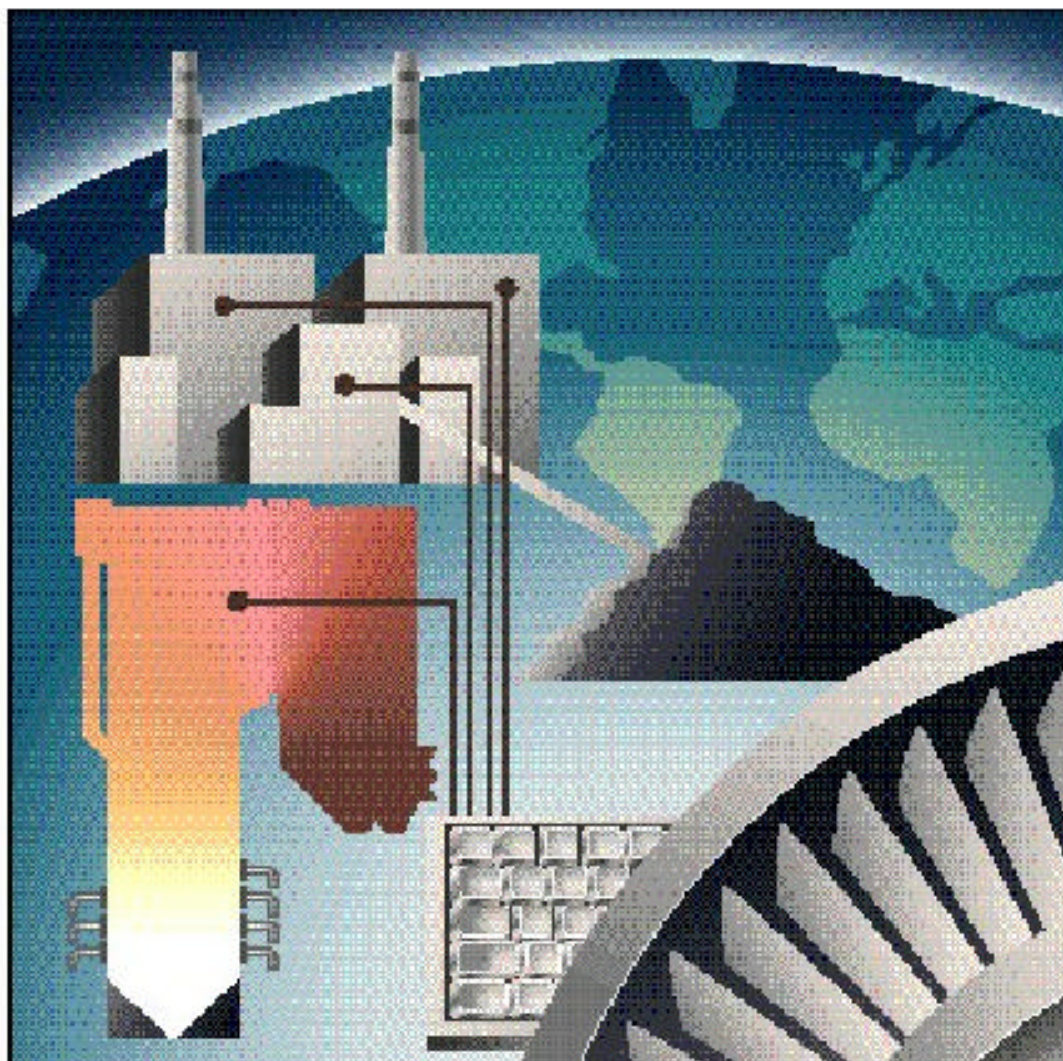


# Plant Maintenance Optimization Assessment Guideline

*Technical Report*





# **Plant Maintenance Optimization Assessment Guideline**

**1000321**

Final Report, December 2000

EPRI Project Manager  
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# REPORT SUMMARY

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A Plant Maintenance Optimization (PMO) assessment is a way to help electric power producers achieve lower operating costs and higher reliability and availability by optimizing the overall maintenance program. The assessment starts by introducing the attributes of an ideal program. The second part of the process evaluates the existing maintenance program and identifies gaps between the existing program and the ideal program. The process concludes by developing an implementation plan to move the program toward the ideal state.

## Background

EPRI has performed PMO assessments at over 50 power generation plants and other industrial facilities. Subsequent implementation initiatives have reduced overall maintenance costs, improved plant availability, improved equipment reliability, and increased both overall and commercial availability.

## Objectives

- To educate an organization in PMO terminology and concepts.
- To gather data and assess an organization on all aspects of plant maintenance.
- To identify and plan activities for optimizing plant maintenance and achieving business goals.

## Approach

In the past, a common approach to reducing budgets was to cut operations and maintenance (O&M) staff. The eventual result was lower reliability, increased cost of equipment failures, and high cost of replacement power. What is needed is a reevaluation of maintenance strategies that will result in an optimum strategy that balances cost and reliability.

An optimum maintenance strategy moves an organization from a “reactive” approach or a “preventive” approach to a “planned” approach where maintenance is performed at the most optimum time before equipment fails. In a “reactive” approach, most maintenance work is reacting to unexpected failures. In a “preventive” approach, most maintenance is performed on a scheduled basis.

This guideline provides a roadmap for assessing the current state of a generation plant maintenance program, which is referred to as the “As-Found” program. This guideline also describes how to define a desired program, which is referred to as the “To-Be” program. By comparing the “As-Found” program to the “To-Be” program, the gaps between the two states are identified. This guideline describes how to plan a change effort to narrow those gaps and get to an optimized maintenance program.

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## **Results**

The guideline is organized into four parts. These parts provide the tools that are needed to understand the current status of a maintenance program and to prepare a plan to reach a desired program.

Part I of the Guideline develops a common understanding of concepts and terms that are necessary to move forward with the assessment process. This section also describes the “To-Be” program concepts.

Part II of the Guideline is structured for gathering station information and data to define the “As-Found” condition.

Part III of the Guideline directs the team in preparing for and conducting interviews of station operations, maintenance, and support personnel.

Part IV of the Guideline provides insight for developing the “To-Be” PMO program implementation plan.

## **EPRI Perspective**

A PMO assessment is the first step to achieve optimum maintenance in a power plant. The assessment evaluates all aspects of a maintenance program so specific areas can be improved. Several improvement efforts have been completed and are underway in EPRI projects. EPRI intends to go back and assess organizations after improvements to verify that planned improvements have been achieved and to enhance the overall assessment-improvement process.

This report is part of EPRI’s development efforts under the Plant Maintenance Optimization (PMO) Target, number 62 in 2000. The PMO mission is to lead the industry by developing and demonstrating products and services that will improve use of power plant maintenance resources and increase profitability for generation businesses.

## **Keywords**

Maintenance

Assessment

Availability

Reliability



# ABSTRACT

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This Guideline provides the steps necessary for a utility to assess the current status of the maintenance process; and, by using this information with the concepts included in this Guideline, develop an optimized maintenance process.

This Guideline includes measurement tools for assessing the overall level of performance of the organization. After developing the ideal organization for the utility, these tools can be utilized to measure and track the status of the implementation improvements.



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# 1

## INTRODUCTION

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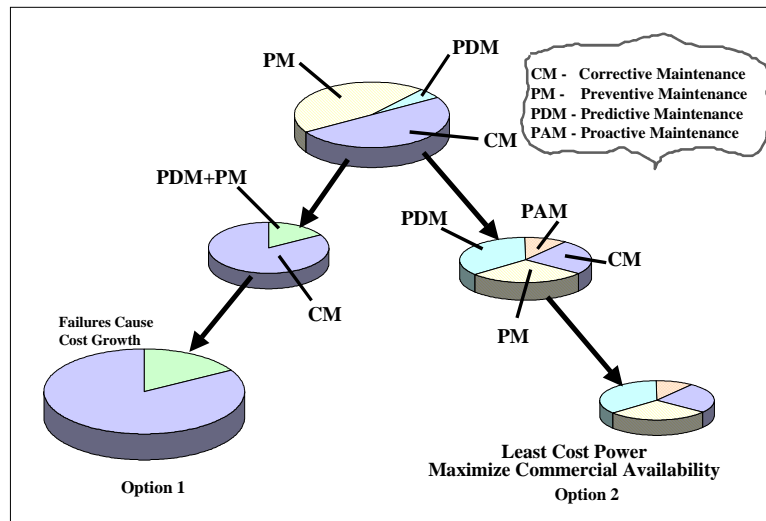
A Plant Maintenance Optimization Assessment (PMO) is a way to help electric power producers achieve lower operating costs and higher reliability and availability by optimizing the overall maintenance program. The Assessment starts by introducing the attributes of an ideal program. The second part of the process evaluates the existing maintenance program and identifies gaps between the existing program and the ideal program. The process concludes by developing an implementation plan to move the program toward the ideal state.

### Industry Trends

EPRI has worked with over 50 commercial power producers and other industries to implement initiatives related to reducing overall maintenance costs, improving plant availability, improving equipment reliability, and increasing both overall and commercial availability.

In the past, the approach to reducing budgets has been to reduce the O&M cost; however, this action has resulted in fewer maintenance resources being available. As a consequence, fewer maintenance resources resulted in cost increases from increased equipment failures. What is needed then is a reevaluation of maintenance strategies that will result in a low-cost, balanced maintenance strategy.

Through the work with the power producers, EPRI has learned that effective plant maintenance programs must use a well-orchestrated blend of Predictive, Preventive, Proactive, and Corrective maintenance strategies to improve plant reliability in a cost effective manner. As shown in Figure 1-1, experience has demonstrated that significant improvement, resulting in substantial cost savings can be achieved through coordination of these strategies with improvement in the overall utilization of information for decision making. Conversely, by failing to use this mix of information, significant cost increases can be anticipated.



**Figure 1-1**  
**Maintenance Cost Reduction Options**

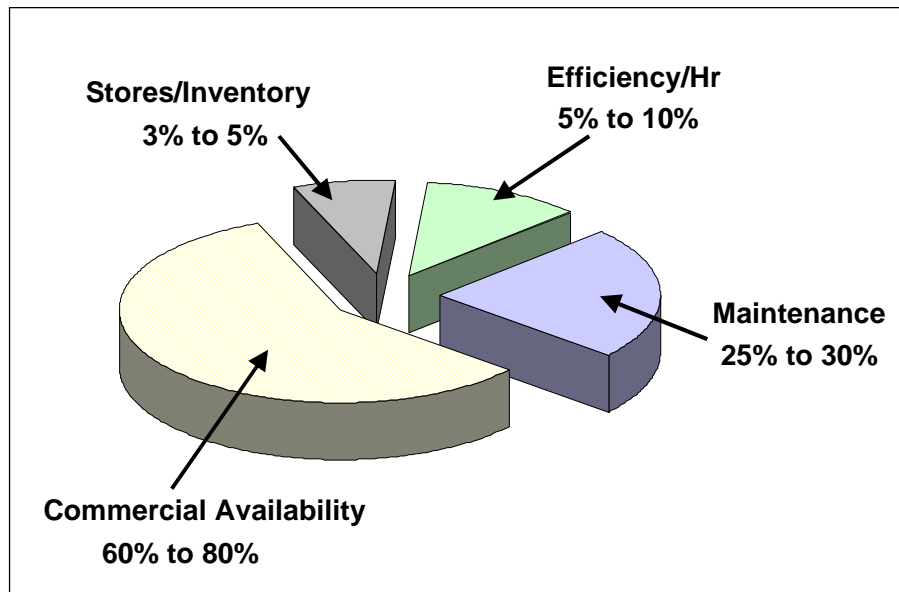
Understanding the strengths and weaknesses of existing programs and identifying opportunities for improvement lies at the core of the process that is referred to as *Plant Maintenance Optimization* or PMO.

## Plant Maintenance Optimization as a Strategy

Plant Maintenance Optimization (PMO) encompasses the process of moving the maintenance program from a “reactive” approach where maintenance is performed as a result of unexpected failures or a “preventive” approach where maintenance is performed on a scheduled basis, to a “planned” approach where maintenance is performed, using key information, at the most optimum time which is often before the equipment failures. Reactive maintenance is more costly and has a negative impact on plant availability, while PMO is more economical and significantly improves plant availability. PMO also optimizes the existing planned maintenance activities at a plant.

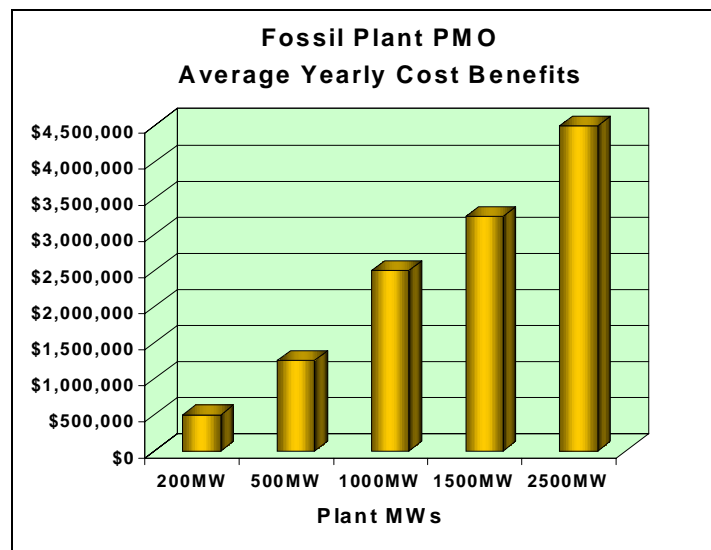
Success in realizing improvements to the overall maintenance process is achieved through understanding the strengths and limitations of each improvement strategy and fully synchronizing the program for optimal results. Output from a Plant Maintenance Optimization Assessment (PMO) as developed in this guideline should help the power producers understand the strengths and weaknesses in their current programs, and also help identify opportunities to improve the overall process.

Experience has shown that significant improvements resulting in substantial cost benefits can be achieved through changes to existing processes with small or moderate investments. Typical savings realized by power producers will be reflected in the following areas as illustrated in Figure 1-2.



**Figure 1-2**  
**PMO Savings Distribution**

When these savings are aggregated, the typical Return-on-Investment (ROI) when compared to Megawatt capacity is shown in Figure 1-3.



**Figure 1-3**  
**PMO Average Yearly Cost Benefits**

A significant degree to which a plant is successful in implementing process change often involves intangibles such as personnel understanding and belief in the technologies, good inter-group communication, high level of personnel enthusiasm, and strong management support and sponsorship of the change process.

## Summary

The information that follows in this report provides a roadmap for assessing the current state of a power producer's plant maintenance program, which is referred to as the "*As-Found*" program. The guideline will also help the power producer define the desired program, which is referred to as the "*To-Be*" program. By comparing the "*As-Found*" program to the "*To-Be*" program, the gaps between the two states can be defined. Using the gaps in program status, this document will provide guidelines for developing the change effort that is needed to get to the optimized program state. In beginning the optimization process, it is recognized that the effort must be performed for the individual company, at the unique station level since every organization is different. The plant personnel best know the unique problems at a particular site (station vintage, equipment age/manufacture, operation mode/demand, etc).

The guideline is broken-down into four sections. These sections provide the tools that are needed to understand the current status of the maintenance program and to prepare a plan to get to the desired program.

