MINING EQUIPMENT MANAGEMENT

MAINTENANCE AND REPAIR MANAGEMENT GUIDE BOOK

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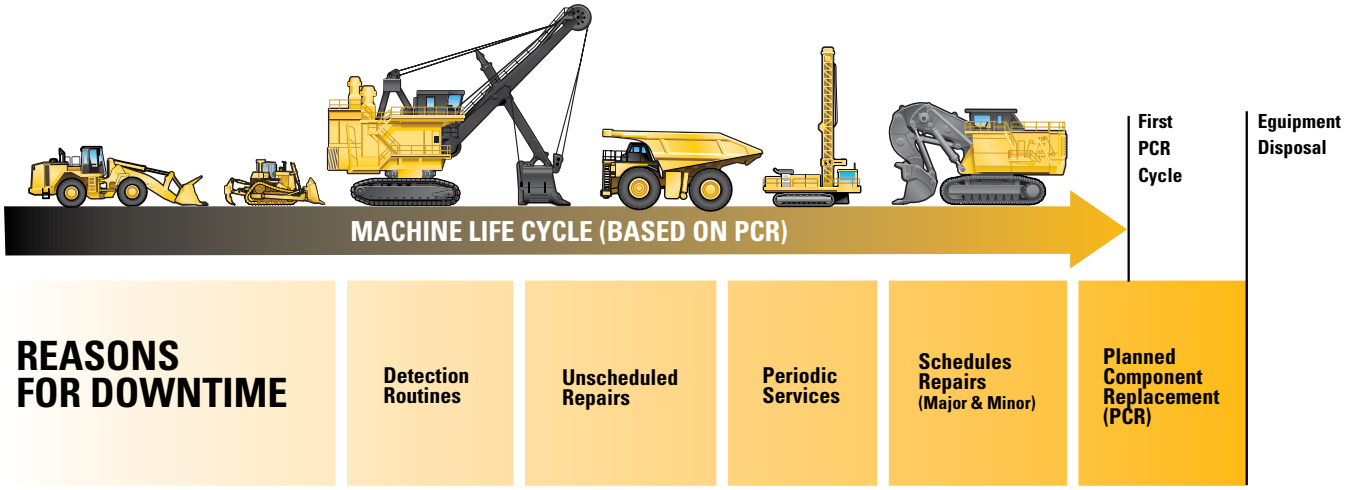
INTRODUCTION

The demanding goals of today's mining industry have motivated and reinforced a continuous search for operating efficiency in all areas of the production process. Mobile equipment plays an important role in the achievement of these goals. Their ability to perform, according to specifications, relies on three major factors: Maintenance, Design, and Application. Each of these three areas must be considered and effectively managed to optimize the productivity of equipment.

Effective maintenance organizations understand the need of well-established processes, supported by appropriate resources, and executed by skilled and well-trained personnel. The study of and partnership with these organizations has built a solid understanding of the processes and techniques that are effective, as well as those that must be identified in order to correct or avoid them.



INTRODUCTION (CONTINUED)

The key for success is a strong partnership between customers, Dealers, and the manufacturer. This maintenance model for mining mobile equipment has been developed to accomplish this goal. The model includes and lays out ten distinct maintenance processes and routines.

A proactive maintenance support system is one in which the condition and application of equipment is monitored constantly.

Maintenance events must be efficiently and effectively managed and executed, supporting the goal of "repair before failure." By identifying potential problems before failure, a mine site can avoid unscheduled downtime, productivity loss, and potentially more costly repairs.

Structuring a maintenance model that is open and flexible is imperative. Having the ability to incorporate valuable techniques and new approaches will enable success in achieving the desired result of a safer, more productive operation at a lower owning and operating cost for the customer.

MAINTENANCE SYSTEM DESCRIPTION

Key functions must be present for a successful maintenance system. These functions determine the roles and responsibilities to consider in the process of structuring organizations for on-site and off-site support. Recommended functions are grouped into five main areas: Detect – Plan – Execute – Evaluate – Correct or Improve. This reinforces the concept of a condition-based maintenance program and the search for continuous improvement based on solid evaluation of results and performance.

