitions. Two key concepts must be retained:

1. A facility must be able to walk before it can run. The basic attributes of a safe, functional O&M infrastructure must be satisfied before it is feasible to attempt increased productivity through any means, high-tech or otherwise.

2. Major productivity increase-decrease cycles are not cost effective. In order to maintain the performance gains of any facility upgrade, a self-sustaining program to provide life-cycle information accuracy is necessary.

There is a reward in the form of significant productivity gains from using the advanced methods and technologies now available. A bottom line 20% reduction in O&M costs over the life of even the best plant is a clearly achievable goal.

A CASE STUDY

In October of 1990 a PNL team visited the Central Heating Plant (CHP) at the U. S. Marine Corps Air-Ground Combat Center (MCAGCC) in Twentynine Palms, California. The CHP, constructed in 1978, utilizes natural gas to provide the heating and cooling requirements for over 15,000 Marines and Sailors at the Combat Center.

As the base population grew, additional demands were placed on an already strained hot water distribution network. The CHP operators, attempting to compensate for these distribution system deficiencies, increased the output water temperature. Subsequently, the plant began experiencing severe water hammer phenomena in the 250 psig subcooled primary circulation loop. The plant, rated at 120,000 Btu/hr, encountered these pressure spikes at an indicated 48% of the maximum plant power. The team quickly identified the cause of the water hammer as boiling (two-phase operation) in what should have been a single-phase loop. A recommendation was made to reduce primary loop temperature and increase pressure to the design maximums; these actions immediately restored single-phase operation. A further recommendation to perform a plant-wide calibration of all critical instrumentation was quickly accomplished. These actions stabilized the operational behavior and removed the potential for a catastrophic plant failure.

A complete characterization of both the efficiency and plant O&M infrastructure was completed and submitted to the Marine Corps Headquarters sponsor. It laid out a recommended strategy for reconstituting the plant's design basis and O&M infrastructure as a key part of the DSOM artificial intelligence development project. Following Headquarters approval of the plan, close coordination between the Twentynine Palms facilities and plant staff, the Naval Facilities Engineering Support Center (NFESC), and the PNL research team resulted in the installation of the DSOM system, and a rather remarkable jump in the efficiency of the base CHP.

THE DSOM SYSTEM INSTALLATION

Installation was accomplished in two phases. Per the characterization scheme, primary attention was focused on giving the plant operators an accurate, ergonomically sound process indicator display. Associated infrastructure elements were simultaneously put in place. These included as-built piping and instrument diagrams, design basis reconstitution, a component labeling system, an instrument calibration laboratory complete with all required calibration instruments and tools, an ergonomically designed control and supervisory monitoring room, and an instrument technician to provide for the necessary maintenance of the hardware system. The Laboratory took the responsibility for instrument set design (based on process monitoring, degradation trending, and diagnostic input requirements) and for proper specification, procurement, and placement of the instrumentation in the plant. The Naval Energy and Environmental Support Agency (NEESA, now NFESC), installed the instruments per the PNL plan and ran and connected the instrument cabling from the remote locations to the central Data Acquisition System (DAS) termination panel.

The second phase was the development of an artificial intelligence monitor to detect inefficient plant operating conditions, analyze the process, and provide the operator with appropriate condition and recovery instructions.

PPROJECT RESULTS

On 6 April 1994, the Efficiency Diagnostic Monitor (EDM) and plant instrumentation Preventive Maintenance System (PMS) were successfully installed in the Twentynine Palms DSOM computer.

The EDM and PMS are the final software products in the current DSOM Twentynine Palms project. The EDM provides on-line oversight of the efficiency of the combustion, heat transfer, and heat transport processes in the plant. Specifically, the EDM enables the DSOM computer to recognize an efficiency condition below acceptable limits, localize, and identify the substandard process to the operator, and provide a prioritized scheme for efficiency recovery. The PMS is essential to maintaining instrument accuracy, thereby ensuring that the computer system provides operators with the correct problem diagnosis.

The successful installation of the Phase III software continues to follow the DSOM value/impact implementation strategy established by the Site Characterization Report submitted in April 1991. Reflecting back to the original project goals of improving plant safety, reliability, and efficiency, the project has accomplished the following:

Safety - The project eliminated a potentially dangerous water hammer condition, and the computer system now provides oversight to ensure continued operation within the original plant design operating specifications.

Reliability - Plant availability and capacity have increased with the vastly improved accessibility and accuracy of operator information and on-line component vibration monitoring. An approximately 30% capacity jump has allowed the site to shelve plans for expanding the central plant. Plant personnel now utilize component vibration levels to identify and avoid potential equipment failures. The time required to train a plant operator has been reduced from 2 years to approximately 6 months.