Part I of the guideline is structured to prepare the participants for the process by developing a common understanding of the concepts and terms that are necessary to move forward with the process. This section also discusses the ideal or "*To-Be*" program concepts, which will be adjusted to the particular site. The following areas are addressed in this section of the guideline:

- Providing an overview of PMO to prepare the team for the assessment process
- Discussion on goal setting
- Introduction to Maintenance Optimization

Having referred to the concepts of PMO (Ideal and "*To-Be*") in Chapter 1, it is now necessary to review the assessment process in detail. As stated before, the assessment process defines the "*As-Found*" program, determines the gaps between the "*As-Found*" program and the ideal "*To-Be*" program and develops an implementation plan to get to the specific "*To-Be*" PMO for the facility. The assessment process consists of:

- Information gathering (Part II)
- Conducting Interviews (Part III)
- Developing an Implementation Plan (Part IV)

Part II of the guideline is structured to gathering the information and data about the station that is needed to define the "*As-Found*" condition. The following areas are addressed in this section of the guideline:

- Identifying prerequisite information
- Developing the "*As-Found*"
- Mapping the existing work process
- Identifying Work Process Issues

- Identifying issues that can impede PMO
- Plant walk down and observing maintenance efforts in progress
- Selecting plant procedures and records for review
- Reviewing corrective and preventative maintenance documents

Part III of the Guideline provides direction necessary for the team to prepare for and conduct interviews of station operations, maintenance, and support personnel. These interviews will further define the “As-Found” condition. The following areas are addressed in this section of the guideline:

- Conducting on-site interviews
- Composition of Assessment Team
- Identifying targets for interviews
- Data Integration
- Conducting an exit interview with the appropriate project sponsors

Part IV of the guideline provides insight to develop the PMO program implementation plan. The implementation program will be developed using the gaps between the “As-Found” program and the ideal “To-Be” state. The following areas are addressed in this section of the guideline:

- Developing implementation strategy
- PMO Report format
- Presentation of the finished product to appropriate project sponsors





# 2

## PART I – KEY ASPECTS OF PLANT MAINTENANCE OPTIMIZATION

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### **Providing an Overview of PMO to Prepare the Team for the Assessment Process**

Prior to assessing the performance of an organization, it is essential that everyone within the target organization be at the same level of understanding of why the plant is being assessed. The following questions need to be answered for the organization prior to proceeding with the assessment:

1. What is a Plant Maintenance Optimization Assessment?
2. What are the concepts of the Plant Maintenance Optimization Program?
3. Why is my employer conducting an assessment of the maintenance program at the specific plant?

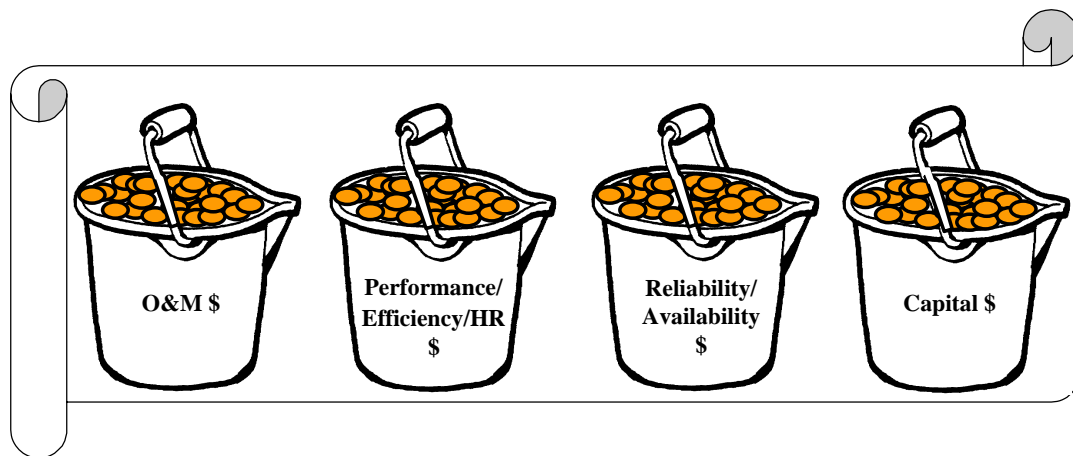
Information necessary to answer questions 1 and 2 will be covered in this assessment guide. It will be necessary for the local plant management to provide the information necessary to answer question 3. In a general sense, the discussion with the organization's stakeholders should review the challenges presented by operating in a deregulated environment and why it is mandatory that power producers change the way they operate in order to survive. A part of the answer to question 3 should be specifically tailored to unique situations at the subject facility. This discussion should stress the economics of why it is important for the units to be available to generate in response to varying demand requirements.

### **Discussion on Goal Setting**

Before undertaking another initiative, it is important that the organization be very clear on the magnitude of what they are planning to undertake through the PMO project; and, further, what they hope to accomplish by subjecting the organization to the rigor of implementing another change process. Everyone in the organization is very busy doing productive work and does not need the additional demands of participating in another process change project (commonly known as the “flavor of the month” program). Management is asking the staff to invest significant effort into a change process. The staff must believe that the potential outcome is worth the effort, that there is benefit to the individual, and that management is wholly committed to providing the resources that are necessary to make the change process successful.

Therefore, it is mandatory that management convey their expectations for the process. This expectation should very clearly define exactly what management expects the new process to provide. These expectations should be conveyed to the organization as goals that align directly to the corporate mission, vision, and goals.

To support management's expectations, goals should be developed at a station level that provides direct alignment with the corporate goals. This alignment allows management to quantify exactly how much return is received for the effort (dollars) invested to meet the goal. The station level goals should be developed in specific areas that will benefit from the improvement to the process. It is expected that dollar saving realized from optimizing the maintenance process will provide savings in the following areas as illustrated in Figure 2-1



**Figure 2-1**  
**Areas of Savings**

Goals should be very specific. The goals should be designed so that goal performance is easily measurable. Goals should be designed such that they are both realistic and achievable and they should be timely so that the benefit of achieving the goal will occur in a time period that the improvement is needed.

Areas where goals can be developed include:

*Corporate*

- Provide quality product at lowest possible cost
- Customer Satisfaction
- Provide uninterrupted/reliable service
- Improve competitive position
- Reduce capital costs

### *Maintenance Organization*

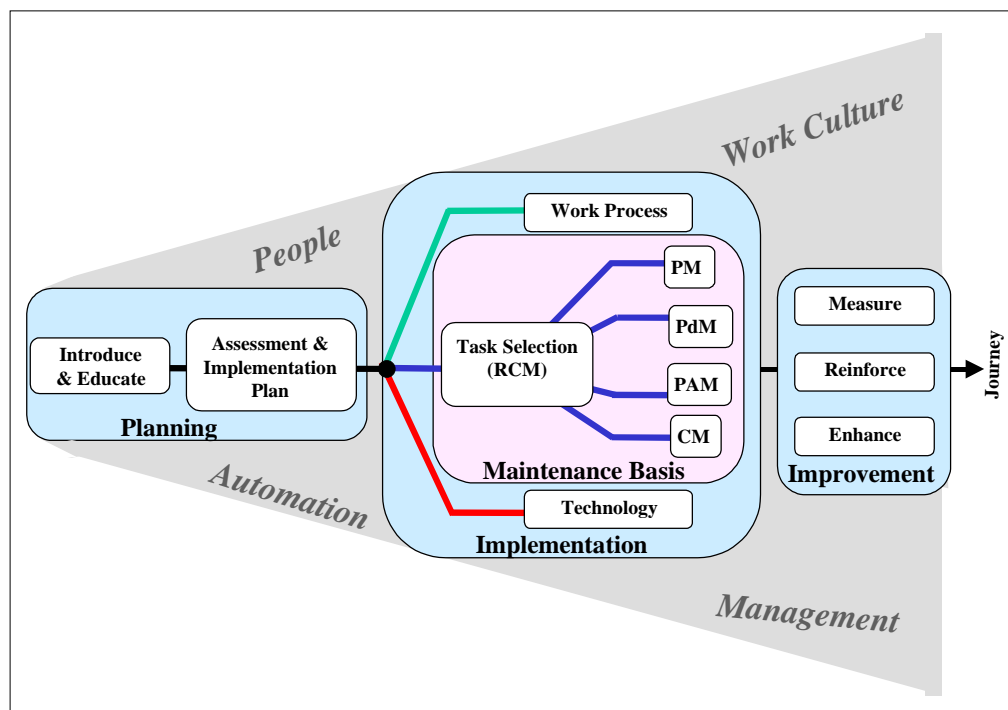
- Minimize O&M costs
- Maximize reliability/availability
- Maximize throughput and quality
- Extend equipment life
- Extend time between planned outages

### *Examples of Specific Goals are as follows*

- Improve summer availability by 30%
- Improve non-summer availability by 15%
- Reduce summer and non-summer heat rate for each unit by 100 BTU/kw-hr

## **Introduction to Maintenance Optimization**

Plant Maintenance Optimization (PMO) involves the people, the work culture and management, the work process, and technology. PMO is a journey that the organization must take as it works to improve the process by learning from the day to day experiences. The chart (Figure 2-2) identifies the Road Map that is needed to take this journey.



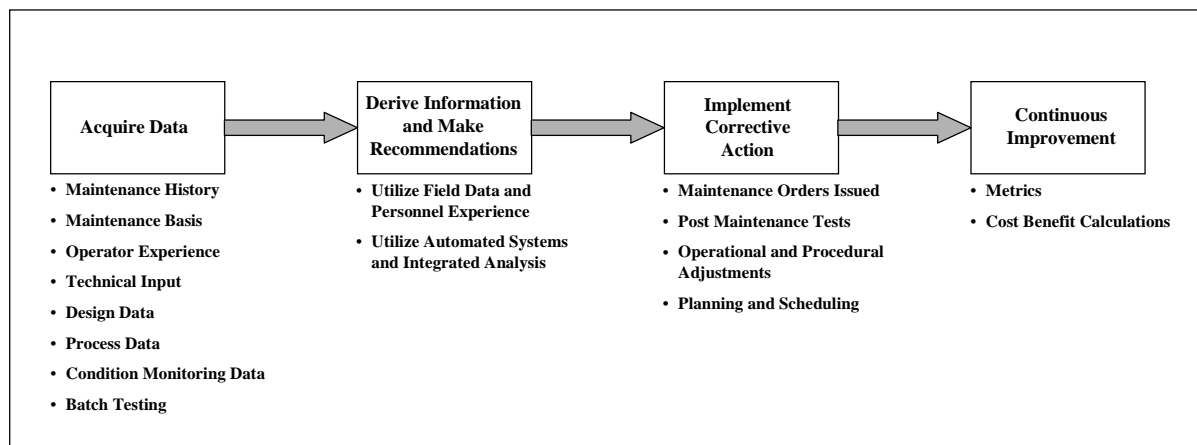
**Figure 2-2**  
**PMO 'Road Map'**

The assessment part of the Road Map, which is illustrated in the major category of “Planning”, is a process to document how the company’s maintenance program currently operates. By understanding where management desires the company to be in the future enables the organization to develop the strategies and implement the changes that are needed to bridge the gap.

Inherent in the strategy to optimize the maintenance process is the need to be able to make decisions for appropriate action on the most current information. Current technologies provide an overwhelming amount of raw data. To support this need, it is necessary to base the action decisions on integrated information (refer to Figure 2-3).

The action that results from this process may be to continue to operate in the same mode even though there are indications of a problem. The important part of this action, from a PMO standpoint, is that the decision to continue to operate be based on an evaluation of the information that is available. This decision should include consideration of the potential for failure and the economic consequences related to repair, versus the cost consequences from the lost opportunity to sell the product during a specific market opportunity. Once this decision is made, the work process must execute the decision in a timely manner.

Since PMO is a journey, a continuous improvement process needs to be in place for the PMO to be successful. The flow of essential information is shown in Figure 2-3.



**Figure 2-3**  
**Flow of Information**

When the plant considers implementation of Plant Maintenance Optimization it is necessary to understand the “what”, the “how”, and the “who” of PMO.

#### **“What” will a plant do differently?**

- Implement Advanced Maintenance Approaches such as: Predictive Maintenance, Reliability-Centered Maintenance, and Proactive Maintenance.

### “How” will a plant carry out the specific maintenance tasks?

- By making improvements to the Work Process.
- It will also be necessary to implement New Technologies to optimize the overall process.

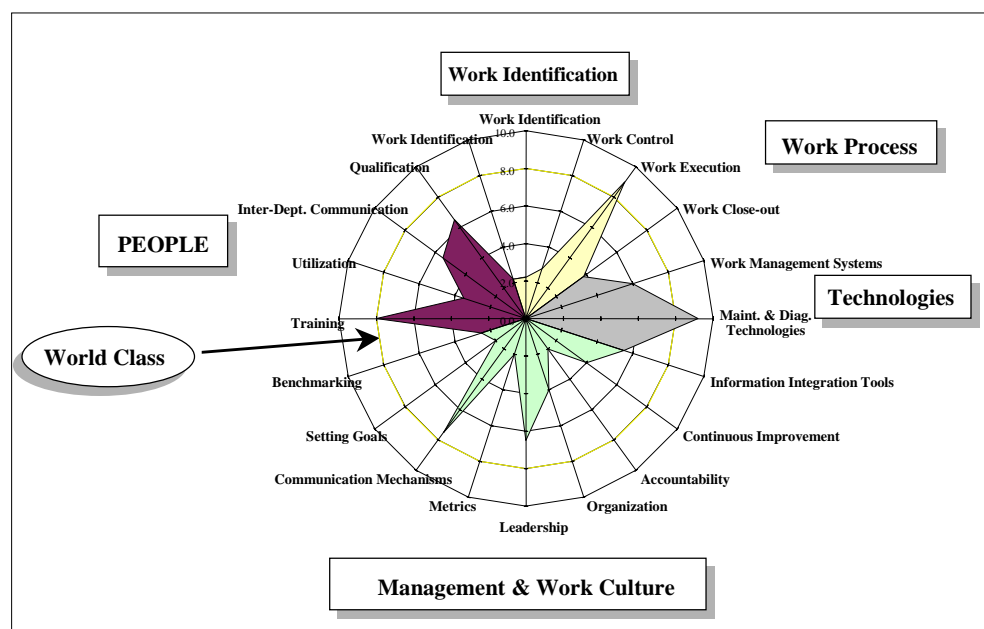
### “Who” will do the work?

- The staff will continue to do all work using improved Skills, while working in modified Work Culture, with strong Management support.

An effective method used to represent the current state of the maintenance program, the “how”, the “what” and the “who”, is through the generation of a Spider Chart. The spider or radar chart provides the organization with a graphical representation of the level of performance for each of the individual attributes of PMO. Developing the data to support this chart will be discussed in the section of this guide that follows.

The key elements of Maintenance Optimization are contained in the spider chart shown in Figure 2-4. This chart shows how a hypothetical organization performs when compared to a standard of performance (best-in-class) that was developed after evaluating a broad-based population of plants. From the figure it is apparent that the example organization is strong in *Maintenance and Diagnostic Technologies* and *Work Execution*; however, *Work Identification*, *Closeout*, *Accountability*, *Goal Setting*, and *Benchmarking*, appear to be areas for improvement. Furthermore, the organization does not appear to manage by *Metrics*.

This type of information can be used as a tool by the assessment team to help the organization, by focusing further assessment efforts on the apparent weaknesses. This tool can also be used by the organization to measure progress during implementation of the process.