The five main areas are further developed into ten processes recommended in successfully supporting a mine site:

- **Preventive Maintenance**
- **Condition Monitoring**
- **Backlog Management**
- **Planning & Scheduling**
- **Parts Management**
- **Repair Management**
- **Human Resources/ Training**
- **Performance Evaluation**
- **Continuous Improvement**

EQUIPMENT FLEET RESULTS

Preventive Maintenance

Condition Monitoring

Backlog Management

Planning & Scheduling

Parts Management

M&R PROCESSES

Repair Management

Component Management

Human Resource/ Training

Performance Evaluation

Continuous Improvement

"High frequency, fixed-interval, planned activities including well-defined service routines, proactive defect detection and repair execution that support the goals of equipment reliability and availability."

Preventive Maintenance

The first function is Preventive Maintenance (PM). PM groups perform a number of activities scheduled at fixed intervals. Intervals are normally determined by oil changes and lubrication periods. These scheduled stops also represent a valuable opportunity to execute other preventive tasks, such as adjustments and minor repairs. Predictive tasks, such as inspections and condition performance tests, should also be performed during scheduled PM stops.

PM activities are the most well-known function and provide a strong platform for the execution and control of basic maintenance tasks. They are also excellent "windows of opportunity" to schedule minor repairs in parallel. Each of the activities incorporated in PM services must be fully planned and defined, including the procedures, personnel, time, tools, parts, and the consumables required.

Example of a well-designed PM bay fully "dressed" to promote efficiency and safe work. See Best Practices (BP 0607-2.9-1081) "Improved PM Operations Using

Example of dedicated tools for Preventive Maintenance.

Example of PM mandatory parts organized as kits.

"Timely and accurate detection of changes in equipment health, operation, and application severity in support of a "repair before failure" maintenance strategy."

Condition Monitoring

Active and complete condition monitoring, along with a good backlog / follow-up systems and effective execution of the repairs before failure are the key elements to maintain running machines. There are often many different types of machine inspections and condition monitoring routines and disciplines. These routines complement one another and each provides part of the total picture of machine condition.

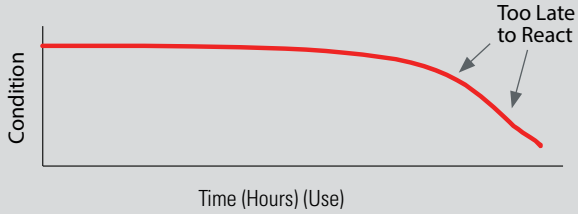
Condition Monitoring routines to consider are:

- **Equipment Inspections**
- **Fluid Analysis**
- **Electronic Machine Data**
- **Site Conditions / Application**
- **Repair History & Backlog**

The main objective of these routines is early detection of symptoms associated with a potential or hidden failure. They can also indicate changes in machine application that may require correction in the operation or maintenance strategy of the equipment.

Once a problem is detected, an action plan is developed and submitted to Planning to schedule a repair before failure or provide operator training, as well as potentially adjust the maintenance strategy for a machine.

