Section VIII: Maintenance Management System

Introduction

Phase II, an examination and evaluation of the organization's maintenance management system (MMS). The MMS is a closed-loop workflow process as illustrated below:

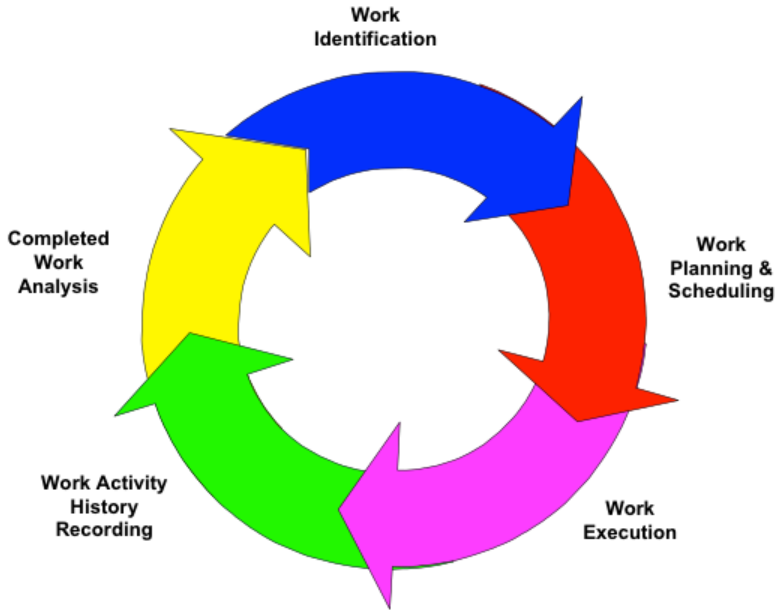


Figure 11: MMS Workflow

Computerized Maintenance Management System (CMMS) Essential Elements

To properly evaluate an organization's CMMS, the essential elements of the system must be reviewed. The generally accepted essential elements include:

- Address all resources involved
- Maintain maintenance inventory
- Record and maintain work history
- Include work tasks and frequencies
- Accommodate all methods of work accomplishment
- Effectively interface and communicate with related and supporting systems ranging from work generation through work performance and evaluation.
- Support each customer's mission
- Ensure communication with each customer
- Provide feedback information for analysis
- Reduce costs through effective maintenance planning

Work Order Management System

The evaluation of the General Services' facilities maintenance work order system was based on standard industry practices and recent discussion of facility maintenance plans key members of the management team.

In general, the maintenance work order system is the tool set for managing the identification, evaluation, assignment, tracking, completion, costing, and recording of planned and unplanned maintenance related activities.

A typical work order management system should address the "who, what where, when, why, and how" of planned and unplanned maintenance activities. To translate the "5-W's and 1-H" a maintenance work order will typically provide a data field for:

- The work order number
- An item description
- The periodicity, (daily, weekly, monthly, etc.)
- The location (of the work)
- Date the work order was issued
- Work requestor (name, contact information)
- Work priority, including the date the work is required to be complete
- Estimated work duration, cost materials
- Work assignment information
- Work approval information

Corresponding to the work order are the work instructions. Work instructions can be part of the work order, or issued as a standing separate document. Typically, work instructions are significantly more static than a work order.

The work instruction document should address the proverbial "who, what where, when, why, and how" of maintenance activities. To translate the "5-W's and 1-H" a maintenance work instruction document will have:

- An item description
- The periodicity, (daily, weekly, monthly, etc.)
- The location (of the work or equipment)
- Date and revisions of the work instructions
- Standing ES&H instructions
- Specific ES&H instructions
- Estimated work duration, cost materials
- Work steps
- Work instruction approval information