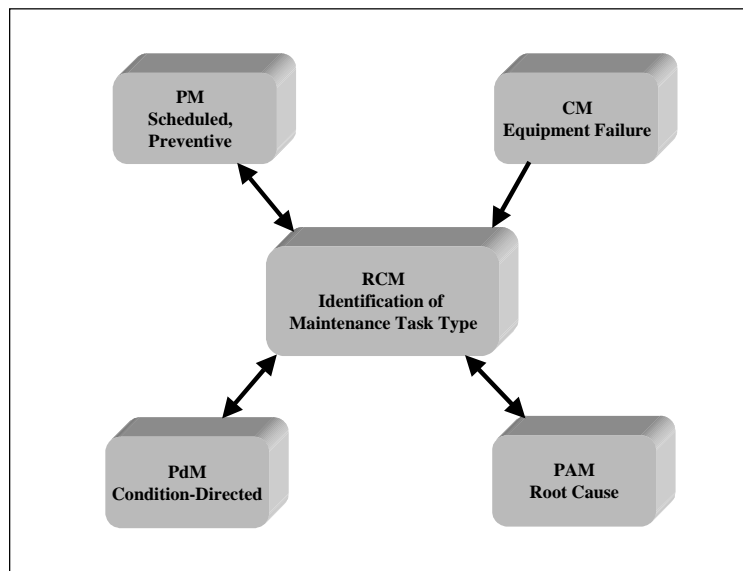
**Figure 2-4**  
**PMO Spider Chart**

As indicated in Figure 2-4, the specific elements of PMO are identified in the Spider Chart. The following section describes each of the elements.

## Work Identification

This element identifies the specific strategies to be used and determines what specific task will be required for a ‘timely’ decision for the work that is to be done.

There are only four approaches available to identify which maintenance work is to be accomplished: Preventive (PM), Corrective (CM), Predictive (PDM), and Proactive (PAM); and, all are part of the Maintenance Basis. This is illustrated in Figure 2-5.



**Figure 2-5**  
**Maintenance Basis**

## Maintenance Basis

The basis that identifies the right maintenance work. To determine the strategy for maintaining the plant equipment, it is necessary to identify the necessary maintenance tasks. EPRI Reliability-Centered Maintenance (RCM) using a streamlined (RCM) analysis should be performed (task analysis and basis) to establish the maintenance basis.

Reliability Centered Maintenance (RCM) programs help power producers optimize maintenance basis while improving plant safety and economy through increased dependability of plant components. RCM includes the following:

- Rank plant system and equipment (Criticality Ranking)
- Determine the failure modes and causes
- Perform a Failure Modes and Effects Analysis (FMEA)

- Establish maintenance tasks (PM, PDM, PAM) and frequency

The process should review the failure modes and causes. Using this information, the strategy to protect the equipment can be determined. It is desirable to let some equipment run-to-failure.

Equipment that does not impact the plants key indicators and has a low criticality ranking should be classified as run-to-failure equipment.

Critical equipment is defined as equipment that does impact the plants key indicators and has a high criticality ranking. Equipment is ranked as; Safety critical; Environmental critical, Cost critical, Reliability critical, and Efficiency critical. Equipment classified as “critical” should be addressed through one of the following strategies:

- Condition monitoring (PDM)
- Time based (PM, Ops Rounds)
- Projects -Root Cause Based (PAM)

Refer to Reference 4 for more detailed discussion on RCM.

Other tools needed to assure the equipment is maintained as identified in the maintenance basis include:

- Maintenance Procedures
- Operation Procedures
- Standardized Work packages

Questions to be asked are: Is a formalized Root Cause Program in place and being utilized; Is PDM (condition driven) being used; Have PM tasks been reviewed; and, Are "As-Found" conditions documented?

### ***Preventive Maintenance PM***

Preventive maintenance uses regularly scheduled inspections, tests, services, repairs, replacements, and other tasks to reduce the frequency and impact of equipment failures. These maintenance activities are performed on a calendar or operating time interval basis to extend the life of equipment and prevent premature failure. Manufacturers usually include a list of these activities and their frequencies, which will optimize the life and prevent failure of their equipment. This technique assumes that the condition of the equipment and its need for maintenance can be correlated with time. Preventive is one of the first major breakthroughs resulting in an increase in reliability and availability. One of its benefits is the identification of early stages of equipment deterioration that, unless remedied, would result in secondary damage at failure. This accounts for a significant part of the lowered maintenance costs. It is important to note that the data collection parts of PDM are also PM tasks.

### **Corrective Maintenance CM**

Early maintenance resources were used to react to equipment breakdowns that caused major operational losses. From this practice the terms, “reactive”, “breakdown”, “corrective”, and “run-to-failure” maintenance descriptions were coined for naming the principal maintenance technique that formed this maintenance strategy. Corrective maintenance can be either good or bad. For some equipment, such as smaller components that are not critical to production, it is the best technique to use. For others, though, it will result in very high repair costs and excessive lost production. It is one of the techniques that must be appropriately applied in order to develop an optimized maintenance strategy. Experience shows that for fossil plants this approach is predominate.

### **Predictive Maintenance-PDM**

Predictive maintenance is a systematic approach to determining the need for equipment repair or replacement, and limiting maintenance activities to only those that are required to prevent costly major repairs or unscheduled downtime. Predictive Maintenance is a process that bases maintenance on the condition of the equipment and recommends the corrective action that is to be taken. Using PDM, all corrective action would be done in a timely manner. (*Note: If the PDM program generates urgent and emerging work orders, it is not working.*) Various monitoring systems are used to detect and analyze incipient faults. Attributes of PDM are as follows:

- Establish the Process (such as)
  - Rolls and Responsibilities of the organization
  - Work Process and how PDM fits into the plant’s work process
- Implement the condition indicators such as; technologies, maintenance and operators’ records, batch testing, and process data. Also utilize the latest automation tools.
- Provide Condition Assessment Reporting
- Continuous Improvement/Metrics such as:
  - Track Net Cost Benefits
  - Monitor Equipment Commercial Availability
  - Track Equipment Maintenance Costs
  - Measure Bad versus. Total Calls
  - Measure High Priority versus. Scheduled Work Orders

For further discussion on Predictive Maintenance refer to references 1, 2, 3, and 5.

### **Proactive Maintenance-PAM**

PAM is used to modify operation or maintenance or change-out component based on root cause analysis. Root Cause is defined as the most basic cause(s) that can reasonably be identified and that management has control to fix, and, when fixed, will prevent or significantly minimize the

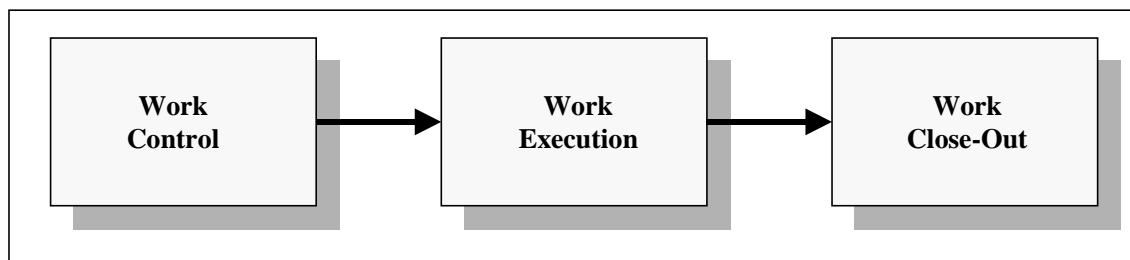


chances of the problem's reoccurrence. Questions that a Root Cause Analysis should answer are as follows:

1. What happened?
2. Why did it happen?
3. Why was it not prevented?
4. What can be done to prevent/minimize severity of recurrence

## Work Process

The process that accomplishes the work. This part of the PMO process addresses the **How** maintenance is accomplished. It examines the work process from work initiation, to planning and scheduling (work control), to work execution, to work completion, and finally to continuous improvement. This process is illustrated in Figure 2-6.



**Figure 2-6**  
**Work Process**

When evaluating this process, many questions need to be addressed.

### **2. Work Control**

Formalized planning and scheduling program in place. Work order generation and prioritization process is needed to be a part of the process. The process should have an initiator/approval and value ranking process to establish priority.

- There should be a formal planning process with work Packages issued to field.
- Parts availability (Stores/Inventory) needs to be considered and included in the work package. Are parts staged in work area?
- Work packages need to include: work procedures, maintenance procedures, operations procedures, permit and blocking procedures.
- It is very important that document and configuration control be maintained.

High priority work needs to be sponsored. Routine work should be scheduled several weeks ahead. Outage work should be planned and ready for implementation during both planned and

unplanned outages. Schedule performance needs to be measured. Replacement parts (just in time) needs to be part of the process. Both outage and major equipment overhaul work should be planned and scheduled.

#### Metrics for Work Process

- Schedule Compliance
- Back Log Management

### **3. Work Execution**

This is the actual performance of work. The following need to be considered.

- Man-Hour Utilization
- Staff Training
- Tools Availability
- Tool Upgrade to Latest Technology
- Metrics for Work Execution
  - Rework versus Total Work
  - “Wrench” Time versus Total Time

### **4. Work Order Close-Out**

Appropriate information on work performed (“As Found”) and “As-Left” condition of equipment must be captured when a Work Order (WO) is closed so maintenance can provide feedback to Operations and PMO. The following should be considered.

- Close-out Feedback to Initiator
- Close-out approval
- House Keeping
- Capture Maintenance History (“as found” - “as left”)
- Post Maintenance Testing
- Identify Unplanned Work, Orders for PAM Review
- Continuous Improvement/Metrics
  - Measure work order Initiators Satisfaction
  - Measure PAM review team satisfaction (Maintenance Histories)

## Metrics for Work Close-Out

The Table 2-1 provides suggested metrics that are characteristic of measures used by a well-run maintenance process. Suggested goal levels are also provided.

**Table 2-1**  
**Suggested Metrics for Maintenance Process**

<b>Metric</b>	<b>Measurement</b>	<b>Primary Accountability</b>
CM Ratio	CM/Total Work	System Owner
Schedule Compliance	Planned Hours/ Worked Hours	Team Leader
Planning Effectiveness	Estimated/ Actual Hours	Team Leaders
Resource Utilization	Complete WOs hrs./ Total pd hrs.	Team Leaders
PM Compliance	Completed PMs/ Scheduled PMs	Planners/ Team Leaders
Sponsored Work	Sponsored Hours/ Total Hours	Operations and System Owners
Emergency Work	Emergency Hours/ Total Hours	Operations and System Owners
Rework	Rework Hours/ Total Hours	Maintenance

## Technologies

This category of PMO focuses on what advanced **Tools** are required to support the workforce. The technology level covers all technical advances such as: automation, condition monitoring, automated maintenance management systems, and distributed control systems. There have been significant advancements in technologies, which can help an organization meet its availability and budget goals.

### 5. Work Management Systems

A formalized work management system should be in place. Most successful maintenance programs now use a computerized system. A formalized work-scheduling tool should be a part of the process. Reporting and decision making process should be in place.

## **6. Maintenance and Diagnostic Technologies**

Condition based technologies should be used and information acquired from the various technologies should be factored into maintenance decision process. The following is a summary of some of the technologies.

### **Periodic Condition Monitoring Systems**

- Thermography
- Portable Vibration Monitoring
- Lube Oil Monitoring
- Acoustic Leak Detection
- Motor Current Monitoring (Broken Rotor Bars)
- Electric Motor Predictive Maintenance
- Valve Diagnostics
- Transformer Diagnostics

### **Continuous Condition Monitoring Systems**

#### *Turbine/Generator*

- Continuous Vibration Monitoring – including (Turbine Balancing and Rotor Crack Detection)
- Ultrasonic Bearing Wear Monitor
- Rotor/Shell Stress Indicator
- Water Induction Detection
- Turbine Performance Monitor

#### *Heat and Turbine Cycles*

- Performance Monitoring
- Water Chemistry Expert System

#### **Boiler**

- Boiler Performance Monitor
- Boiler Stress Condition Analyzer
- Ultrasonic Gas Temperature Monitor
- Acoustic Boiler Tube Leak Detection

- Acoustic Header Leak Detection
- Carbon-In-Ash Monitor
- Burner Diagnostics
- Boiler PDM Program

#### **Mechanical Equipment**

- FW Heater Leak Detection
- Valve Monitoring
  - Stem Force
  - Current Monitoring
  - Valve Leak Detection
- Acoustic Coal Chute Flow Detection

#### **Electrical Equipment**

- Circuit Breaker Diagnostics
- On-Line Meggering

#### **Emerging Technologies**

- Electric Motor EMF Analysis
- High Temperature Electronics
- Power Scavenging Sensors
- Radiation Hardened Electronics
- FEA - Physical Rotor Modeling - Virtual Sensors
- Formalized Acoustic / Ultrasonic Applications (Renewed Interest)
- Bayesian Belief Networks
- Wireless Data Transmission (Vibration, Temp, Flows, etc.)

### ***7. Information Integration Tools***

Condition status reporting mechanisms should be in place and these systems should be used to integrate information from multiple sources of information. Systems may be available on the network for multiple user access. Information needs to be current. Financial, schedule and budget information should be available in an integrated system.

## PMO Process Automation Tool (EPRI PlantView Tool)

### *PDM Module*

- Equipment Condition Status Summary
- Technology Exams-Readings taken and interpreted at regular intervals
- Equipment Assessments-Component status established at regular intervals

### *Maintenance Basis (EMOMs) Module*

- Maintenance basis Templates
- Standardized Work Packages
- Maintenance Procedures

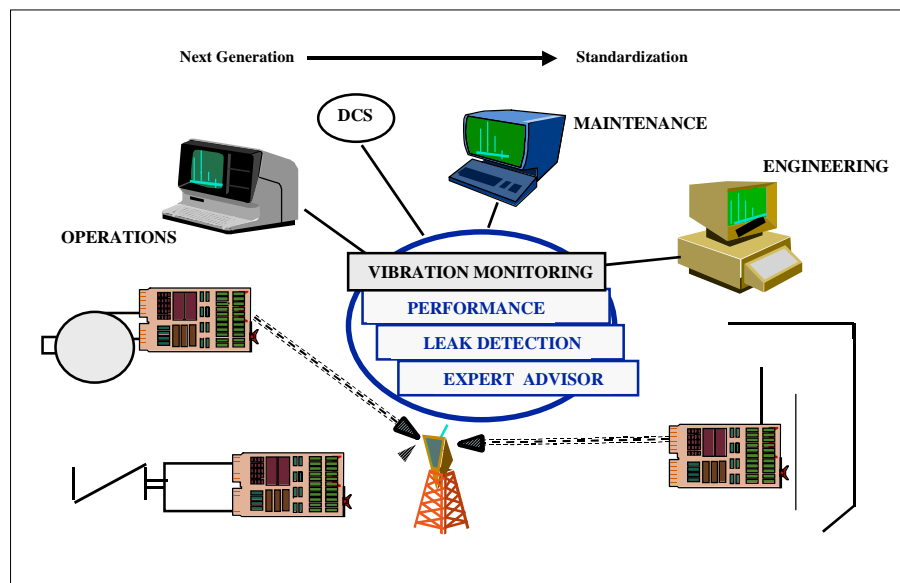
### *Case History*

- Equipment Problems and Solutions

### *Cost Benefit*

- Continuous Improvement Measure

The Figure 2-7 illustrates the Technology Automation process. It includes networks wireless data transfer and standard data acquisition systems.