Optimum Detection Time

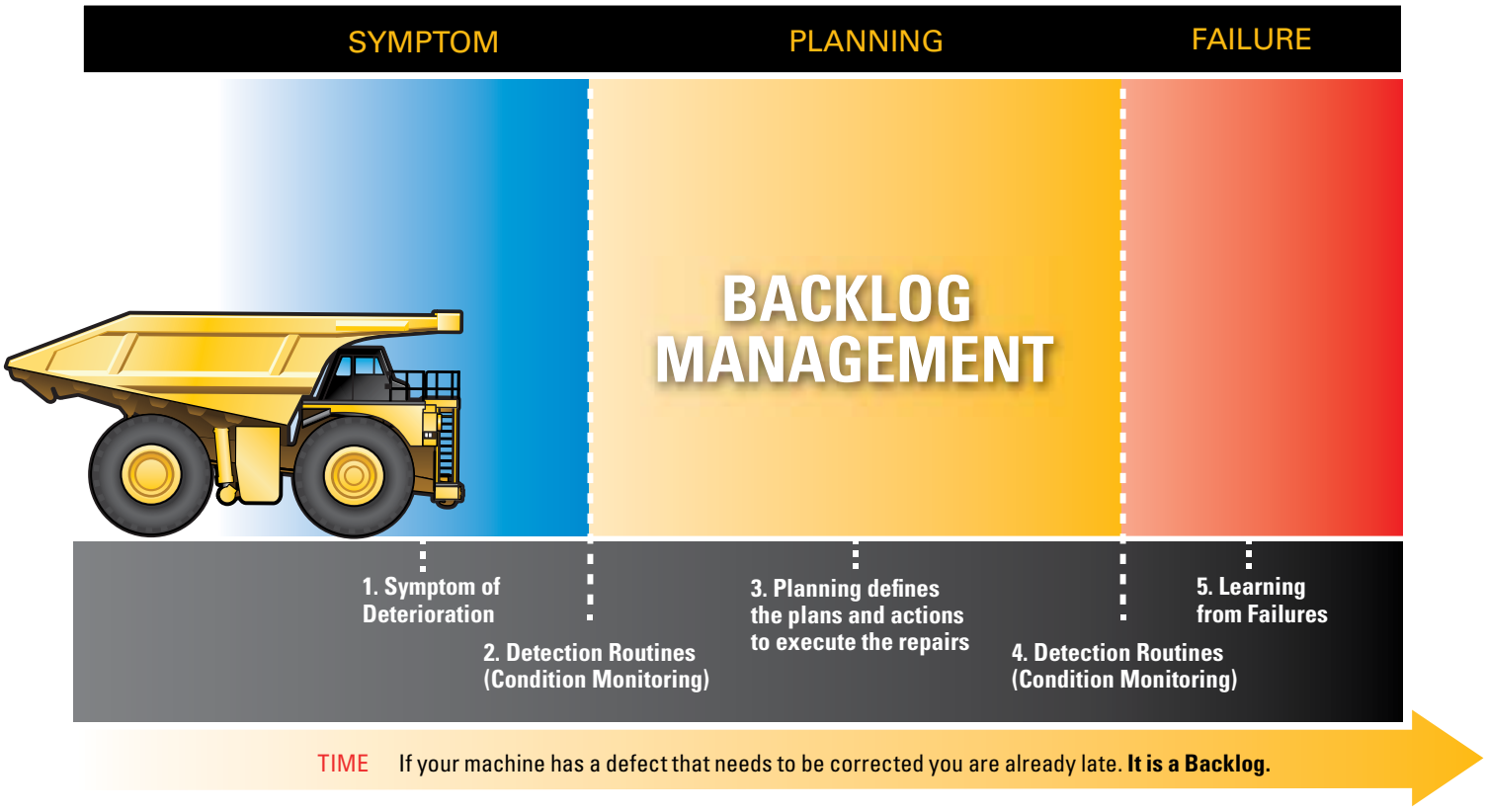


"It is a Planning function that is designed to effectively manage the pending "To Do List" to schedule the repairs/corrections before failure."

Backlog Management

Backlog Management is also key to a good equipment maintenance system. If the effort that goes into condition monitoring does not result in a high percentage of planned and scheduled repairs, the resulting reliability, costs, and availability will be adversely affected, along with disrupted planning and scheduling routines.

In mining equipment management, we define backlog as the defect / work that has been detected and the corrective action can be deferred to a convenient window of opportunity. In this way, we empower backlog management to be a powerful tool to proactively work in failure prevention.



"The brain of your operation...
It plays a critical role in achieving the goal of 80% scheduled events."

Planning and Scheduling

A "repair before failure" philosophy and a high percentage of planned and scheduled repairs (benchmark - 80%) should be the foundation of the overall repair strategy. The Planning and Scheduling function plays a critical role in achieving these goals, and should be carefully considered when structuring on-site operations. Planning and Scheduling defines and gathers necessary fleet equipment information and transforms it into clear and effective plans and activities, including the scheduling of execution and controlling results.