Efficiency - Since the beginning of the project in October 1990, plant output efficiency has increased by approximately 13%. The DSOM advisory system has identified that an additional 3% to 4% heat rate improvement is achievable via thermal insulation upgrades. When the insulation upgrades are completed, the total efficiency gain due to the project is expected to be approximately 16%.

The development and implementation of the DSOM integrated infrastructure approach has resulted in making the Twentynine Palms CHP plant the most efficient plant in the Marine Corps. The understanding and support of the project from Headquarters, the cooperation of the plant operators in assisting the PNL team, the willingness of the site managers to provide the necessary support requirements, and the dedication of the NFESC installation team all played vital roles in making this a successful, and a permanent productivity improvement project.

Field Performance Model

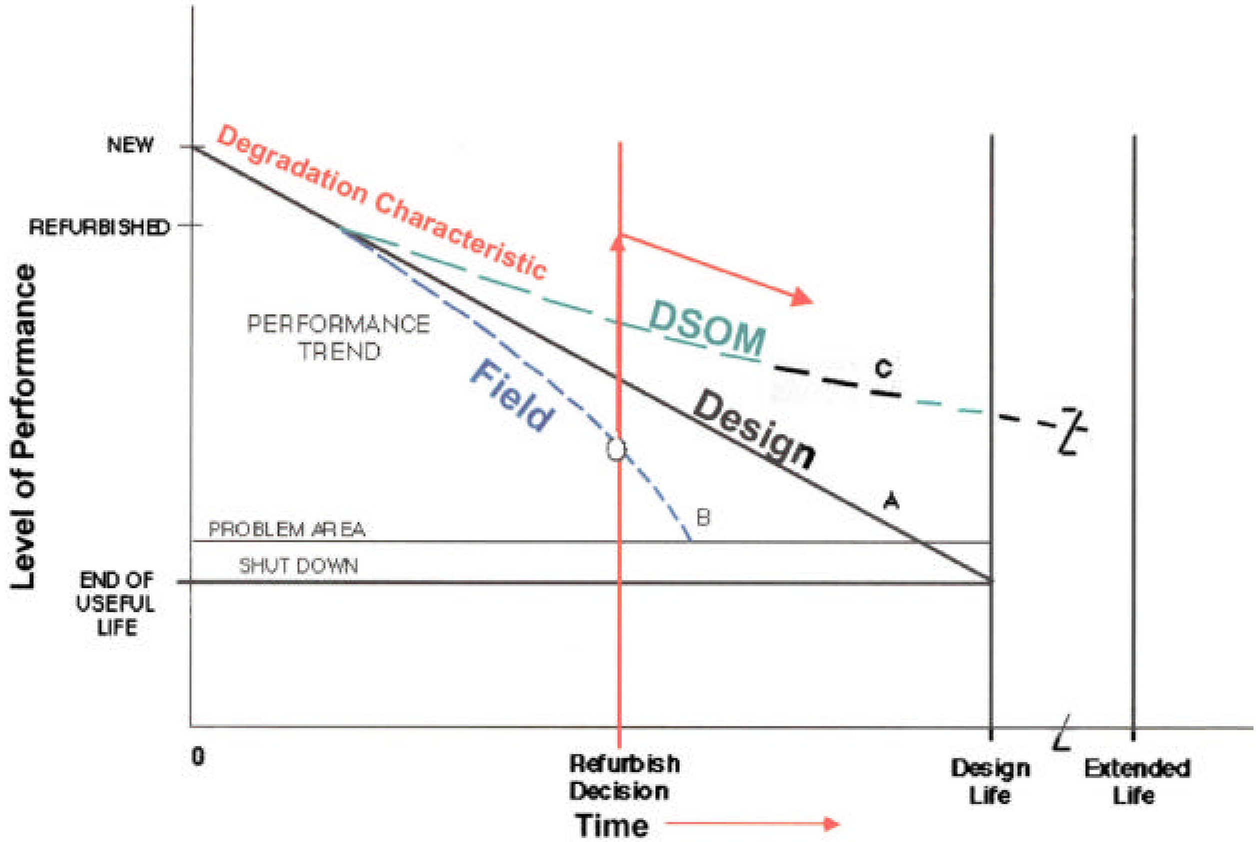

Figure 1

OPERATIONS AND MAINTENANCE FUNCTIONAL INTERACTIONS

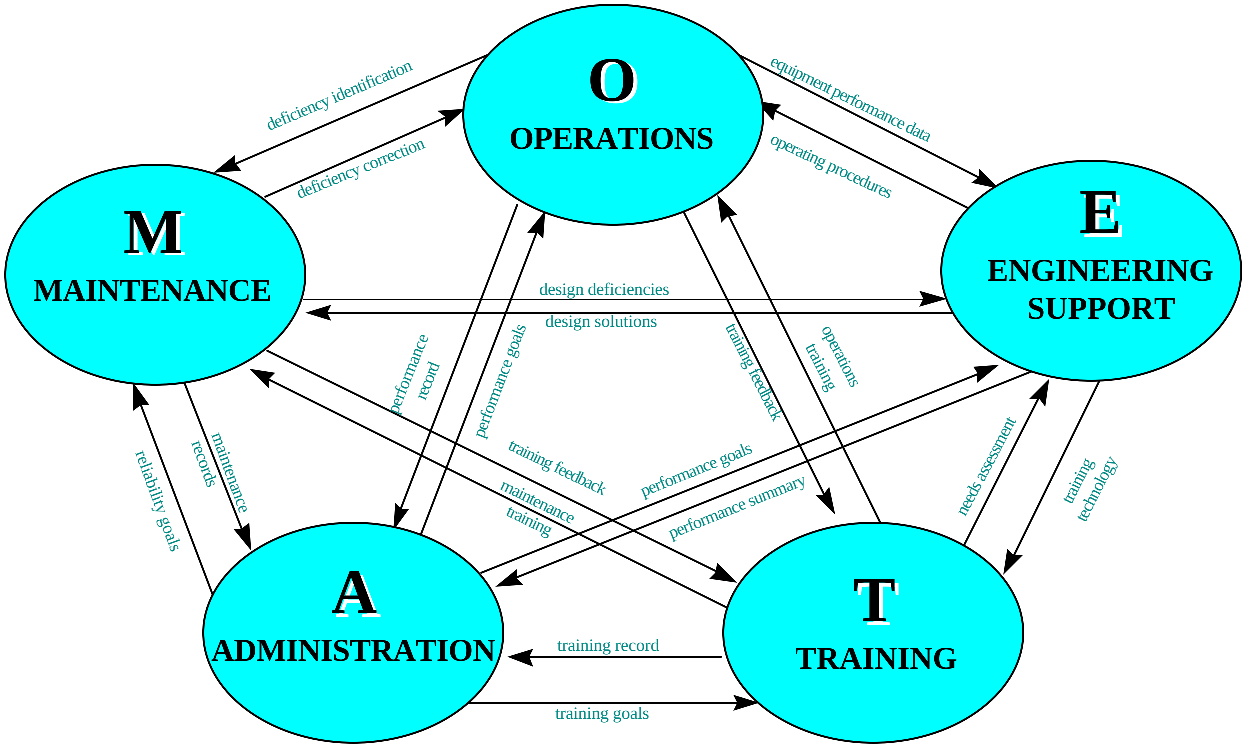

Figure 2

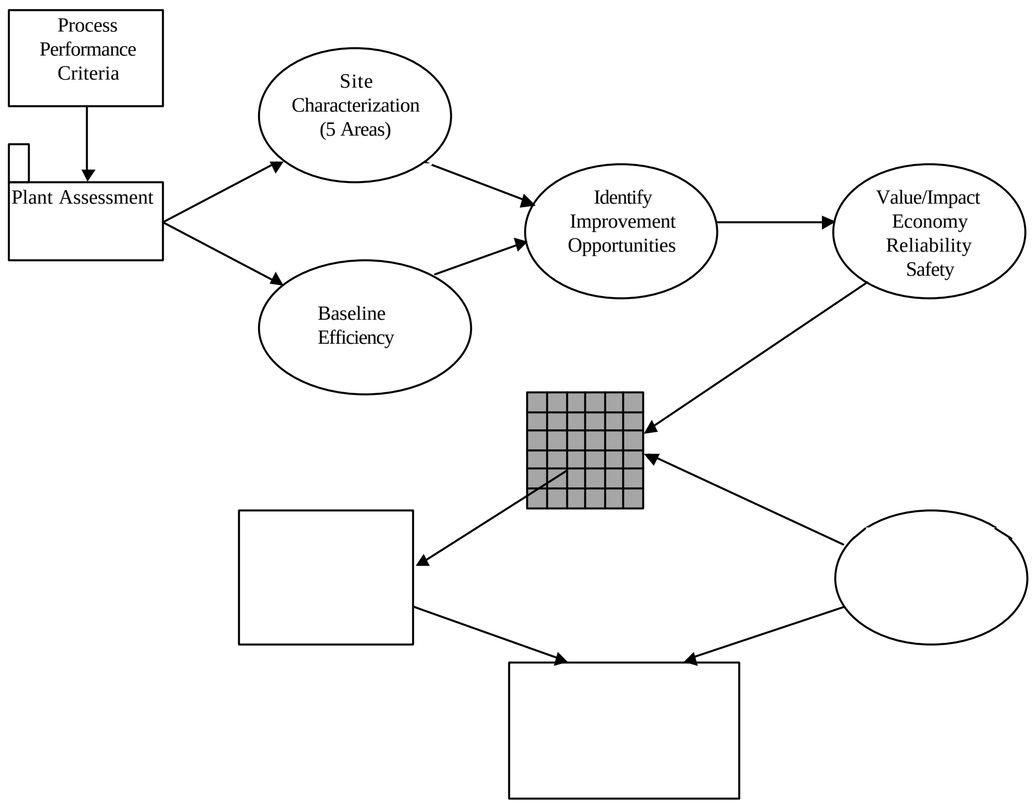

Figure 3 - DSOM Characterization Methodology

Plant Productivity Focus

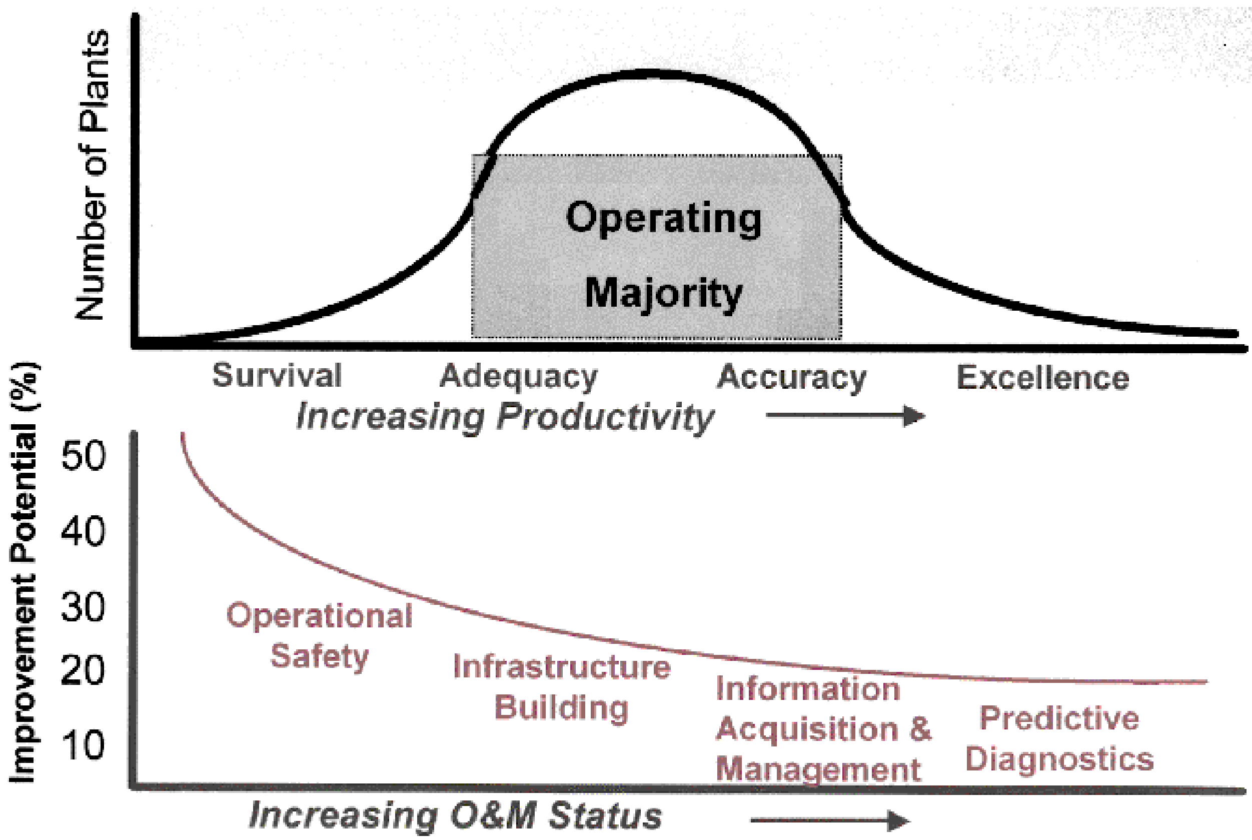

Figure 4