A General Model for the Work Instruction

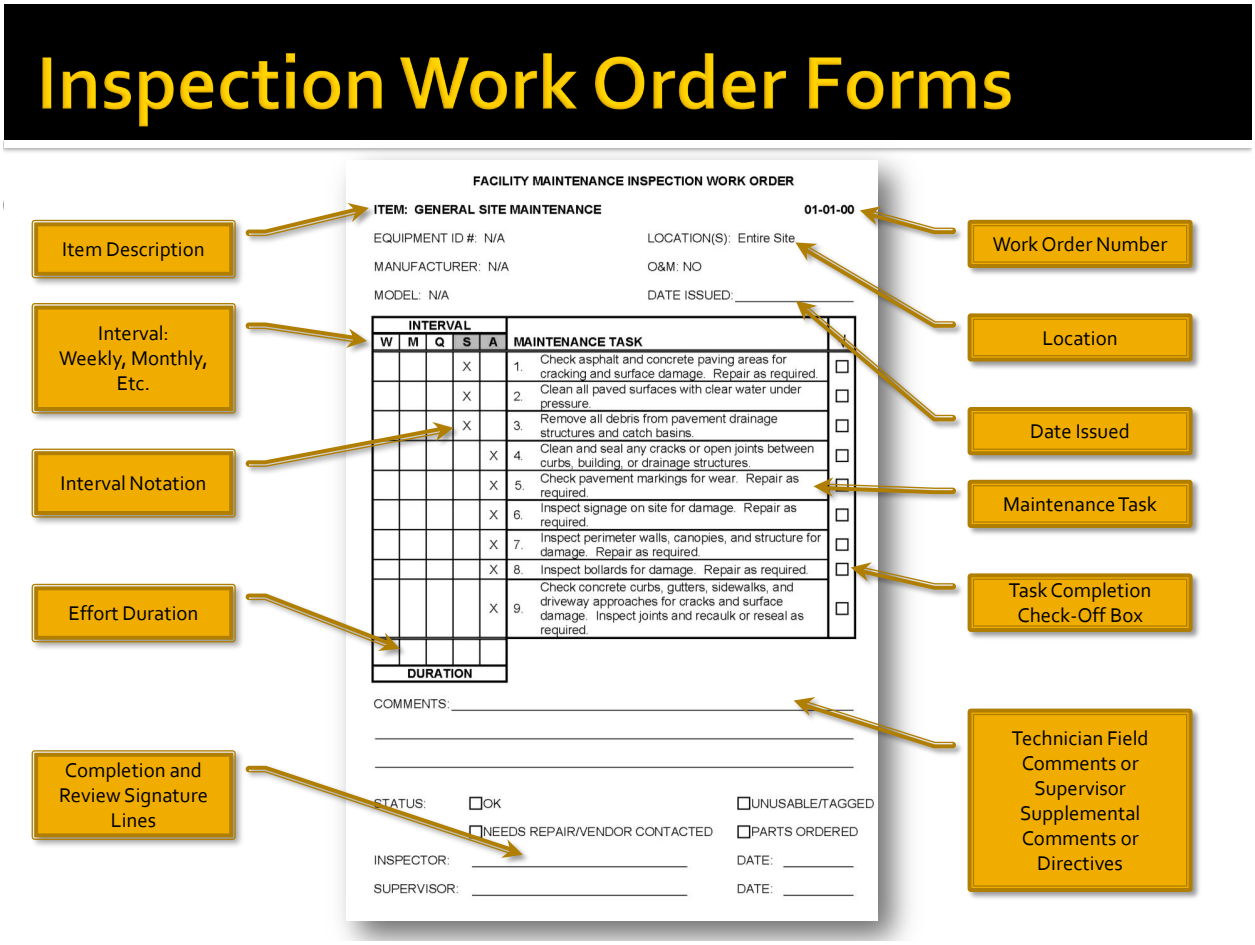


Figure 12: Work Order Model

Facility maintenance work orders are typically one of four types. The typical types of work orders include:

- Inspection
- Administrative
- Scheduled maintenance
- Repair.

Less typical in the maintenance operation are:

- Audio visual support
- Janitorial services

Regardless of the specific type of work order, each work order should address seven steps in a correct work order instruction.