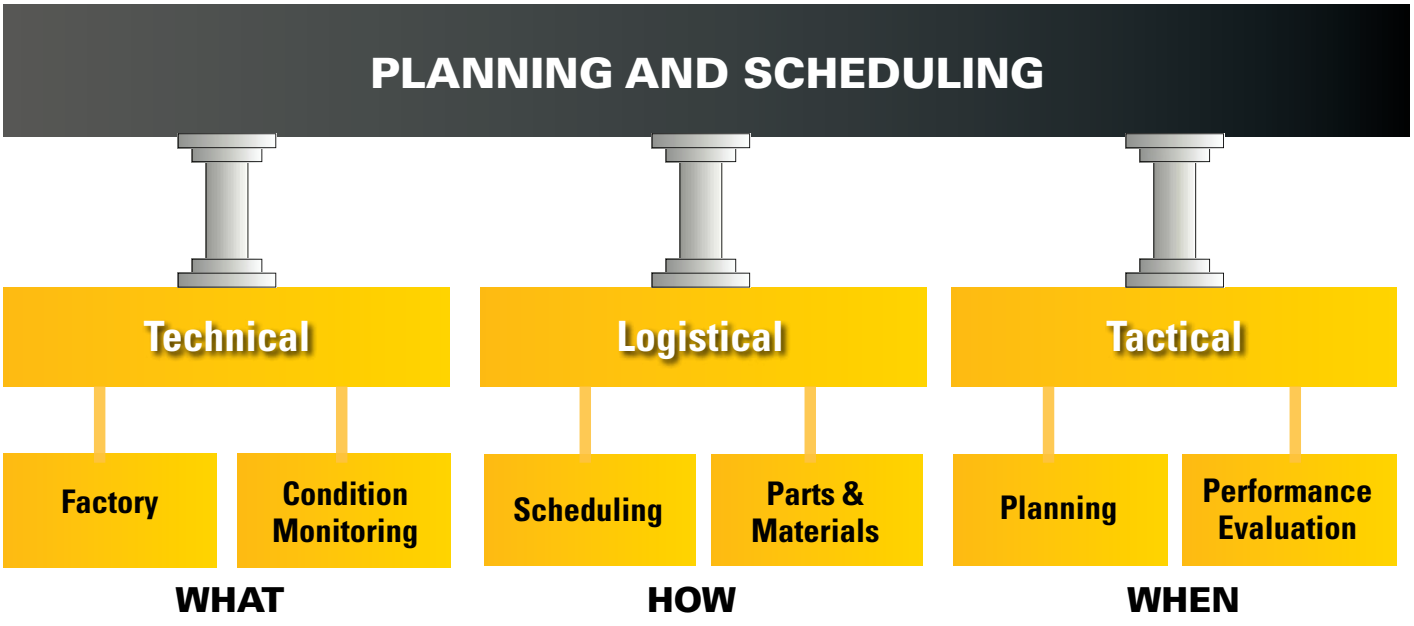
Planning defines and establishes plans, and forecasts activities and how they will happen — including special resources and parts needed, labor requirements and shop space. These plans are then forwarded to Scheduling to coordinate with the repair centers and determine the best execution dates.

Planning and Scheduling are involved in the five types of machine stoppages in the life cycle of equipment:

- **Periodic services**
- **Planned component replacement (PCR)**
- **Major and minor repairs**
- **Detection routines**
- **Unscheduled events**

Planning and Scheduling are involved in all five types of machine stoppages in the life cycle of equipment. These are periodic services, planned component replacement, major and minor repairs, detection routines, and unscheduled events.

Effective Planning and Scheduling ultimately achieves a balance between maintenance and repair activities that need to be done and resources and overall fleet availability.



"An essential logistical function, the ultimate goal… Deliver Parts at the Right Time, in the Right Quantity and at the Right Location."

Parts Management

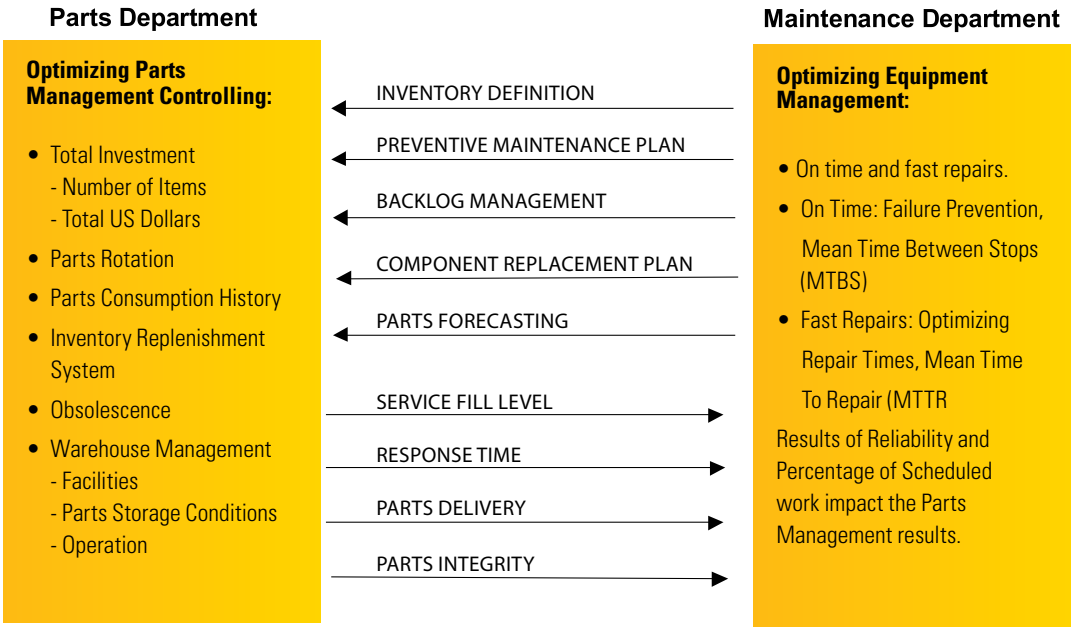
"Having the Right Part in the Right Quantity and at the Right Time" is probably one of the most commonly used phrases when maintenance people refer to the function of the Parts Department. Achieving this ideal scenario requires strong and clear communications between the Parts and the Maintenance Departments.