**Figure 2-7**  
**Technology Automation Process**

## Work Culture and Management

For maintenance optimization to be successful, it requires a well-trained work force, good management, and an organizational structure that incorporates decision making based on the advanced maintenance strategies. A work culture that is receptive to new work ideas is needed. This aspect of the PMO approach focuses on **Who** does the work.

### 8. Continuous Improvement Methods

The organization should be a "Learning" organization that is able to avoid repetitive mistakes (refer to discussion under Work Process). The continuous improvement process considers the following.

- Categorize Work Orders (“good” versus “bad”)
- Review “bad” Work Orders
  - Root Cause Analysis
  - Failure Mode and Cause
  - Task Addition/Modification
  - Modify/Add Procedure
- Periodic Review of “good” Work Orders (PMs, PDMs, Run-to-Failure CMs)
  - Utilize Maintenance Histories
  - Utilize plant staff experience
- Modify Maintenance Basis
- Continuous Improvement/Metrics
  - Planned versus Reactive
  - Good versus Bad Work Orders
  - Track maintenance costs for different types of work orders

All Maintenance Work Orders are not undesirable. Undesirable Work Orders resulting from unplanned work should be tracked and action plans developed to manage reducing the overall number.

When categorizing the Work Orders, it is necessary to recognize that work orders at most plants are divided into Corrective Maintenance (CM) and Preventive Maintenance (PM). There are various categories of corrective Work Orders.

CM-RTF	<i>Run-to-Failure</i> (Pre-planned strategy from RCM analysis)
CM-CDM	<i>Condition-based Maintenance</i> (Work resulting from PM, PDM, PAM)
CM-CDM-P1&P2	<i>Condition-based Maintenance</i> (Work resulting from PM, PDM, PAM that has urgent or emergency priority)
CM-U	<i>Unplanned Work</i>

Also there are different categories of Preventive Maintenance.

PM-PDM	Predictive Maintenance data collection tasks
PM	Preventive Maintenance tasks

## 9. Accountability

Accountability should be a part of the plant culture. People should recognize what is expected of them and they should perform accordingly. In the end, they should be held accountable for the operation of the plant.

## 10. Organization

The organization should be structured to be successful using condition-based information (Process Teams, Component Ownership, Process Ownership, Fix-it-now, etc.). Clearly defined lines of reporting, responsibility, and accountability should be evident. The Organization chart, Figure 2-8, provides one example of how an organization can be structured to provide for organized decision-making. The individuals encompassed by the dotted box make up the reliability decision-making group with overview and guidance provided by the upper levels of management.

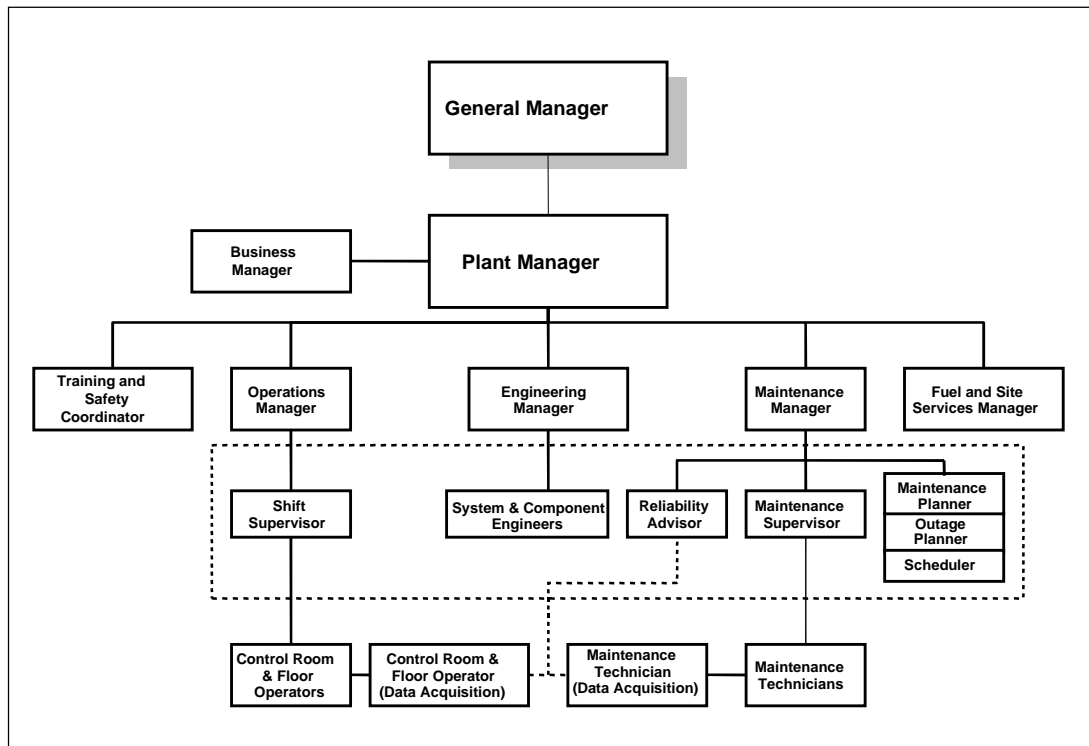


Figure 2-8  
Organizational Chart



### **11. Leadership**

Management should provide sponsorship for changes as well as clearly defining expectations, and providing the necessary budget for initiatives to be successful. Metrics should be used to manage the business. Workers must be empowered to make decisions, and adherence to the plan and schedule should be monitored.

### **12. Global Metrics and Reporting**

Metrics available that adequately measure success of the process (financial, reliability, safety, regulatory, customer satisfaction, Plant Capacity, Plant Availability (EFOR), O&M budget, Plant thermal performance) should be available to manage the day-to-day and longer-term performance of the plant.

### **13. Communication Mechanisms (Inter-Organization)**

The quality (formal and informal) of communications and information exchange between Maintenance, Management, Operations, Engineering, and others within the organization.

### **14. Goal Setting**

Goals should be prepared for the Maintenance Program. They should be in alignment with the overall objectives (refer to discussion under goal setting).

### **15. Benchmarking**

Benchmarking of the plant performance should be performed to allow for a direct comparison of the organizational practices with the Best-in-Class, or at least standard practices within industry.

## **People/Skills**

### **16. Training**

The training program should be reviewed from content and direction perspectives, to ensure that they prepare people with the skills necessary to support the program.

### **17. Utilization**

Productivity and utilization factors for the labor resources should be measured and tracked.

## 18. Inter-Department Communication

The quality of both formal and informal communication and information exchange within the organization is very important.

## 19. Qualifications/Job Descriptions

A documented measure of the qualification and skills of functions within the organization, with a focus on whether qualifications and skills are capable of supporting program goals. A skills matrix should be available that identifies the unique skills required to perform various maintenance functions.

## PMO Process Summary

The PMO process includes taking the 19 elements described above and integrating them into a cohesive approach.

The advanced maintenance strategies address *What* maintenance approaches will be undertaken to move the maintenance program from reactive or scheduled to planned. This approach includes optimizing the maintenance basis, implementing predictive maintenance program, and developing a living proactive maintenance program.

Plant Maintenance Optimization includes both the *Maintenance Basis* and the *Work Process*. The sequence of the process is illustrated below. Figure 2-9 identifies how work gets identified, how it is conducted through the work process, how the work gets reviewed regularly, and how adjustments to the maintenance basis are made as needed.

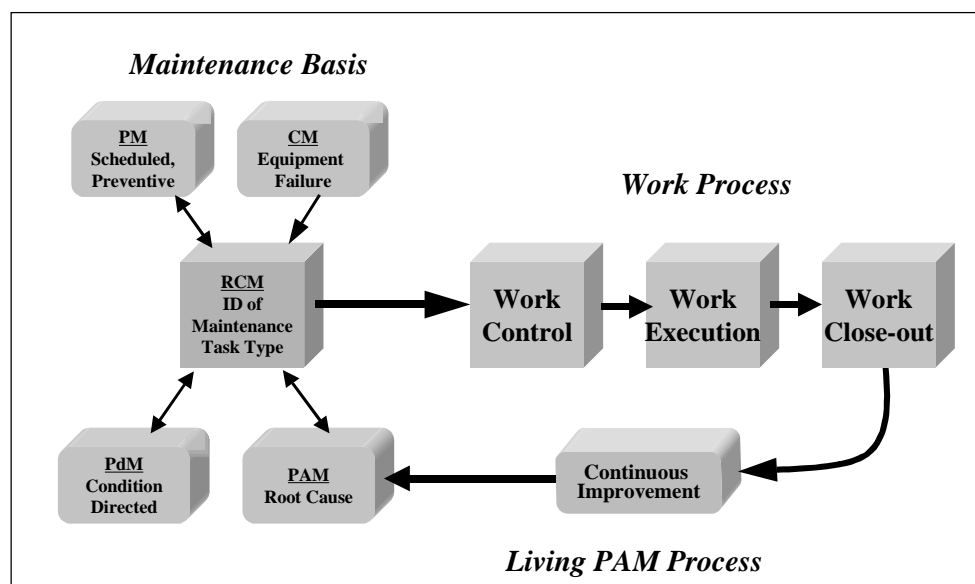


Figure 2-9  
Sequence of Maintenance Basis/Work Process

# 3

## PART II – INFORMATION GATHERING

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### Identifying Prerequisite Information

To assess an organization with the intent of designing an optimized maintenance program, it is necessary to review, understand, and use the information that is available within the existing systems of the current organization. This serves several purposes.

1. The team performing the assessment must have a working-level understanding of the condition, capabilities and limitations of the equipment, systems, and processes in place at the target facility
2. The basic premise of optimizing the maintenance process is that systems are needed to capture needed *data* and that the data can be converted to the relevant *information* needed to make informed *action*-based decisions. The assessment team must be able to test and evaluate the effectiveness of these systems.

The following list of information should provide the basic knowledge basis needed to begin the assessment process:

- Plant operating history for the past 1 to 3 years
  - availability
  - efficiency
  - MW production
- Plant Process Drawings
- Capital Improvement Process (Projects accomplished/cost)
- Major equipment list (by system) with operating history
- Plant organizational chart with specifics on maintenance staff functions and responsibilities
- Description initiatives and process changes underway
- Trend in maintenance budgets over past three years, and changes resulting from recent initiatives

Along with the above information, it will be necessary to conduct workshops to generate the following information.

- Spider Chart (refer to information that follows under conducting PMO overview workshop)

- Issues that could impede PMO implementation
- Marking the As-Found Work Process (refer to information that follows under conducting PMO overview workshop)
- Listing of Work Processes Issues (refer to information that follows under conducting PMO overview workshop)

Finally it is necessary to review the procedures and maintenance records and to conduct a plant walk-down.

## Developing the “As-Found”

Having reviewed the concepts of PMO in Section 1 of this Guideline, it is now necessary to begin acquiring data about the organization. The Spider Chart is an appropriate place to capture this data. As a starting point for the assessment, it is important to understand where the organization feels it stands when compared to other, similar type organizations. To provide a picture of this performance, the group should perform a self-evaluation using the questionnaire in Table 3-1. The individuals should score how well they feel the organization performs against the individual attributes. Scoring should be provided with a score from 1 to 10, with 10 being the highest level of performance. It is advisable to have a facilitator support this activity.

Results from this evaluation should be segregated by level (i.e. management, work group supervision, and worker). Using this information, a “*Spider Chart Self Evaluation*” should be prepared for responses of the entire group. Separate spider charts should also be prepared for each of the general levels within the organization, i.e. management, supervision, and worker. Comparing the information from the different levels will enable the assessors to identify areas within the organization where alignment exist as well as areas where there is disagreement on how the organization performs.

**Table 3-1**  
**Spider Chart Self-Evaluation**

	<b>Select one</b>	Manager Supervisor Worker
	<b>Score:</b>	<b>1 to 10</b>
<b>Work Identification</b>		
1.	<b>Work Identification</b> – Has RCM been performed? Is formalized Root Cause Program in place? Is PDM being used? Have PM tasks been reviewed? Is “As-Found” condition documented?	
<b>Work Process</b>		
2.	<b>Work Control</b> – Is formalized planning and scheduling program in place? Is work scheduled greater than one week ahead? Do standard work packages exist? Is schedule compliance measured?	
3.	<b>Work Execution</b> – Actual performance of work includes man-hour utilization, training, tool availability, tool upgrade to latest technology, continuous improvement metrics (rework vs. total work, wrench time vs. total time)	

**Table 3-1**  
**Spider Chart Self-Evaluation (Continued)**

		Select one	Manager Supervisor Worker
		Score:	1 to 10
4.	<b>Work Order Close-Out</b> – Is appropriate information on work performed and “As-Left” condition of equipment captured when WO is closed so maintenance can provide feedback to Operations and PDM?		
<b>Technologies</b>			
5.	<b>Work Management Systems</b> – Is a formalized work management system in place? Is it being computerized?		
6.	<b>Maintenance and Diagnostic Technologies</b> – Are condition-based technologies being used and is information being factored into maintenance decision making process?		
7.	<b>Information Integration Systems</b> – Do condition status reporting mechanisms exist? Do these systems integrate information from multiple sources? Are systems available on network to multiple users? Is information current?		
<b>Work Culture and Management</b>			
8.	<b>Continuous Improvement Methods</b> – Is the organization a ‘Learning’ organization that is able to avoid repetitive mistakes?		
9.	<b>Accountability</b> – Is accountability a part of the plant culture? Do people recognize what is expected of them? Do they perform accordingly?		
10.	<b>Organization</b> – Is organization structured to be successful using condition-based information?		
11.	<b>Leadership</b> – Does Management provide sponsorship for PDM, expectations, and necessary budget for initiatives to be successful? Are metrics used to manage business?		
12.	<b>Global Metrics and Reporting</b> – Are metrics available that adequately measure success of the process?		
13.	<b>Communication Mechanisms (Inter-Organization)</b> – The quality (formal and informal) of communication and Information Exchange between Maintenance, Management, Operations, Engineering, and others within the organization.		
14.	<b>Goal Setting</b> – Have Goals been set for the Maintenance Program? Are they in alignment with the overall objective?		
15.	<b>Benchmarking</b> – Has Benchmarking activities been performed to allow a direct comparison of the organizational practice with the Best-in-Class, or at least standard practices within power industry?		
<b>People / Skills</b>			
16.	<b>Training</b> – Review training program from content and direction perspective to ensure it prepares people with skills to support program.		
17.	<b>Utilization</b> – A review of productivity and utilization factors of the labor resources		
18.	<b>Intra-Department Communication</b> - How well is information communicated within the work group.		
19.	<b>Qualifications / Job Descriptions</b> – A documented measure of the qualification and skills of functions within organization with a focus on whether qualification/skills are capable of supporting program goals.		

(Note: See Appendix 1 for a form to be used in this exercise.)

## Identifying Issues Preventing a Successful PMO

Having presented the PMO concepts to the organization, measured current level of performance (Spider Chart), and mapped the organization work process, it is now necessary to surface issues that can prevent the PMO process implementation from being successful at this plant. To identify these issues, canvas an assembled cross section of the staff. Have each individual identify 3 issues that impede flow of information within the work process. Discuss each issue and ask clarifying questions until there is clarity among the group on the specifics of the issue. After the list of items has been developed, have the group prioritize the issues. Table 3-2 lists some typical issues that have been developed during visits to other plants. It is advisable to have a facilitator support this activity.