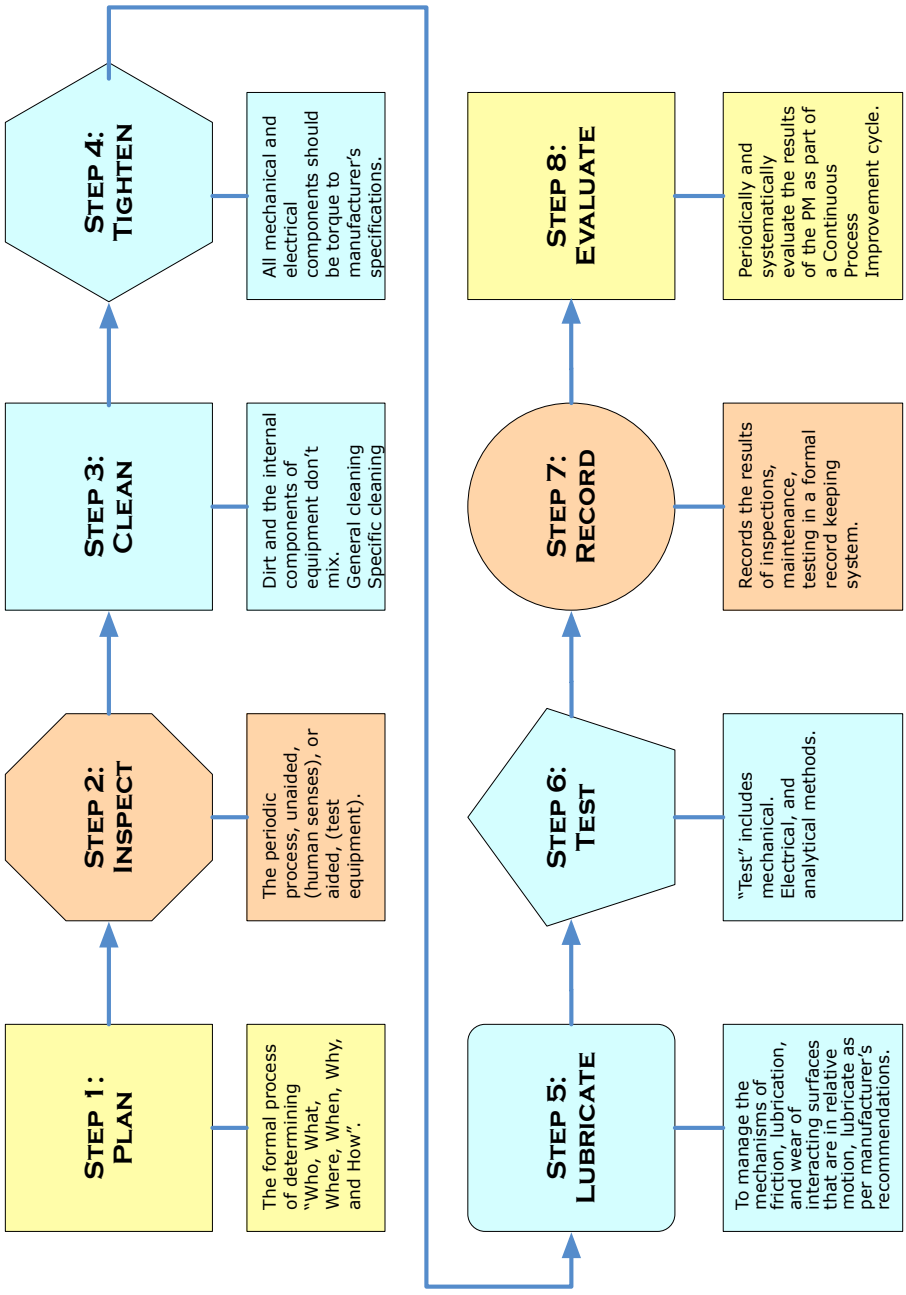


Figure 13: maintenance Steps

Maintenance Management Maturity Model

An operations and maintenance (O&M) program determines to a large degree how well a facility (building) lives up to its' design intent. The comprehensive facility operations maintenance maturity model (MMM) is a useful method for determining how effective that program is, what might be lacking, and for benchmarking performance to drive continuous improvement throughout the life cycle of the facility.

This understanding enables on-going concrete actions that make the facility a safer more reliable, and operationally more efficient.

The MMM uses as the "yardstick" the 14-element approach identified generally in Figure 3, and more specifically in Table 3