Accurate and complete parts demand history, and a well-supported forecast of future needs, are key elements the Maintenance Department must provide to the Parts Department in order to define, implement, and maintain correct on-site parts support. Parts and Maintenance Departments, through the planning and service groups, need to coordinate activities and share information related to all repairs, repair plans, and parts logistics.

Based on the information provided by the Maintenance Department, the Parts Department must design and implement the required functionalities, both on-site and off-site.

Elements to consider in the implementation of Parts Management are:

- **Parts supply channels/sources**
- **Communications**
- **Specialized labor (HR)**
- **Management support tools**
- **Facilities**
- **Inventory (parts and components)**
- **Backlog parts**
- **Working procedures**
- **Performance evaluation**



Fleet Goals achieved in the most cost effective manner.

Parts Management (Continued)

The on-site storage of parts and components represents a challenge in terms of facilities and parts integrity preservation. Parts and components are expensive and must be in perfect condition when needed. Contamination control practices must be fully observed.

It is important to consider the level-of-control of fleet maintenance and repair activities, which as a significant impact on the performance results of parts support. Measuring the "Percentage of Scheduled Downtime" provides an indication of the control over the M&R activities of your fleet.

*"Components are key cost drivers…
they must be managed efficiently and effectively."*

Component Management

Components are key cost drivers. Success in managing them (achieving expected life cycle and operational cost) is critical in meeting maintenance and production cost (cost/ton) of the equipment. While relatively small and frequent repairs primarily affect availability, operational cost is directly affected by major repairs, especially components. As a result, a separate process in the model is dedicated to Component Management. Within this process, there are stages and critical activities to consider:

- **Acquire/define component life goals**
- **Define component strategy**
- **Determine component inventory (protective and normal PCR)**
- **Define R&I parts kits and incorporate into the inventory**
- **Commission new machine components to establish performance baseline**
- **Implement an effective component tracking system.**
- **Define and execute adequate PMs**
- **Execute in-frame repairs as needed**
- **Keep components clean; observe oil and fluid cleanliness specifications**
- **Condition Monitoring**
  - Track component health and application
  - Incorporate CM input into short-term (condition) and medium/long-term plans (target life projections)
- **Establish PCR forecasts (medium and long term)**
- **Planning and Scheduling**
  - Standard jobs
  - Backlog execution goals
  - Incorporate PCR into maintenance and repair plans
- **Define and apply pre-PCR inspections**
- **Follow recommended removal and installation (R&I) procedures**
- **Establish a performance baseline for all components installed in the machine**
- **Maintain consistent communication with repair centers**
  - Submit accurate, complete, and timely information regarding components removed
  - Acquire and receive information of the components to install.
  - Learn from failures; perform wear analysis
- **Produce and keep accurate records**
- **Evaluate performance of components and all steps of the process**
- **Apply immediate corrections to problems or pursue solutions through Continuous Improvement**

"Adequate resources organized and managed to perform efficient & effective repairs."

Repair Management

Repair Management is dedicated to the execution of all maintenance activities on the equipment. These activities can be planned or unscheduled, requiring appropriate preparation from the on-site organization in terms of resources and skills to respond adequately.

The shop and the field are two distinct service areas that Repair Management must consider in a mining operation. The nature of the services performed in these two areas must be considered when organizing support by developing and assigning specialized personel.

FIELD SERVICE
is the first line of support for the equipment fleet operation. Primary responsibilities include:

- **Responding to unscheduled calls as the first line of customer support**
- **Quickly diagnosing the problem and defining actions for repair**
- **Repairing immediately in the field, or sending equipment to the repair shop as needed**
- **Assisting with the coordination of the machines scheduled for repairs/maintenance**
- **Coordinating all work in the field, such as lube, tires, third parties, inspections, etc.**
- **Performing and reporting constant application – operation observations.**

The nature of the services performed in the field and the performance of Field Service directly influence Mean Time Between Stops (MTBS) results.