**Table 3-2**  
**Issues Preventing PMO Success**

- |  |
|--|
| <ol style="list-style-type: none"><li>1. Training on technologies</li><li>2. Root Cause Analysis is needed</li><li>3. CMMS – limited functionality, limited metrics</li><li>4. Integrating results into the maintenance plan</li><li>5. Lack of technologies</li><li>6. Buy-in from everyone</li><li>7. Manpower restrictions, can't take any more on</li><li>8. Level of awareness to all plant personnel as to why we're doing this. Get a true shared vision</li><li>9. Too many fires to put out during transition to adequately manage the program</li><li>10. Lack of budget (and further demands, cuts, re-appropriation)</li><li>11. Failure to follow up on PDM recommendations</li><li>12. Lack of accountability of PMO team leader and people</li><li>13. Company must be willing to replace and upgrade plant equipment</li><li>14. Ability to document and communicate costs and benefits of PMO</li><li>15. Management acceptance of PMO results (approval to act on PDM recommendations)</li><li>16. Bad data (SRCM) leads to a bad plan. (Don't get adequate or 'right' data)</li><li>17. PMO team must be open to all people, all departments, in their data collection</li><li>18. Roles and responsibilities not understood</li><li>19. Resistance to change, especially new diagnostic tools and recommendations</li><li>20. 'False Alarms' could kill the project (especially during the learning curve)</li><li>21. Large backlog of PM Work Orders</li><li>22. Missed 'failure' detection causes credibility loss</li><li>23. Plant Management and Load Dispatcher may override PMO recommendations in favor of generation</li><li>24. What is in it for me? (clearly communicated)</li><li>25. Adequate and accurate information on Work Order required. Good creation – good close-out</li></ol> |
|--|

## **Mapping Existing Work Process**

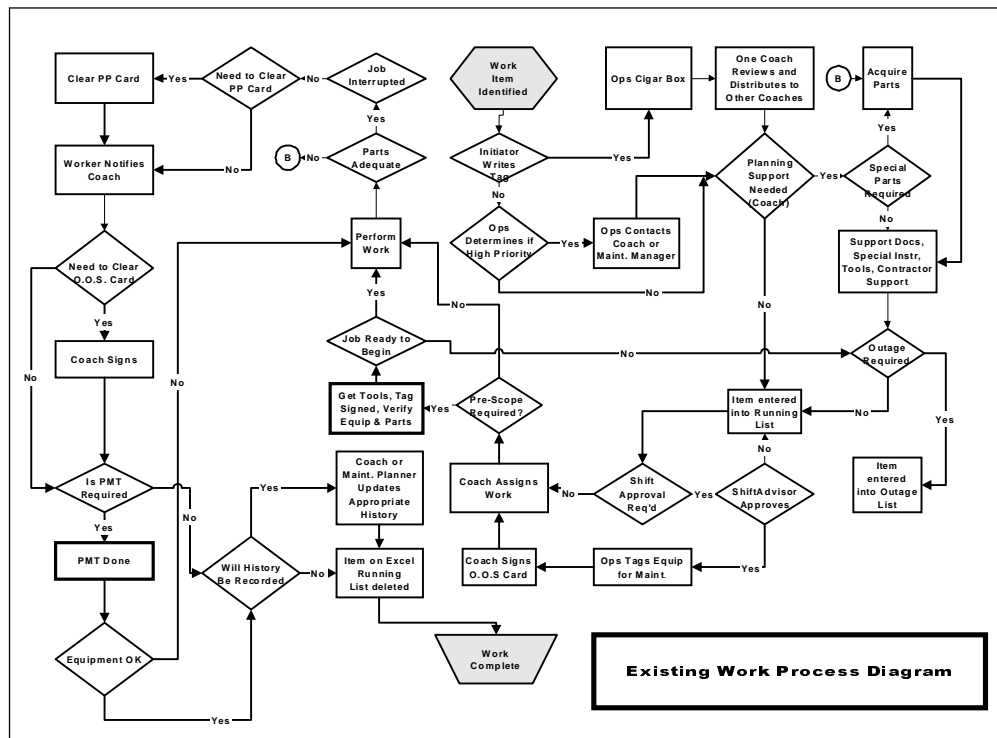
To get a better understanding of where changes may be necessary in the work process, it is necessary to understand how the process really operates in the field. The reality of how things actually get done in the field may vary significantly from how the process is defined in existing procedures and guidelines.

To construct the existing work process diagram, have members of the organization walk through the process. The assembled group should be able to identify the following:

- how work is identified (CM, PM, PDM, PAM)
- once the work task is identified, who is involved in the various decisions on whether or not the work gets done
- who determines when the work gets done
- who determines which individuals or teams perform the work task
- who plans the work
- who assembles parts
- who is responsible to document and close out the individual tasks
- who determines if post maintenance testing is performed
- how is work history captured

In going through this mapping process it is very important to understand every interface, handoff, and decision/approval step in the process. Furthermore, does the process loop back on itself, or is there a clear, direct flow from start to completion. It is advisable to have a facilitator support this activity.

The flow diagram Figure 3-1 represents the “as-found” work process at a typical plant. This format can be used to assemble the above requested information.



**Figure 3-1**  
**Existing Work Process**

## Work Process Issues

Another useful exercise that the organization should perform is to identify problems or potential roadblocks with the work process. To identify these issues, canvas the assembled cross section of the staff. Have each individual identify at least 3 issues that impede flow of information within the work process. Discuss each issue and ask clarifying questions until there is clarity among the group on the specifics of the issue. After the list of issues has been developed, have group prioritize the issues. Table 3-2 lists some typical issues that have been developed during visits to other plants. It is advisable to have a facilitator support this activity.

**Table 3-3**  
**Work Process Issues**

1.	History not captured
2.	Parts delays
3.	lack of Resources during short outages
4.	No formal Work Request Process, no parts system to equate Equipment ID to OEM P/N, no system to identify lead time for parts
5.	Poor Work Prioritization
6.	No Approval Process
7.	Communication between Operations and Maintenance
8.	No formal Scheduling Process
9.	Jobs not ready for maintenance worker
10.	Running maintenance resources limited
11.	Need better Problem Definition
12.	No priority on work close-out



## **Plant Walk-Down/Observing Maintenance Efforts in Progress**

In-process work should be selected and observed that is characteristic of how work is actually being accomplished in the field. The review should compare how the organization thinks work is being accomplished (refer to “As-Found” work process prepared by group) versus how work is actually accomplished in the field.

### ***Selecting Plant Procedures and Records for Review***

Procedures should be selected and reviewed that reflects how work is accomplished. The procedure review should compare how the organization thinks work is accomplished (refer to “As-Found” work process prepared by group) versus how work is actually controlled by procedures.

### ***Reviewing Corrective and Preventative Maintenance Documents***

A representative number of work orders should be reviewed to determine whether or not the “As-Found” conditions and “As-Left” conditions are appropriately captured in the work orders. The work orders should also be reviewed to see if replacement parts are adequately captured in the histories as well as whether or not the craft time has been documented. The work order should be reviewed to determine whether the task was conducted in accordance with appropriate procedures and whether post maintenance acceptance testing was performed and documented.



# 4

## PART III – CONDUCTING INTERVIEWS

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### Conducting Interviews

The assessment process is somewhat akin to conducting a root cause analysis on the maintenance process and the organization. The team is trying to determine:

- What is the plant maintenance program?
- How are specific maintenance tasks are executed?
- Who does the maintenance work?
- What advanced tools are being used to perform maintenance tasks?

The assessment team should test the validity of the various data that were self-identified by the organization (refer to Section II of this Guideline under the heading of “Information Gathering”). These data include:

- “Prerequisite Information (refer to Section III)
- Spider Chart “Self Evaluation”
- Mapping “As-Found” workflow
- “Work Process Issues”
- “Issues” that can impede implementation of PMO
- Plant walk down/in-process work observations
- Procedures and records review
- Corrective and preventive maintenance record review

The assessment interview process should work toward developing an understanding of the causal factors that led to the identification of the various data. The data, as presented, may only represent the apparent problem, which, in fact, on further investigation may be masking the true problem or issue. When reviewing the spider chart data for the various levels within the organization, responses for segments of the spider chart should be reviewed for consistency. Does the data show that the management responses are in agreement with the data provided by supervision and worker, or is there significant level of disagreement on how the organization performs? Alignment at a high level of performance indicates that the entire workforce sees the attribute as a strength. Alignment at a low level of performance indicates that the entire workforce sees that attribute as a weakness. Areas where there is a variation in the level of response should be a focus of the individual interviews. This line of questioning should be

pursued on both a vertical cut-Management, supervisor, worker, and horizontal cut from worker, etc. to worker or group to group. By proceeding with this line of questioning with various individuals in the same work group, with individuals from interfacing work groups, and with individuals from various levels of management, the root cause of the responses should be better understood. Reviewing procedures and walking down systems can also help fill voids in understanding the organization.

Typical questions for use in the interview process are included in Appendix 3. These questions should be modified and tailored to the specific facility being assessed. These questions have been developed to assist the interviewer's focus on issues that may prove useful in identifying gaps within the organization. This question set has been segregated on the five basic areas for Plant Maintenance Optimization:

- Work Identification
- Work Process
- Technologies
- Management and Work Culture
- People

When conducting the interviews, confidentiality is of utmost importance if useful responses are expected from those being interviewed. It is important that the interviewee be comfortable with the process. It should be stressed that the interviewer is taking notes but that the information will be held confidential among the assessment team. Further, it should be explained that the answers given would be presented only in a summarized format such that responses will not be able to be attributed to individuals.

## **Composition of Assessment Team**

Experience has shown that the most effective team size for conducting the individual assessment interviews is two individuals. Depending on the size of the target population, the overall project may need to be composed of several assessment teams with different two-person teams being used for interviewing different levels within the organization or interviewing different disciplines. The two-person team allows one member of the team to formulate and present the question to the interviewee, while the other team member listens intently to the answer and captures the essential information provided by the interviewee. This process allows the initial questioner to listen to the response and formulate the next question, or to request clarifying information on the initial response.

The two-person team should be comprised of individuals with different backgrounds or skill sets.

## **Targets to be Interviewed**

Experience has shown that a population between 10% for the largest organizations and 15% for the mid-sized organizations of the target workforce should provide an adequate basis for a

successful PMO Assessment. For the smaller organization, the target interview population may have to be further increased in order to get independent validation on the issues. Table 4-1 provides a suggested list of interviews.

**Figure 4-1**  
**Suggested Interviewees**

<b>Interviewee</b>	<b>Number</b>
<i>Corporate Management</i>	
Generation VP	1
Central Support Organizations	3
<i>Plant Management</i>	1
<i>Operations Management</i>	
Operations Manager	1
Shift Manager	2
Lead Operator	2
Operators	2
Floor Operators	2
<i>Maintenance Management</i>	
Maintenance Manager	1
Maintenance Foreman	3
Maintenance Mechanic-Electrical	2
Maintenance Mechanic-Mechanical	2
Maintenance Mechanic-I&C	2
Maintenance Planning and Scheduler	1
PDM Group Manager	1
<i>Storeroom</i>	1
<i>Engineering Management</i>	
Engineering Manager	1
System Engineers	2
Design Engineers	2
<i>Contractors Supporting Maintenance</i>	2
<b>Total</b>	<b>34</b>

To get verification of effectiveness of communication channels and to validate objectives of assessment, it may also be necessary to conduct part of the assessment at the corporate headquarters. This will be determined by the extent of autonomy provided to the subject site.

## **Data Integration**

Following each day of interviewing, while the information is still fresh, the various teams should meet to discuss the apparent findings (strengths and opportunities). Information gleaned from these data integration sessions should be used as a basis for preparing for the next set of interviews. Using this information, missing information can be pursued and areas where adequate responses have been provided can be ignored in subsequent interviews. However, when apparent conclusions have been identified, these conclusions should be tested through the subsequent interviews to establish validity.

## **Conducting Exit Meeting with Appropriate Project Sponsors**

Prior to preparing the implementation plan, an exit meeting with the sponsoring management should be conducted. At this meeting, preliminary observations should be discussed.

# 5

## PART IV – DEVELOPING AN IMPLEMENTATION PLAN

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Having defined the attributes of an optimized maintenance process in Part I of this guideline, it will be necessary to identify which areas to focus on when developing a customized PMO implementation plan for the individual power producer. To do this, it will be necessary to analyze all of the data that was acquired in Part II, Information Gathering, and Part III, Conducting Interviews. This data includes:

- Spider Chart
- “As-found” work process
- Work Process Issues
- Issues that will prevent the PMO from being successful
- Prerequisite information
- Data from interviews
- Information obtained from plant walk down
- Information collected from reviewing plant procedures and records
- Information obtained from reviewing PM and CM work orders
- Exit Meeting

By reviewing and digesting this information, an overall picture of where the organization today can be developed. Strengths, opportunities, and recommendations should be determined. With a firm understanding of where the organization is today compared to the concepts of PMO, the gaps in performance will be evident. The implementation plan should be developed to address:

- Gaps between the As-Found and the desired program state
- Implementation cost and return on investment
- Step by step schedule for implementation of each activity

Table 5-1 can be used as a tool to help quantify the areas of strengths and opportunities within the organization when compared to the key attributes of PMO. Use the top-level attribute for each category as the ten (10) and the lowest entry as the zero (0). Score performance against each of the 19 individual attributes. When this has been accomplished, a clear picture of the current organization performance should be apparent. This information should be compared against the spider diagram that was developed in Part II, Acquiring Data. Looking at this comparison, it is possible to document the assessors’ opinions on organization performance against how the organization believes it performs.