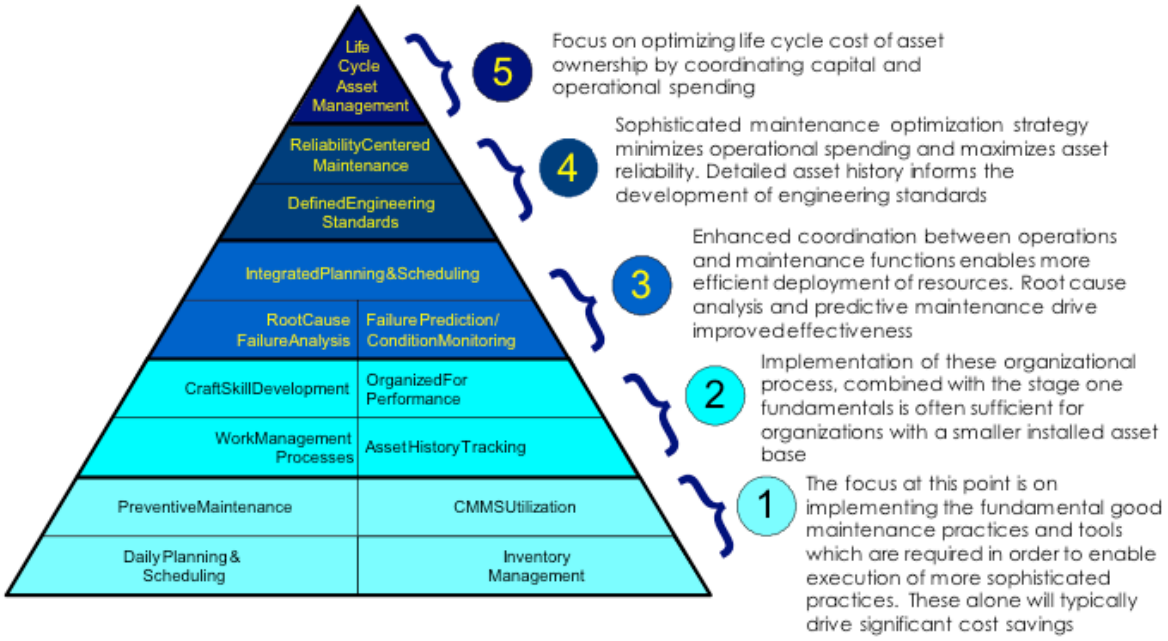
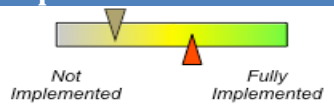
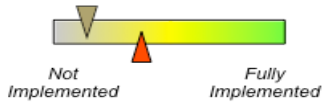
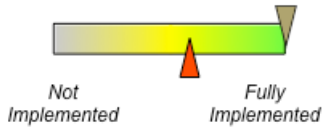
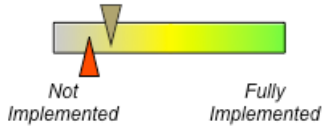
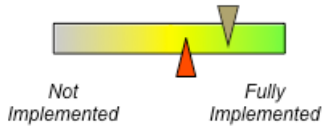
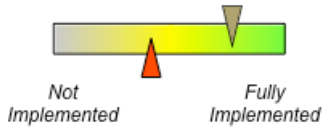
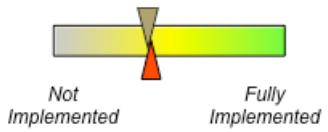
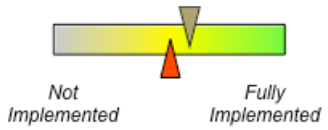
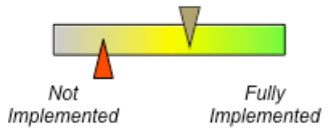
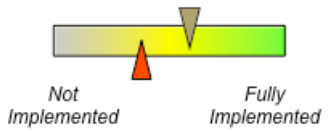
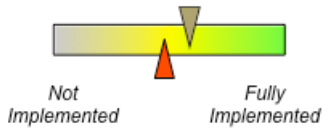
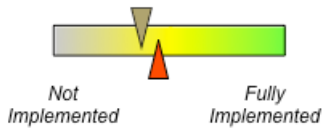


Figure 14: Maintenance Maturity Model

Each graphic uses a horizontal bar with an upper carrot and lower carrot. The upper carrot (gray) is the benchmark for the MMM element, and the lower carrot (red) is the evaluated implementation.