REPAIR SHOP
The repair shop is dedicated to scheduled repairs, including PMs and PCRs, and unscheduled repairs that cannot be performed in the field because of time, resource, or contamination control reasons.

Shop service responsibilities include:

- **Execution of scheduled activities**
  - PMs
  - PCRs
  - Major and minor scheduled repairs
- **Execution of unscheduled repairs**
- **Coordination of all on-site repair centers, such as Tire, Welding, Communications, etc.**
- **Monitor and support Field Service**
- **Primary area for providing planned availability.**

Adequate resources, both in quantity and skill, organized effectively, and equipped with the right tools and facilities, are critical contributing areas to performance results for Repair Management.

"People…the most valuable asset to a company."

Human Resources/Training

The scope of operation, mine production goals, and the maintenance strategy are the starting points for defining the required on-site organization. The functions to be performed dictate the quantity and characteristics of the personnel required. Defining the organization is the first step. Ask this question. What is necessary, in terms of the number of people and the skills required, in order to perform the job and meet expected goals?

The key to success is having the right people, in quantity and skill, organized effectively to execute specific routines and functions, and who share a common goal.

Every person in the organization brings a set of values, personal goals, and abilities developed from past experience and education. This represents the first challenge. Develope a skills/competencies inventory. Assign the correct person to the appropriate function or role in the organization. Start managing resources and logistics to ensure this team of people can work to their maximum abilities. Major areas to concider are:

- **Maintenance organization**
- **Roles and responsibilities**
- **Competencies**
- **Personnel recruiting**
- **Outsourcing**
- **Personnel career management**
  - Skills/competencies
  - Additional training needs
  - Leadership development
  - Performance evaluation
- **Labor management**
- **Benefits and compensations**
- **HR logistics**
- **Personnel retention and succession**
- **Company regulations compliance**

The integration of Human Resources with the other on-site areas (Planning, Shop, Field, Administrative, etc.) is critical in understanding the needs and providing adequate support for an effective operation.

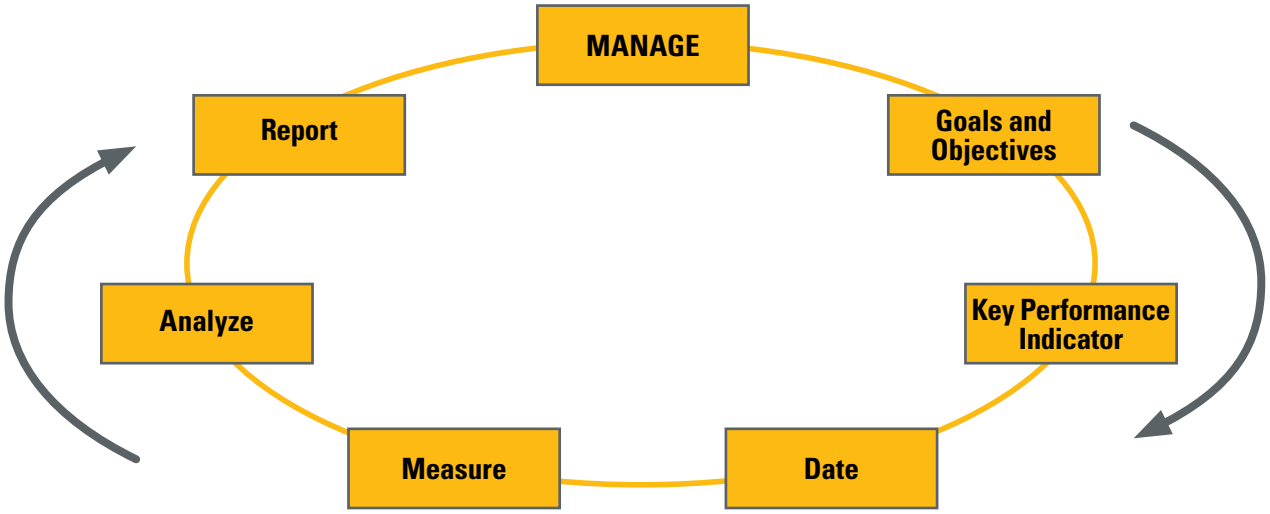
Performance Evaluation

Effective management requires measuring performance, comparing results with targets and goals, discovering problems or substandard areas and focusing prioritized actions to improve, correct, or ensure sustainability of gains already obtained.