**Table 5-1**  
**Strengths and Opportunities Quantifiers**

Score High 10 ↑ ↓ Low 0	<b>Work Identification</b>		<b>Work Process</b>	
	<b>Work Identification</b> Integrated CBM Program SRCM Has been accomplished PM/PDM) Strong RCA Work Order review process  Large Backlog of PM and PDM work Highly Reactive Work Environment	<b>Work Control</b> Priorities are set and approved Work packages are prepared Parts Availability Clearances/Blocking Timely - Work Packages A multi-week scheduling process is being used Scheduling Compliance is greater than 95%  Parts unavailable Priorities are not reviewed Work Packages are not prepared No scheduling process	<b>Work Execution</b> Zero Rework Good Metrics Planned hours vs. actual within 10% Task benchmarking has been performed  No benchmarking Planned hours vs. actual not tracked Large Percentage of Rework	<b>Work Close Out</b> Post Maint Testing Identified As Found and As Left captured in CMMs Maintenance Histories Updated Initiator gets feedback Good Housekeeping Work Reviewed by supervisor  Limited learning from work performed No feedback
	<b>Technologies</b>			
	<b>Work Management System</b> Great Metrics - Global and Component Specific RCA identified from Histories Good Maintenance Histories High percent of work uses CMMS User friendly  Do not have a CMMS Very Limited use	<b>Maintenance &amp; Diagnostic Technologies</b> All know what & where info is E&CI Optimized Technologies (Oil Analysis, IR, Vibration, Leak detection On-line and periodic data, leak detection)  Reactive not taking advantage of Condition Info	<b>Information Integration Technologies</b> All decisions driven by integrated info Easy access to all information System and Component based info Integration Tools exist LAN Exists CMMS - Financial System - Dispatch info DCS or Plant Process Computer  No integration tools exist	
	<b>Management and Work Culture</b>			
	<b>Continuous Improvement</b> Good process in-place yielding results - learning org. Team Problem Solving Periodic self appraisals RCA in place Employees solicited for ideas Must be recreated for further improvement  “Program of the Month” Too reactive for betterment  <b>Global Metrics</b> Mgmt Initiatives linked to Metric Improvement Creative Global goals have focused improvement Plant Strategies linked to Goals with Metrics Work linked to Metric Improvement HR, O&M Costs, EFOR, System Availability Overall Plant Goals Tracked and Posted  Goals seem unrelated to work ongoing at plant	<b>Accountability</b> All are held accountable for performance Good metrics provide clarity Owners exist - Process, Technology, Equipment Performance linked to plant success Employees know roles and responsibilities  Empowerment incorrectly has halted accountability No Ownership until reaching Plant Manager  <b>Communication (Inter)</b> Mgmt Issues are understood by workforce Communication paths exist technology, engineering  Turf Battles prevent good communication systems	<b>Organization</b> Everyone is responsible to PMO Process Teams Process Owners - Equipment Owners Vertical Organizations Ops, Maintenance, Technology, Engineering  Does not promote good communications done Heavy functional boundaries - turf battles  <b>Setting Goals</b> Plant Goals linked to various plant org goals Good alignment of Goals (pers - org - plant) Good local metrics Workforce know plant goals and strategy Workforce is business literate Workforce participates in setting goals Employees have current expectations  Workforce unsure of plant objectives	<b>Leadership</b> Walks the Talk - Direction and Discipline accountability effectively Reinforces by confirming why and provides rewards  Program of the Month Incongruent Behavior  <b>Benchmarking</b> exists at Workforce Studies have been performed recently  “We’re the Best” prevention Unaware and unconscious to best practice
	<b>People</b>			
	<b>Training</b> Training driven off Existing/Required Matrices Manage skill/knowledge of organization PMO Awareness is well understood Training performed as requested Training Budget exists  Training budget cut with no plans	<b>Utilization</b> System work grouping - Good Metrics Good Planning - Scheduling - Schedule adherence Multi-discipline capability FIN approach  Frequent trips to storeroom or parts unavailable	<b>Communication (intra)</b> People learn from each other People work well within Teams Team to team communication free-flows Proactive behavior  Compliant behavior Resistance exists People are fearful for their jobs	<b>Qualifications</b> Responsibilities No rework - people are well qualified Qualifications measured - Re-qualified Written Job Descriptions  Rework not measured No qualification tracking

(Note: See Appendix 2 for a form to be used in this exercise.)

Each area where the performance is identified as being low should be further explored to fully understand the causal factors for this level of performance. Each of these causal factors should be developed into clearly stated findings. Using these individual findings, develop individual recommendations or corrective actions that, when implemented, will move the organization toward the desired level of performance.

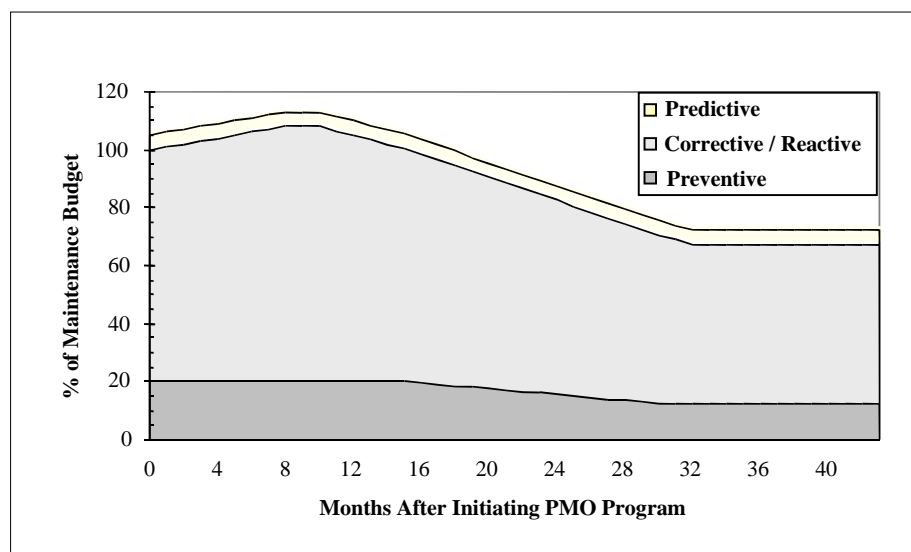


Prior to implementing any changes to the existing organization, the expected return on the investment for each change should be developed. Management must understand the extent of the investment required and, further, what savings can be expected. Consideration should also be given to the time required to implement the specific changes. This information can be used when the organization develops the priority and schedule for implementing each of the recommendations.

The development of the implementation priority should be based on goals of the Corporation. If goal setting is identified as one of the weak areas, the implementation plan should start by developing specific goals for the plant that will align with the Corporate goals (refer to discussion on goal setting in Part 1). Once these goals have been identified, the rest of the implementation plan can be developed to support these goals. However, it is very important that no change to the existing processes should be attempted without having appropriate metrics in place to measure effects from implementing the change. It is expected that all action plans that are developed as a result of the assessment will provide the organization with a significant return on its investment; however, that may not always be the case. Therefore, without having the tools in place to track the performance using very specific metrics, success cannot be demonstrated.

Furthermore, it is important to understand that by changing the process, and having implemented changes that will provide overall performance improvement over time, there is a transition period of time when the cost to do business actually increases. Management should be prepared ahead of time to recognize this initial increase. As the implementation effort moves forward, problems with the equipment are going to be identified and must be dealt with. These are items that would appear further down the operating cycle as problems; but now through early identification, the opportunity allows for the problem to be resolved before the item can result in catastrophic failure.

Refer to Figure 5-1 which describes the effects that changes have on maintenance costs over time from the initiation of the PMO implementation Plan.

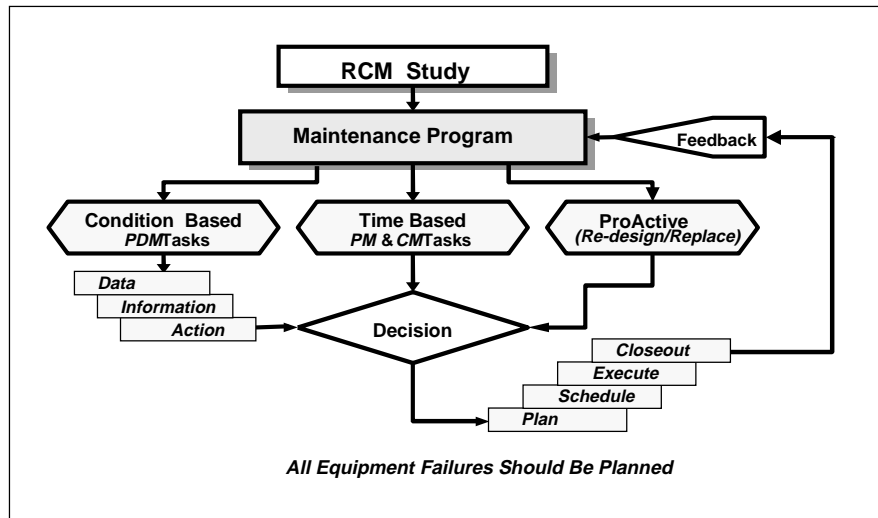


**Figure 5-1**  
**Effects of PMO Implementation Plan**

## Developing Implementation Strategy

Creating alignment between stakeholders and selecting significant issues.

The model, illustrated in Figure 5-2, shows how the integration of decision making and feedback (continuous improvement) leads to optimization of the plant maintenance process.



**Figure 5-2**  
**Integration of Decision-Making**

In the section that follows, typical recommendations will be addressed for each of the 19 key attributes needed for an effective PMO.

### Work Identification

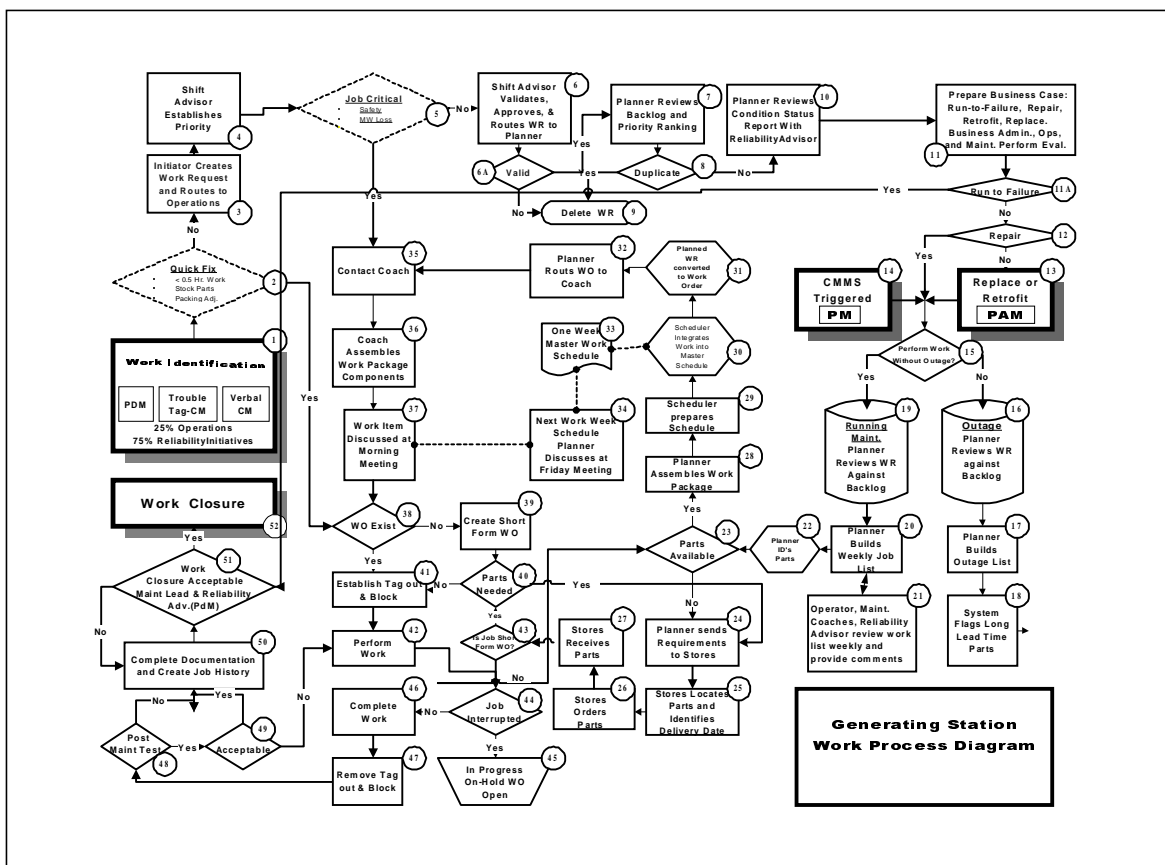
#### 1. Work Identification

- A Reliability-Centered Maintenance (RCM) program should be used to identify a protection strategy for each piece of critical equipment.
- The RCM program should be interactive to the point that when equipment failure is experienced that falls outside of the conditions dictated by the RCM program, the program protection strategy should be modified when the root cause of the failure has been identified.
- Clearly defined preventive, corrective, predictive, and proactive maintenance practices should be in place.
- Separate, identifiable budget for PDM organization.
- The goal of the maintenance program should be to work toward a highly planned workload with no more than 30% of the work being Corrective maintenance.
- Work orders should be reviewed to identify repetitive failures.

- A Proactive approach should be taken to solve these problems (modify operation or change-out component based on operation history and root cause analysis).
- In cases where the failure mode is not apparent and the impact from the failure is significant, a Root Cause Analysis should be used to identify the failure initiator.
- CMMS history should be reviewed prior to issuing new work order.
- A root cause analysis should be performed for recurring failures to identify root cause of failure initiator.

## Work Process

One of the many results contained in the implementation plan is a recommendation around the work process. The work process flow diagram shown as Figure 5-3 was developed for a typical plant that was optimizing the maintenance process. The diagram was developed to resolve weaknesses in the existing work process (refer to “As-Found” work Process diagram developed in Part II Information Gathering), and to incorporate improvements in the overall use of information in decision making.



**Figure 5-3**  
**Work Process Diagram**

## 2. Work Control

- A formalized planning process should be in place (preferably Computer-based).
- Criteria should be developed for setting priorities (consider criticality of equipment, economics of time related generation).
- Prepackaged work packages should be developed which include; work procedure references, drawing references, parts required, permit and blocking plans, and prerequisites.
- Minor work (less than one hour and on non-critical systems) can be accomplished without a formal work order. These are the tasks that never get done because of low priority. Consider a roving multi-skilled team that roves the plant one-day or week per month to address these problems. These teams are known as-FIN “fix it now or “you find it, you fix it”.
- Parts availability and minimum/maximum stocking levels should be reviewed on an annual basis.
- A multi-week scheduling process should be in place and performance to plan should be measured.
- Scheduling Compliance should be greater than 95%.
- A progressive planning process should be in place so that work is identified and scheduled for work several weeks out. As the scheduled work date gets closer, more detailed planning is accomplished. By the one-week prior to work date, the completed work package should be ready to work. Having work packages on the shelf and ready to go gives flexibility to the organization since the work can be substituted for scheduled work if an existing is placed on hold for any reason.

## 3. Work Execution

- Rework should be minimized. A system should exist to track rework. The goal for rework should be zeros.
- Good Metrics should be developed and used to manage work and backlog.
- Planned hours should be within 10% of actual hours.
- Task benchmarking should be performed.

## 4. Work Order Close-Out

- Post-Maintenance Testing should be identified in work order.
- “As-Found” and ‘As Left’ conditions should be captured in CMMS history.
- Maintenance Histories should be updated for each work order.
- Work order initiator should get feed on “As-Found” condition.
- “As-Found” condition compared to condition identified in diagnostic data.
- Good housekeeping should be encouraged-workers have pride in keeping work area clean.

- In-process and completed work should be reviewed by supervisor.

## ***Technologies***

### **5. Work Management Systems**

- Metrics should be both Global and Component Specific.
- The root cause of the problem should be identified in History.
- Good Maintenance Histories should be maintained.
- A high percent of work should be managed through the Computerized Maintenance Management System (CMMS).
- The CMMS should be user friendly to the occasional user as well as the heavy duty user.

### **6. Maintenance and Diagnostic Technologies**

- All workers should be familiar with diagnostic technologies, know what information is available, and know where information is stored.
- Equipment and Condition Indicator Matrix should be developed and in used in decision process.
- The following technologies should be considered as the minimum for diagnostic testing:
  - Oil Analysis
  - Thermography
  - Leak Detection
  - Vibration
  - On-Line and Periodic
  - Lubricant Analysis

### **7. Information Integration Systems**

- All decisions should be driven by integrated information.
- Easy access to all information.
- Responsibilities should be both System and Component based.
- Integration Tools should exist.
- LAN to provide easy access to information should exist.
- The CMMS should Financial information and man-hours for each task.
- DCS or Plant Process Computer should be in use.