General Services: Maintenance Maturity Model; Summary

Element No.	Maturity Element	Graphical Evaluation
1	Daily Planning and Scheduling	
2	Inventory Management	
3	Preventive Maintenance	
4	CMMS Utilization	
5	Work Management Processes	
6	Asset History Tracking	
7	Craft Skill Development	
8	Organized for Performance	
9	Root Cause Failure Analysis	
10	Failure Prediction and Condition Monitoring	
11	Integrated Planning and Scheduling	
12	Defined Engineering Standards	

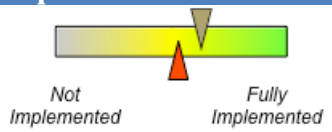
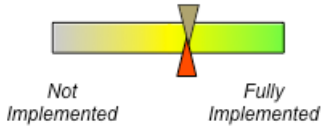
Element No.	Maturity Element	Graphical Evaluation
13	Reliability Centered Maintenance	
14	Life Cycle Asset Management	

Figure 15: General Services MMM Summary

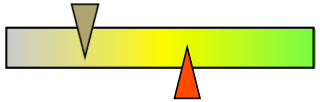
General Services: Maintenance Maturity Model; The Detail

For each Division, (General Services and Community Services, Jorgensen uses a maintenance maturity model presenting the fourteen evaluation elements in a pyramid structure.

The detail evaluation for the general Service organization is presented on the following pages:

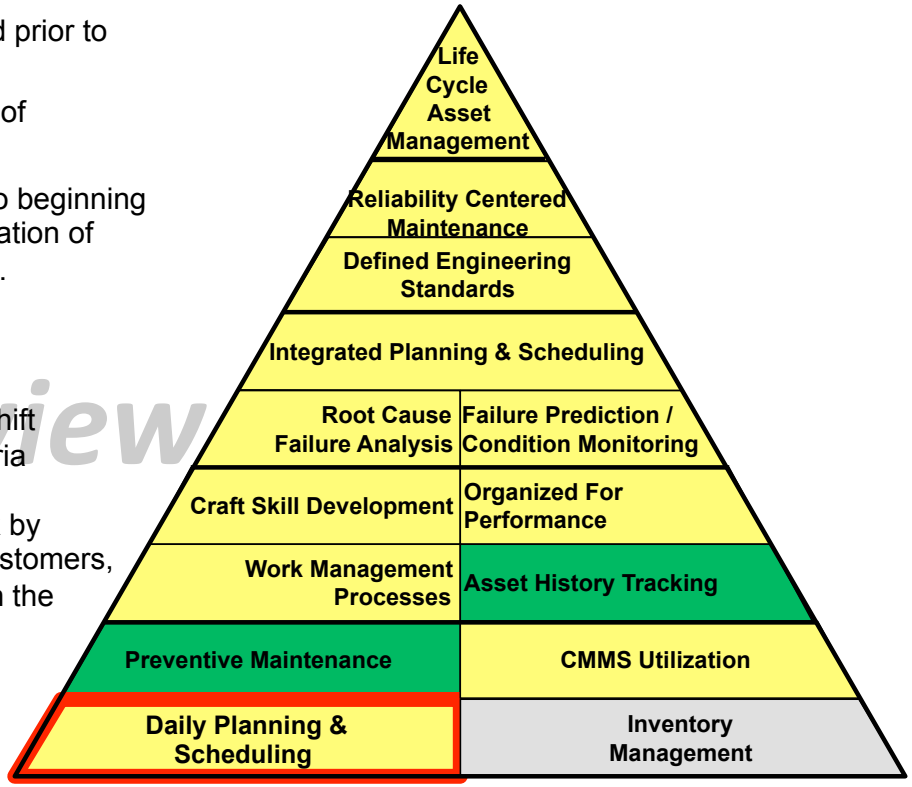
The MMM evaluation for Community Services (Parks and Recreation) follows the General Services evaluation.

Daily Planning & Scheduling



Not Implemented — *Fully Implemented*

Level 5 (Best in Class)	• Daily work schedule is created prior to beginning of work shift • Schedule targets 110 – 120% of expected workload
Level 4	• Daily Schedule created prior to beginning of work shift based on prioritization of outstanding work requests (i.e. emergency, urgent, routine).
Level 3	• Work is assigned by priority • Work is prioritized at start of shift using some independent criteria
Level 2	• Employees are assigned work by supervisor as requested by customers, or on an ad hoc basis, through the course of the workday.
Level 1	• Daily schedule is not created • No systematic method of prioritizing work exists.



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Daily Planning & Scheduling Defined

Planning and Scheduling

Although often discussed together, planning & scheduling are two distinctly different processes.