Performance Evaluation is the recommended process used to encourage the disciplined analysis of information generated by on-site operations.

- **Define the desired outcome (What are we here for?)**
- **Define goals, objectives, and targets**
- **Select and define the Key Performance Indicators (KPIs) to use**
- **Establish information required to generate KPIs**
- **Review, design, and implement the data collection process**
- **Design reports and distribution network**
- **Establish interpretation guidelines**
- **Gather accurate information**
- **Calculate KPI results and generate necessary reports**
- **Analyze and interpret results**
- **Distribute results and reports**
- **Identify corrections, improvements, and management actions**

Managing without solid information and meaningful management metrics is managing by intuition.



Continuous Improvement

Continuous Improvement (CI) is the logical final function. After measuring and detecting areas of opportunity, the entire organization must be involved in the search for solutions. A formal and organized approach is needed to guide the organization and keep them on track and focused on the critical areas of opportunities.

There are many Continuous Improvement methodologies available from which to choose, adopt, and adapt to specific site characteristics. The methodology of "6 Sigma" is a systematic approach to find the root cause of problems and identify the incremental improvements to implement.

Major steps to observe in implementation of this approach include:

- **Identify opportunities**
- **Determine impact, return on investment, prioritize, select**
- **Assign projects**
  - **Select team members**
  - **Form teams**
- **Define problem, scope, and outcomes**
- **Conduct CI meetings**
  - **Measure**
  - **Analyze**
  - **Document**
- **Identify solution/improvement**
  - **Define solution**
  - **Develop implementation/operation procedures**
- **Present solution to process owners**
  - **Discuss solution(s)**
  - **Train the process owners in the proposed improvement**
- **Implement**
  - **Follow up implementation**
- **Follow up results**
  - **Measure**
  - **Analyze**
  - **Document**
- **Validate solution or recycle to CI process/team**
- **Communicate results**

The process must be monitored and overall results measured to ensure sustainability and the most effective return on investment.

Continuous Improvement should be a series of ongoing efforts. It is an ongoing journey that will continue throughout the life of the maintenance organization.

The implementation of the ten recommended processes will allow you to take control of the maintenance operation. This is the key for successful management of the site. Review and assess operations. Determine if the recommended functions are in place and performing as expected. Identify gaps and opportunities, and implement improvements as needed. Measure the end results.

IMPLEMENTATION STEPS

1. EVALUATE CURRENT ON-SITE MAINTENANCE OPERATIONS.

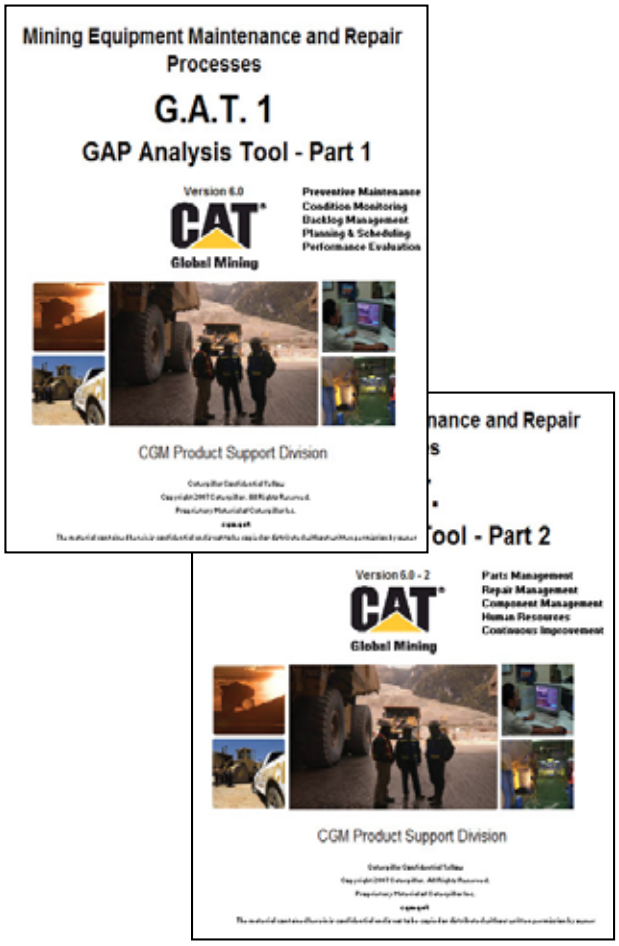
Apply Gap Analysis Tool (GAT) – available through Global Mining Product Support. The GAT is a survey dedicated to evaluating the ten processes recommended by Caterpillar Global Mining.