## **Work Culture and Management**

### **8. Continuous Improvement Methods**

- Good processes should be in place which yield results characteristic of a learning organization.
- Team Problem Solving should be in place.
- Periodic self-appraisal process should be in place.
- Root Cause Analysis process should be in place.
- Employees should be solicited for ideas.

### **9. Accountability**

- All are held accountable for performance (both individually and globally)
- Good metrics provide clarity
- Owners exist for Process, Technology, and Equipment
- Performance linked to plant success
- Employees should know roles and responsibilities

### **10. Organization**

- Everyone should be responsible to PMO.
- Process Teams should exist.
- Both Process Owners and Equipment Owners should exist.
- The organization should be vertically structured for Operations, Maintenance, Technology, and Engineering.

### **11. Leadership**

- Leadership must Walk-the-Talk for both direction and discipline.
- Management must provide adequate resources and demands accountability.
- Expectations must be very clear. Metrics should be used to measure progress.
- Management should reinforce by confirming why and provides rewards.

### **12. Global Metrics and Reporting**

- Management Initiatives must be linked to Metrics to measure improvement.
- Creative Global goals are needed to focus improvement.

- Plant Strategies must be linked to Goals with Metrics.
- Work linked to Metric Improvement.
- Overall Plant Goals should be tracked and posted for work force (HR, O&M Costs, EFOR, System Availability).

### 13. Communication Mechanisms (Inter-Organization)

- Management Issues need to be understood by workforce.
- Communication paths exist (open door policy by management).
- No boundaries between operations, maintenance, technology, engineering.

### 14. Goal Setting

- Plant Goals need to be linked to various plant organization goals.
- Good alignment of Goals in necessary (individual understands how his contribution aligns with work group and to plant).
- Good local metrics so local accomplishment is recognized.
- Workforce must know plant goals and strategy.
- Workforce must be business literate (understands competitive market environment challenges and benefits of economic availability).
- Workforce must participate in setting goals.
- Employees have current expectations.

### 15. Benchmarking

- Benchmarked Best Practice knowledge must exist at Workforce level.
- Data needs to be current (Studies have to be recent).

## ***People/Skills***

### 16. Training

- Training should be driven off Skills Existing versus Skills Required Matrices.
- The organizations skill/knowledge basis needs to be managed.
- PMO Awareness must be well understood by workforce through management.
- Training should be performed as requested.
- Training Budget should exist.

## 17. Utilization

- System work grouping-Good Metrics.
- Good Planning-Scheduling-Schedule adherence.
- Multi-discipline workforce capability.
- FIN (fix-it-now) approach.

## 18. Inter Department Communication

- People learn from each other.
- People work well within Teams.
- Team to team communication free-flows.

## 19. Qualifications/Job Descriptions

- Skills required for work clearly defined.
- Clear and Concise Roles and Responsibilities.
- No rework-people are well qualified.
- Qualifications measured-Re-qualified.
- Written Job Descriptions exist and are frequently reviewed.

## **Plant Maintenance Optimization Report Format**

- Executive Summary
- Program Overview
- Purpose
- Scope
- Findings and Recommendations
- Goal
- Economic Environments
- Reporting
- Work Flow
- Existing Organizational Structure
- Maintenance Basis
- PDM Process
- PAM Process



- Continuous Improvement Process
- Roles and Responsibilities
- Organization Structure with PMO
- Financial Analysis
- Program Cost Summary
- Cost Benefits
- Training Requirements
- Appendices
- References
- Implementation Schedule

### **Presentation of Finished Product to Appropriate Project Sponsors**

It is important that the individuals who participated in the assessment be included in the roll-out process. These people invested their time and shared their thoughts on how things should work. They should be given the opportunity to understand the reasoning behind the recommendations that the assessment team has assembled. This provides one additional sanity review. The participants may point out an obvious issue, or make a point that was not raised during this process.



# 6

## REFERENCES

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1. Predictive Maintenance Guidelines EPRI TR-103374 August 1994
2. Predictive Maintenance Guidelines Volume 2 EPRI TR-103374-2 October 1994
3. Predictive Maintenance Assessment Guidelines EPRI TR-109241 November 1997
4. Smith, Anthony M., Reliability Centered Maintenance, McGraw Hill, 1993
5. Plant Performance Success Indicators for Predictive Maintenance Programs, Matusheski, paper published in the P/PM Technology magazine, July 1997



# **A**

## **APPENDIX A – SPIDER CHART SELF-EVALUATION**

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		<b>Select one:</b> Manager Supervisor Worker  <b>Score:</b> 1 to 10
<b>Work Identification</b>		
1.	<b>Work Identification</b> – Has RCM been performed? Is formalized Root Cause Program in place? Is PDM being used? Have PM tasks been reviewed? Is “As-Found” condition documented?	
<b>Work Process</b>		
2.	<b>Work Control</b> – Is formalized planning and scheduling program in place? Is work scheduled greater than one week ahead? Do standard work packages exist? Is schedule compliance measured?	
3.	<b>Work Execution</b> – Actual performance of work includes man-hour utilization, training, tool availability, tool upgrade to latest technology, continuous improvement metrics (rework vs. total work, wrench time vs. total time).	
4.	<b>Work Order Close-Out</b> – Is appropriate information on work performed and “As-Left” condition of equipment captured when WO is closed so maintenance can provide feedback to Operations and PDM?	
<b>Technologies</b>		
5.	<b>Work Management Systems</b> – Is a formalized work management system in place? Is it being computerized?	
6.	<b>Maintenance and Diagnostic Technologies</b> – Are condition-based technologies being used and is information being factored into maintenance decision making process?	
7.	<b>Information Integration Systems</b> – Do condition status reporting mechanisms exist? Do these systems integrate information from multiple sources? Are systems available on network to multiple users? Is information current?	
<b>Work Culture and Management</b>		
8.	<b>Continuous Improvement Methods</b> – Is the organization a ‘Learning’ organization that is able to avoid repetitive mistakes?	
9.	<b>Accountability</b> – Is accountability a part of the plant culture? Do people recognize what is expected of them? Do they perform accordingly?	
10.	<b>Organization</b> – Is organization structured to be successful using condition-based information?	
11.	<b>Leadership</b> – Does Management provide sponsorship for PDM, expectations, and necessary budget for initiatives to be successful? Are metrics used to manage business?	
12.	<b>Global Metrics and Reporting</b> – Are metrics available that adequately measure success of the process?	
13.	<b>Communication Mechanisms (Inter-Organization)</b> – The quality (formal and informal) of communication and Information Exchange between Maintenance, Management, Operations, Engineering, and others within the organization.	
14.	<b>Goal Setting</b> – Have Goals been set for the Maintenance Program? Are they in alignment with the overall objective?	
15.	<b>Benchmarking</b> – Has Benchmarking activities been performed to allow a direct comparison of the organizational practice with the Best-in-Class, or at least standard practices within power industry?	
<b>People/Skills</b>		
16.	<b>Training</b> – Review training program from content and direction perspective to ensure it prepares people with skills to support program.	
17.	<b>Utilization</b> – A review of productivity and utilization factors of the labor resources.	
18.	<b>Intra-Department Communication</b> - How well is information communicated within the work group.	
19.	<b>Qualifications/Job Descriptions</b> – A documented measure of the qualification and skills of functions within organization with a focus on whether qualification/skills are capable of supporting program goals.	

# ***B***

## **APPENDIX B – STRENGTHS AND OPPORTUNITIES QUANTIFIERS**

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Appendix B – Strengths and Opportunities Quantifiers

Work Identification		Work Process		
Score High 10 ↑ ↓ Low 0	Work Identification	Work Control	Work Execution	Work Close Out
	Integrated CBM Program SRCM Has been accomplished Highly planned Work Load (30%CM/70% PM/PDM) Strong RCA Work Order review process	Priorities are set and approved Work packages are prepared Parts Availability Clearances/Blocking Timely - Work Packages A multi-week scheduling process is being used Scheduling Compliance is greater than 95% Parts unavailable Priorities are not reviewed	Zero Rework Good Metrics Planned hours vs. actual within 10% Task benchmarking has been performed No benchmarking	Post Maint Testing Identified As Found and As Left captured in CMMs Maintenance Histories Updated Initiator gets feedback Good Housekeeping Work Reviewed by supervisor
	Large Backlog of PM and PDM work Highly Reactive Work Environment	Work Packages are not prepared No scheduling process	Planned hours vs. actual not tracked Large Percentage of Rework	Limited learning from work performed No feedback
Technologies				
Work Management System		Maintenance and Diagnostic Technologies	Information Integration Technologies	
Great Metrics - Global and Component Specific RCA identified from Histories Good Maintenance Histories High percent of work uses CMMS User friendly		All know what and where info is E&CI Optimized Technologies (Oil Analysis, IR, Vibration, Leak detection On-line and periodic data, leak detection)	All decisions driven by integrated info Easy access to all information System and Component based info Integration Tools exist LAN Exists CMMS - Financial System - Dispatch info DCS or Plant Process Computer	
Do not have a CMMS Very Limited use		Reactive not taking advantage of Condition Info	No integration tools exist	



**Management and Work Culture**

<b>Continuous Improvement</b>	<b>Accountability</b>	<b>Organization</b>	<b>Leadership</b>
Good process in-place yielding results - learning org.	All are held accountable for performance	Everyone is responsible to PMO	Walks the Talk - Direction and Discipline
Team Problem Solving	Good metrics provide clarity	Process Teams	Provides resources - demands accountability
Periodic self appraisals	Owners exist - Process, Technology, Equipment	Process Owners - Equipment Owners	Sets expectations - uses metrics effectively
RCA in place	Performance linked to plant success	Vertical Organizations Ops, Maintenance, Technology, Engineering	Reinforces by confirming why and provides rewards
Employees solicited for ideas	Employees know roles and responsibilities		
Must be recreated for further improvement			
		Does not promote good communications	
"Program of the Month"	Empowerment incorrectly has halted accountability	Org limits workers from getting right thing done	Program of the Month
Too reactive for betterment	No Ownership until reaching Plant Manager	Heavy functional boundaries - turf battles	Incongruent Behavior
<b>Global Metrics</b>	<b>Communication (Inter)</b>	<b>Setting Goals</b>	<b>Benchmarking</b>
Mgmt Initiatives linked to Metric Improvement	Mgmt Issues are understood by workforce	Plant Goals linked to various plant org goals	Benchmarked Best Practice knowledge exists at Workforce
Creative Global goals have focused improvement	Communication paths exist	Good alignment of Goals (pers - org - plant)	Studies have been performed recently
Plant Strategies linked to Goals with Metrics	No boundaries between operations, maintenance, technology, engineering	Good local metrics	
Work linked to Metric Improvement		Workforce know plant goals and strategy	
HR, O&M Costs, EFOR, System Availability		Workforce is business literate	
Overall Plant Goals Tracked and Posted		Workforce participates in setting goals	
		Employees have current expectations	
	Turf Battles prevent good communication		"We're the Best" prevention
Goals seem unrelated to work ongoing at plant	Workforce and Management have different belief systems	Workforce unsure of plant objectives	Unaware and unconscious to best practice

**People**

<b>Training</b>	<b>Utilization</b>	<b>Communication (intra)</b>	<b>Qualifications</b>
Training driven off Existing/Required Matrices	System work grouping - Good Metrics	People learn from each other	Clear and Concise Roles and Responsibilities
Manage skill/knowledge of organization	Good Planning - Scheduling - Schedule adherence	People work well within Teams	No rework - people are well qualified
PMO Awareness is well understood	Multi-discipline capability	Team to team communication free-flows	Qualifications measured - Re-qualified
Training performed as requested	FIN approach	Proactive behavior	Written Job Descriptions
Training Budget exists		Compliant behavior	
		Resistance exists	Rework not measured
Training budget cut with no plans	Frequent trips to storeroom or parts unavailable	People are fearful for their jobs	No qualification tracking

# C

## APPENDIX C – MAINTENANCE OPTIMIZATION ASSESSMENT

---

Name: \_\_\_\_\_ Position: \_\_\_\_\_ Date: \_\_\_\_\_

### Work Identification

#### ***1 Work Identification***

1. What is your overall maintenance strategy?
2. What is the current mix?    \_\_\_\_%CM    \_\_\_\_%PM    \_\_\_\_%PDM    \_\_\_\_%PAM
3. How do you categorize repair activities?
4. What is your definition of Predictive Maintenance?
5. What is your understanding of your company's Predictive Maintenance efforts?
6. Do you think PDM could be or has been effective in reducing O&M cost, increasing availability, or decreasing plant heat rate.
7. On what are you basing your belief?
8. Do you think that better control of the plant's temperatures, pressures, flows (Such as main steam temperature, main steam pressure, coal and combustion air flows) would eliminate unnecessary stresses and would be effective in reducing O&M costs, increasing availability and decreasing plant heat rate?
9. On what are you basing your belief?
10. What is the plant's actual heat rate? How does it compare with industry benchmarks?
11. Do you track EFORs or Peak EFORs? How do they compare with industry benchmarks?
12. Are there any technologies additional that would be beneficial to the plant that should be or will be implemented in the near future?
13. Are you considering the addition of Control Valve Diagnostics or Valve Leak Detection technologies?

14. What are the most troublesome equipment or component in the plant?
15. What, if any, monitoring or diagnostics have been applied to these systems?
16. Do you keep a running list of the top 10 or 12 problems? Could we get a copy of the list?
17. Do you track costs on individual pieces of equipment? Can you? Would this be useful?
18. Do track individual availability on major components? Can you? Would this be useful?
19. Do repairs recommended reflect the actual “as found” problem?
20. Describe the plant control system. DCS or analog? Year installed? Plans for upgrade?
21. What is the physical condition of the Control Valves and Control Dampers used to control the Plant’s Processes? Do they operate smoothly and provide precise control of the processes?
22. Are any of the plant’s process (DCS) controls run routinely in manual instead of automatic?
23. Is it necessary to place DCS controls temporarily in manual due to processes becoming unstable? Is priority given to correcting these problems and eliminating their negative effect on equipment reliability.
24. What key process data points are used for plant control?
25. Are there any process data points that are often used for identifying equipment problems or troubleshooting?
26. Are techniques such as performance testing employed to verify the accuracy of installed plant instrumentation? Are you confident that the installed instruments are accurate and presenting an accurate picture of actual plant operating conditions?
27. Are installed plant instruments checked for accuracy and calibrated on a regular basis?
28. What portable diagnostic tools are regularly used by operators?
29. Is the plant adequately covered with monitoring systems? Yes/No. What monitoring technologies would you like to see applied and to which equipment?
30. Do you track running hours on individual pieces of major equipment? Is it possible?

## **Work Process**

### ***2 Work Control***

1. Is there a Work Planning Group? What are their responsibilities?

2. How is work scheduled? Is “performance to schedule” tracked?
3. Is operations (or the customer) involved in the scheduling process?
4. What performance metrics are used to assess Work Execution? Is that data taken from CMMS?
5. Are documents controlled (i.e., latest revision entered, used by worker, tracked, serialized)?
6. Describe, step by step, how a maintenance work order is initiated, reviewed processed and closed out. Are operators involved in evaluating the equipment condition? If not should they be, and how?
7. Is there a standard Work Order format? What data from the Work Order is entered into CMMS?
8. Are workers required to record (on the Work Order) :
  - -work performed?
  - -conditions found?
  - -failure codes?
9. Does anyone check to see if the Work Order is a duplicate?
10. Does anyone verify the correct priority code on the Work Order?
11. Who sets the priority for work requests/work orders? Who should?
12. What % of work orders are planned? How far in advance?
13. How much does it cost to process a work order?
14. On the average, how many maintenance orders do you receive per year?
15. Who assigns resources (people and materials)?
16. Are there existing work packages or are they developed as needed?
17. Are there any existing procedures or processes that you consider to be highly efficient and cost effective? (i.e. quality program, heat recovery, etc...)
18. Are there any old processes or procedures that should be brought back?
19. In your opinion, are current resources adequate for operating and maintaining the plant, safely and efficiently?
20. How much of your plant maintenance is done on overtime? Do you track this by employee? By component?