Planning: *The preparatory work given to individual maintenance work orders before assigning them to specific craft persons for work execution. This preparatory work, when properly done, greatly increases maintenance productivity. After someone requests work to be done, a planner plans the work order by specifying job scope, craft, skill level, and time estimate, as well as specifying anticipated parts and tools. The planner does not necessarily specify a detailed procedure. By including skill levels and time estimates on jobs scheduling can assign the proper amount of work to the crews*

Scheduling: *This refers to the resources assigned to and the timing of individual work orders. Typically A Scheduler develops a 1-week schedule for each crew based on a craft hours available forecast that shows highest skill levels available, job priorities, and information from job plans. Consideration is also made of multiple jobs on the same equipment or system and of proactive versus reactive work*

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Daily Planning & Scheduling Observations

General Services

- ▲ Work is generally assigned by craft type (electricians, HVAC, etc.)
- ▲ General Services (GS) is very customer focused and responds quickly to customer requests
- ▲ The facility service center has a formal work prioritization process for assigning priorities
- ▲ GS has a high completion rate for planned tasks
- ▲ Supervisors have a good sense of what work needs to be done and the priority of the work
- ▶ SBC employee customer calls are frequent and a very quick response is expected in most cases interrupting daily work routines
- ▶ The squeaky wheel definitely gets attention. There are "direct call" numbers for going around the facility service center directly to the facility service center supervisor
- ▶ The technicians and supervisors do not focus on the assigned priority of the work
- ▼ GS does not use a formalized system base schedule. Work such as PMs are planned but they are not scheduled
- ▼ Work is not scheduled based on craft, parts or equipment availability
- ▼ GS craftsmen often have to leave jobs to attend to call outs
- ▼ No consistent structured process for setting and defining daily schedules

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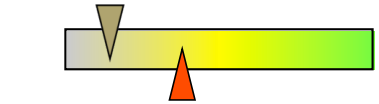
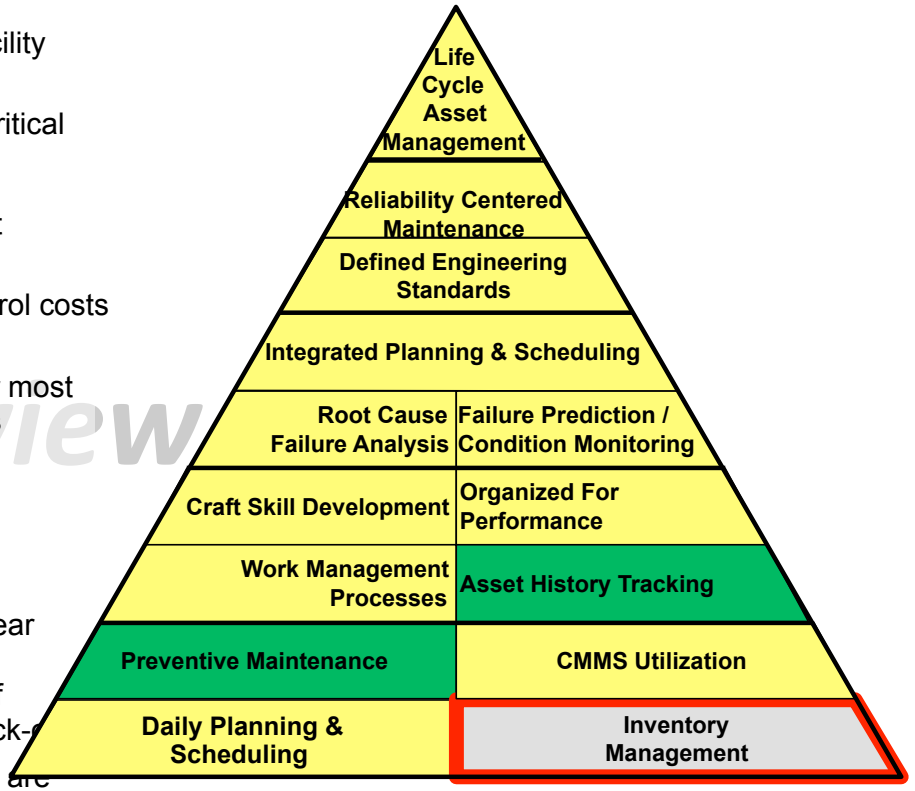
Inventory Management