Establish the "As Is" situation, by performing two distinct activities:

- Determine the Process Flow Diagrams of all the processes implemented on-site.
- Based on the observations guided by the GAT tool and the on-site investigation, document the current processes.

Measure current performance results and document for future reference. Apply the metrics recommended in the Caterpillar Global Mining document "METRICS (KPIs) TO ASSESS PROCESS PERFORMANCE", which can be obtained from a Caterpillar Mining Equipment Management consultant.

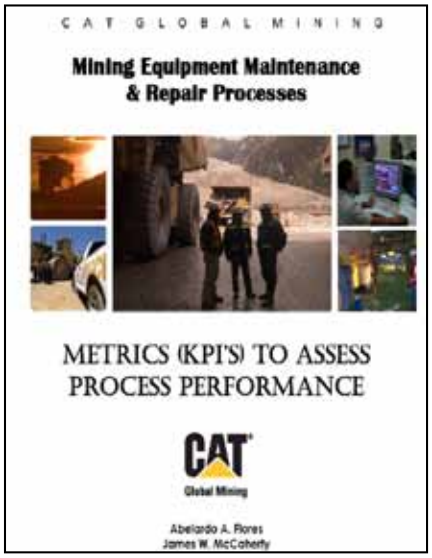
Determine areas of opportunity.



2. PROJECT DEFINITION

It is important to develope a clear Project Charter to document 6 important areas:

- Business Case
- Opportunity Statement
- Goal Statement
- Project Scope
- Project Plan (Timeline)
- Project Team



IMPLEMENTATION STEPS (CONTINUED)

3. IMPLEMENTATION PLAN

Document findings. The 3W (what, who, when) form is recommended to record findings and opportunities.

Devise and document solutions to improve or correct weaknesses. Use related BPs to support the search for ideas and solutions. Use a separate column on the 3W form to record solutions and actions to be taken.

Analyze and determine resources needed, time to implement and expected benefits.

Prioritize implementation of the different actions based on Return-On-Investment (ROI) results.

Assign responsibilities and expected completion dates for each activity.

Get "Buy-In" (acceptance) from the on-site organization.

It is important to get the buy-in of the on-site organization. They are the ultimate process owners of the maintenance and repair strategy. Present the action plan, implementation strategy and expected benefits. Involve them in the implementation of solutions and plan in-depth training for all involved personnel.

Approve the plan and start implementation

4. PROJECT MANAGEMENT

Progress Tracking

- Follow up the implementation of the action plan.
- Set up check points.
- Review compliance of completion dates for tasks.
- Receive and analyze work progress from the responsible personnel.
- Reinforce positive results.
- Identify and eliminate threats and obstacles.
- Support ownership of the on-site organization.
- Support the positive change of personnel and correct negative attitudes or oppositions.
- Make adjustments as needed.

Validation & Reports

Validate the progress and communicate results to the implementation team, process owners, process operators and all stakeholders.

Corrective Actions

Apply corrective actions if needed to ensure progress of the implementation.

5. FINAL VALIDATION

The final validation of the project includes two important actions. The first is the validation of the accurate execution of the implemented process(es); the second is the measurement of the results and impact on the goals of the maintenance and repair operation.

SUMMARY

The recommended maintenance and repair model presented here is a result of years of analysis and the observation of many different mining operations. This includes more than fourteen years of collecting and collaborating on dealer best practises. Effective organizations were studied, as well as those that needed help to improve. With the understanding of "what works and what doesn't," the foundational elements of the proposed system were established.

The successful implementation and management of the proposed maintenance system model is based on critical functions that must be performed. There are a wide variety of mining operations with different characteristics in size, complexity, equipment, geography, and more. These variations determine the type of organization and resources that will be assigned to execute and control the work on-site. The final structure of the organization is not the main concern. It is the implementation and execution of specific functions, functions that must be implemented and managed to ensure the effectiveness of the system

We are confident the implementation of the processes presented here, and the disciplined execution of the involved tasks, will help in gaining control of the maintenance operation.

You are in control and can guide the organization in the direction defined by the maintenance strategy, and ultimately, the production plan of the mine.

The final contribution of a consistent and effective maintenance system is to support safe and productive operations of the mining equipment at the lowest possible cost per ton.

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