21. Is your company planning to reorganize or down-size anytime soon?
22. Will personnel reduction resulting from down-sizing cause problems maintaining or operating in the future?
23. Will personnel reduction result in reduction of safety? Will personnel reductions result in reductions in plant efficiency or reliability?
24. What steps should be taken to relieve some of these difficulties?
25. Are you aware of any other programs for cost reductions either at the plant level or at the corporate level?
26. Are you aware of programs to increase plant efficiency? To increase reliability? To reduce emissions?
27. Do you have a “performance group” or process experts on staff?
28. What are the risks involved with reducing these costs?
29. How do seasonal variations effect plant maintenance workload.
30. Does management support you when requesting investment in maintenance?
31. As a result of post maintenance testing, how is any rework justified? Do you track rework?
32. Spare Parts
  - What is your spare parts policy?
  - What is the basis for the policy?
  - Where are spare parts kept?
  - Has your store-room been recently purged for overstocked or obsolete parts?
  - Who orders spare parts?
33. How are Spare Parts tracked? Is material staged for scheduled work?
34. How are jobs awaiting parts/material tracked?
35. Are procedures used? Is there any written guidance as to how and when?
36. Are spare parts generally available when needed? Give an overall percentage availability
37. Is parts control in the CMMS or is it a separate system? Manual or computerized?
38. Does the plant have any problems with regulatory mandated emission or discharge systems?

### 3 Work Execution

1. What types of preventive activities are carried out on a regular basis?
2. On which equipment?
3. Do the maintenance crews capture the “as found” condition of the components that were repaired or replaced during these preventive procedures?
4. Are there any written schedules for performing these activities?
5. How is outage scope derived?
6. Are diagnostic results used to direct outage maintenance?
7. Is there an outage planning group? If so, do they have formal guidance/procedures?
8. Is outage work prioritized in advance (1 day, 1 wk plans)? Who sets the priority for work?
9. How are jobs in the planning process tracked?
10. Is material staged for execution? How?
11. Is there an outage scheduling group? Is operations (customer) involved?
12. Are contractors used for outage work?
  - How are they managed?
  - What procedures do they use?
13. What performance metrics are used to assess outage performance? How do you know if the overall duration and cost of your outage is competitive?
14. Are documents controlled?
15. Is there a formal “lessons learned” file for future outage planning/execution?  
What services does the plant use on a regular basis from Central corporate or contractor support? *Check all that apply(either Central or Contractor)*

\_\_\_\_Diagnostic Testing (including NDT Inspections)

\_\_\_\_Laboratory

\_\_\_\_Engineering Design

\_\_\_\_Troubleshooting

\_\_\_\_Outage Maintenance

16. What is the current maintenance order backlog? Is this normal? (in worker-weeks)
17. Is the backlog increasing, decreasing or staying the same?
18. Do you periodically purge the backlog for duplicates or outdated work requests?

#### **4 Work Close-Out**

1. Is post maintenance testing done?
  - By whom?
  - What tests are done,
  - On which machines?
  - How is it documented?
2. Are PMT acceptance criteria identified?
3. What action is taken if PMT acceptance criteria is not met?
4. Does anyone check to ensure that the Work Order is filled out properly after job completion? Who does this?
5. How do systemic (repetitive) failures get identified? Is action assigned to conduct Root Cause Failure Analysis, etc. to determine long term resolution of these problems? If so, who is action assigned to?
6. Are the following failure causes identified and dealt with:
  - Improper performance of work by the worker
  - Defective Spare Parts
  - Non-calibrated test instruments
  - Improper operation of equipment by the operator
  - Unsatisfactory product quality or rate
7. Are “as-found-as-left” data identified? How/where is it recorded? Is it used for future maintenance planning?
8. Is there any guidance/procedures for the workers with respect to documentation of completed work?
9. Is there an equipment “tag-out” procedure? How is equipment transferred to operations after maintenance is complete? Is there a procedure?
10. Who is responsible to clean up the work site? Recommend evaluator tour some work sites to get a feel for overall plant cleanliness



11. What performance metrics are used regarding Work Orders? For example, backlog of PMs and Reactive Maintenance Tasks, open actions discovered upon review of completed work such as Root Cause Failure Analysis, improper vendor performance, PM revisions required, Drawing Revisions required, etc.

## **Technology**

### **5 Work Management System (CMMS)**

1. Does your facility have a computerized maintenance management system? How is it used?
2. Do you use this system? Who Does?
3. Is there a training program in place for the use of the CMMS? Who is trained?
4. Who is responsible for the CMMS system?
5. What CMMS modules are used (planning, scheduling, electronic work orders)?
6. Is CMMS tied to the warehouse parts management system?
7. How are min/max spare parts levels determined?
8. Are spare parts identified on each PM tasks?
9. Is there a formal scheduling process? Describe?
10. Are Spare Parts requirements tied to the work scheduling process?
11. Is there a continuous improvement process in place (e.g., failure trending, action item tracking, worker suggestions, PM revision status, etc.)?
12. What are the most frequently recurring problems faced by your maintenance department? Does your system flag these recurring problems automatically?
13. Do you know your plant's production costs?
14. Are you aware of any sort of equipment trouble list? Who keeps it?

### **6 Maintenance and Diagnostic Tools**

1. What diagnostic technologies are used in your plant's maintenance program?
2. What diagnostic technologies are used your maintenance craft personnel?
3. Are there any technologies that are used by operations?
4. Are any technologies conducted by plant technical staff or outside organization?

5. Are there any contracted services that have been effective?
6. What condition monitoring diagnostic technologies do you know of that your company is not using?
7. To what equipment problems would you apply them?
8. Which diagnostic system, on-line or periodic, is utilized in the PDM program?
9. Do you have reporting responsibility to a specific plant person or group?
10. Are there any existing procedures for condition based testing which you perform for the plant? (i.e. lube oil sampling, vibration, etc...)

### ***7 Information Integration Tools (Financial, Budget, Schedule, Dispatch, Tech Equip)***

## **Work Culture and Management**

### ***8 Continuous Improvement***

1. Do you have a formal root cause analysis process? Are people trained in the process? Is there a dedicated root cause team? How often is a root cause assessment performed? (*Management question*)
2. How do you use root cause information to prevent recurrence of a problem? Is the effectiveness of this process tracked? How? (*Management question*)
3. Do you apply root cause analysis to process and management issues? (*Management question*)
4. Do you capture the “as-found” condition of equipment when you do maintenance? Where is this data captured? In the CMMS? Is this information used to make changes in the operation and maintenance processes? Is this information reviewed before planning or performing maintenance on the same piece of equipment?
5. Are “as-left” conditions noted on the work order or in the CMMS? Is this information reviewed during planning or prior to working on the equipment the next time?
6. Is the effectiveness of these interventions or changes to work practice tracked or periodically measured to assure that the changes had a positive effect on the process by extending equipment life and optimizing time-based maintenance?
7. Periodic plan review
8. Team Problem Solving

## **9 Accountability**

1. What meetings are held regularly to address plant equipment problems or other O&M issues?
2. Who attends these meetings?
3. What reports are you aware of (paper, electronic, voice mail) are currently available to you? Who produces these reports?
4. What mechanisms are in place to hold employees accountable?
5. Is a formal action item system/report used to document and track action to completion? Does management review/status open actions items?
6. Is management involved in progressing overdue actions?
7. Is operations required to be accountable to maintenance for the proper operation of equipment? How is this done?
8. Are support organizations (Engineering, Stores, I.S.S., others) held accountable to ensure all work on hold is made “ready to work” as soon as possible? How?
9. Is there a formal performance evaluation process in place?
10. Does each level of management set goals for their subordinates? If so, are employees evaluated based upon their performance to the goals?
11. Who are the customers? (Evaluator ask the customers if maintenance is accountable to them for product quality, rate, safety, etc.)
12. Are performance metrics used to assess levels of accountability? For example, are overdue action items tracked and trended? When a particular organization (engineering, stores, operations) has excessive overdue action items, what steps are taken to resolve?

## **10 Organization (Vertical, Process Teams, Component Ownership, Process Ownership, Fix-it-Now)**

Are performance metrics used to assess levels of accountability? For example, are overdue action items tracked and trended? When a particular organization (engineering, stores, operations) has excessive overdue action items, what steps are taken to resolve?

## **11 Leadership (Management Support)**

1. Is management committed to remaining in the generation business? Will they invest in improvements that enhance plant reliability and operations?
2. Does plant management support Predictive Maintenance philosophy?

3. Who prioritizes work associated with PDM program findings?
4. Do you perform cost benefit analysis?
5. At your plant, has PDM effected the following:
  - \_\_\_Component or plant availability?
  - \_\_\_O&M costs reductions?
  - \_\_\_Capital Expenses?
  - \_\_\_Plant heat rate reduction?
  - \_\_\_Safety or regulatory compliance?
6. How much extra cost does your company incur which your plant is not available to produce?
7. Are there incentives for plant managers who meet their goals for generation, control costs, personnel caps, others?
8. How did your current organization evolve, and do you see any changes in the near future?
9. Where does the PDM Group effort in your organization?

## **12 Global Metrics and Reporting**

1. How do you define a forced outage?
2. What is your average forced outage average rate? *All units*
3. What is the goal for average availability for the plant as a whole, or by unit?
4. Is the plant meeting goals for production? How much room is there to improvement?
5. What is your current total plant budget? Fuel? O&M Labor? Expenses?
6. Is there a line item in the budget for PDM?
7. Capital Expenditures
  - What is your typical expected payback period for investment in capital equipment?
  - How are capital expenditures justified?
  - Is there a written procedure?
  - Have there been any major capital investments for plant equipment. Are any planned?

### **13 Communication Mechanism**

1. On a scale of 1 to 10 (10 being perfect) how well does your company, within the plant and also with any central support group, communicate information regarding diagnostic testing or special testing related to a specific equipment problem?
2. On a scale of 1 to 10 \_\_\_\_DATA \_\_\_\_INFORMATION \_\_\_\_ACTION
3. Is your department involved in the process of evaluating component conditions?
4. If yes, how is this information transferred to other parts of the organization?
5. How do you make other plant personnel aware of diagnostics results?
6. Is there a standard procedure for reporting of anomalies?
7. Is the report by exception only or on all equipment tested?
8. Are there any hard copy reporting requirements? (get copy?)

### **14 Goal Setting**

1. For the plant under study, prioritize the following:
  - \_\_\_\_Availability Improvement
  - \_\_\_\_Safety
  - \_\_\_\_Equipment Life
  - \_\_\_\_Operations Management
  - \_\_\_\_Reduction of Maintenance Costs
  - \_\_\_\_Emissions Reduction
  - \_\_\_\_Heat Rate Reduction
  - \_\_\_\_Increasing Capacity
  - \_\_\_\_Reduce Start-Up Times
  - \_\_\_\_Increase Unit Ramp Rates
2. What is the plant history? Ask only if we don't already have this information.
  - Operating Profile
  - Remaining Life. Any plans for life extension?

- Availability
- Forced outage rate
- Peak EFORs
- Heat rate
- Has the plant readily met goals for production, availability, emissions, forced outage, heat rate and budget?

3. Are there any existing corporate-wide initiatives for:

\_\_\_quality improvement

\_\_\_safety

\_\_\_reliability improvements

\_\_\_problem solving

\_\_\_cost reduction

\_\_\_other personnel development.

\_\_\_emissions reduction

\_\_\_heat rate reduction

## **15 Benchmarking**

Have benchmarking activities been performed to allow a direct comparison of the organizational practices with the Best-in-Class, or at least against the standard practices within the power industry?

## **People**

### **16 Training**

1. Is the current training program adequate to meet the needs of plant Operations, Maintenance, I&C, Electrical, Engineering and Technical Staffs? What other courses should be offered?  
*(As a general Rule, power plant people (including management) think of the term “maintenance” as including only maintenance mechanics, welders, etc. The term doesn’t usually include I&C, Electricians Engineering, etc. Basically you have Operations, Maintenance and “some other folks” that are not really necessary but that are sometime nice to have around. This thinking (culture) must be altered so that there is some realization of the importance of process control to the bottom line).*

2. Do you feel you need training? If so, in what areas?
  - Program training
  - Condition monitoring technology training
  - Specific Equipment maintenance or operation training
  - Plant Process Optimization, Efficiency Improvement, Emissions Reduction Training?
3. Do you have any experience using personal computers? Would training in this area be helpful?
4. Do you feel confident in previous craft oriented training or would some refreshers help?

### **17 Utilization (Wrench Time/Multitasking/Bargaining Unit)**

1. Are you currently operating with a Multi-skilled work team?
2. How you determine who gets a work assignment?
3. How many shifts per week do the operators work?
4. How many operators per shift?
  - \_\_\_Control Room
  - \_\_\_Roving
5. Describe responsibilities of operations managers and shift supervisors.
6. Has this always been the same?
7. Is overall productivity of the workforce measured? How?
8. Is the number of jobs completed per person per shift measured? How?
9. Is the 1st Line Supervisor generally at the work site to assign and progress work performed?  
What percentage of the time (average) is the 1st Line Supervisor on the floor?
10. Does the 1st Line Supervisor assign all work to the employees? If not, who does?
11. Is the General Foreman available to assist the workers in removing roadblocks to the performance of work?
12. Are daily meetings conducted to progress work? If not, how is work progressed?
13. What performance metrics are used to assess worker productivity (schedule performance, backlogs, number of tasks completed per person per shift, etc.)

14. When work is awaiting parts, engineering drawings, special tools, etc., is there a formal method to involve Engineering? Stores? Operations? Vendors?
15. How are relations between management and the union? Is the contract flexible? Discuss specific examples (e.g., utilization of overtime, skills vs. seniority, cross-crafting, etc.)
16. Is there any effort towards better utilization of resources, such as multi-disciplined workers, cross training and assignment, specialized teams, etc.?
17. Is the customer satisfied with worker performance? Evaluator talk to customer and rank satisfaction on a scale of 1-10.
18. How is the morale of the workers? Evaluator talk to at least 5 workers from different trades and shifts and rank from 1-10.

### **18 Inter-Departmental Communication**

1. Are PDM capabilities and procedures well known among:
  - Plant management
  - Engineering staff
  - Maintenance craft
  - Operators
2. Are operators or maintenance supervisors and craft ever consulted before work orders are issued on PDM program findings?

### **19 Qualifications**

1. What is your current function in the organization?
2. How long have you held this position?
3. What is your background?
4. Are you currently operating with a Multi-skilled work team?
5. How you determine who gets a work assignment?
6. Do qualifications reside in the CMMS, /does the individual craftsman maintain a “Qual Card”?
7. Does the company operate an apprentice program?





*Target:*


## Work Process Improvement Guidelines & Techniques

### About EPRI

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

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