Level 5 (Best in Class)	• Stock accounts for <0.5% of facility replacement value • Separate Stock-out targets for critical spares and non-critical spares
Level 4	• Inventory ordering based on part criticality • Use Just-in-Time models to control costs
Level 3	• Minimum order quantities set for most parts with computerized controls • 1 – 1.5 inventory turns per year
Level 2	• Centralized tracking of inventory • Some private Stashes • Less than 1 inventory turn per year
Level 1	• No central monitoring/tracking of inventory – parts ordered by stock-o • Unofficial "stashes" of inventory are common



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Inventory Management Observations

General Services

- ▲ GS Staff works to negotiate best pricing for commodity parts
- ▼ There is no controlled parts stock room
- ▼ There is no centralized purchasing of M&O parts
- ▼ Spare parts are not tracked using a CMMS system
- ▼ Not leveraging the capabilities of CMMS to automate parts ordering
- ▼ Verbal confirmation only of order acceptance. No proactive notification of parts arrival.
- ▼ Supervisors and technicians cannot electronically check parts availability – this can particularly hamper productivity when the stores and shops are not co-located.

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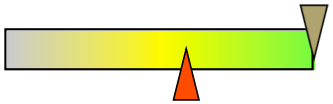
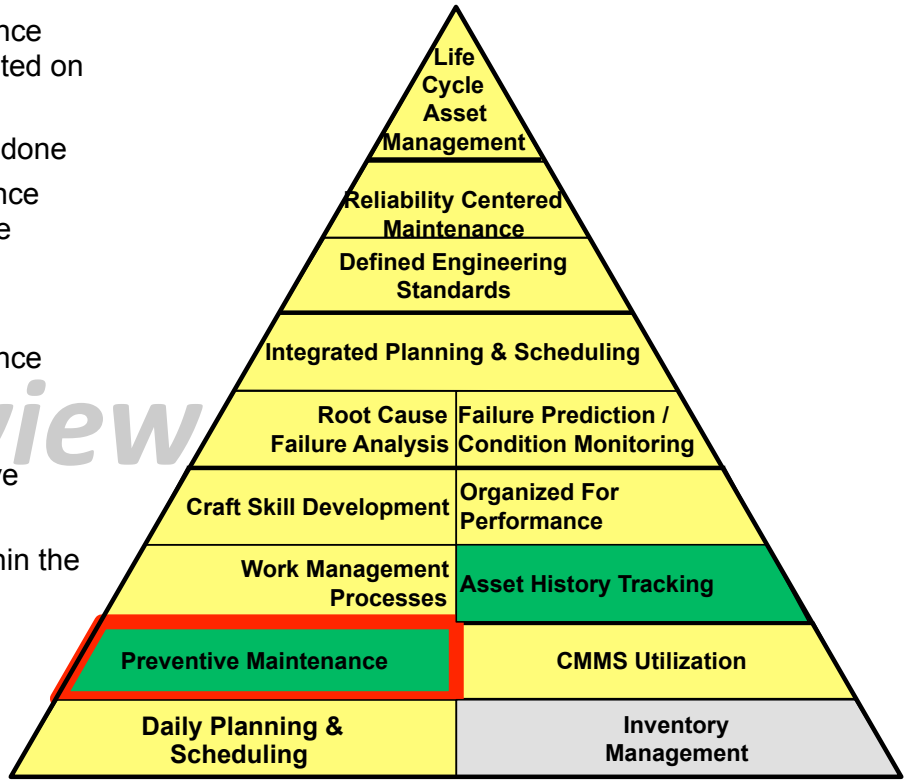
Preventative Maintenance



Level 5 (Best in Class)	• Formal preventative maintenance program is reviewed and updated on a regular basis • Documented basis for al work done
Level 4	• Formal preventative maintenance optimization processes in place • Asset criticality, age, and cost performance are all measured
Level 3	• Formal preventative maintenance program in place • Highest priority asides from emergency work is preventative
Level 2	• Preventative maintenance is performance, although not within the context of a site preventative maintenance program
Level 1	• No preventative or predictive maintenance is performed • Only breakdown and corrective maintenance



Preventive Maintenance (PM) Defined

Preventive Maintenance

Probably the most commonly used term in discussions concerning the operations and maintenance of a facility.

Preventive Maintenance or PM are maintenance tasks conducted at regular scheduled intervals based on average statistical or anticipated nominal lifetimes to avoid failure.

PM tasks may include inspection, with or without disassembly, services, and or replacement.

Task intervals may be scheduled by calendar or operating time or cycles.

PM tasks scheduled on a calendar typically consist of Daily, Weekly, Monthly, Quarterly, Semi-annual, and Annual plans. Annual plans beyond one year are typically presented as 2-year (2YP), 5-year (5YP) and so on plans.

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Preventative Maintenance Observations

General Services

- ▲ GS has a very strong PM program, (for equipment in the asset inventory), most of the BIC practices have been implemented in this area
- ▲ PM's are given a high priority by the organization
- ▶ The window for completion for PM's is very wide which leads to skewing the % complete number high
- ▶ PM's are not always closed out in the system when they are completed
- ▶ PM performance against planned schedule not well known by supervisors and technicians
- ▼ PM routines not typically printed and included with work orders. Mechanics perform most preventive maintenance routines from memory

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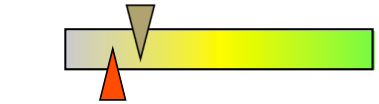
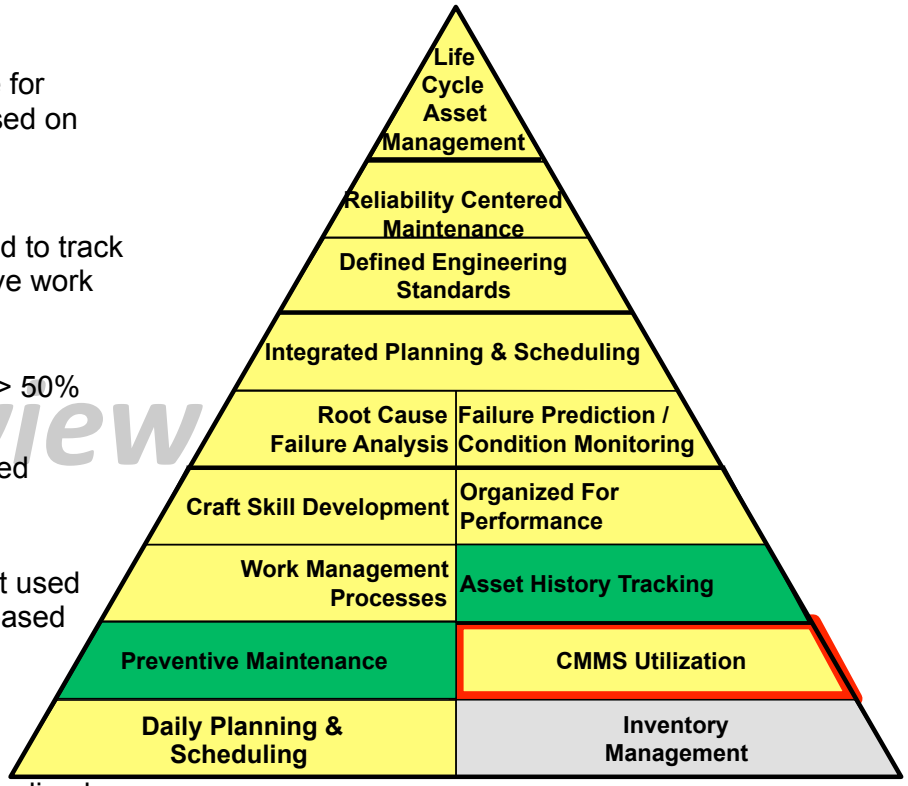
CMMS Utilization



Level 5 (Best in Class)	• CMMS system fully responsible for daily planning & scheduling based on inventory, asset criticality, etc.
Level 4	• CMMS system fully implemented to track preventative as well as corrective work orders
Level 3	• Computerized system handles > 50% of work order tracking • Work orders delivered and closed electronically
Level 2	• CMMS system implemented but used solely for tracking limited data based on paper reports
Level 1	• No CMMS system in place • Paper-based system is not centralized



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CMMS Utilization Observations

General Services

- ▲ GS has implemented a CMMS system / program for managing their work
- ▲ Asset history is tracked for all assets (for approximately the last three years)
- ▲ CMMS system is used to manage preventative maintenance as well as maintenance work requests
- ▶ Hand held device technology has not been implemented
- ▼ Craft technicians work off paper work orders
- ▼ CMMS system not used for inventory control or parts ordering

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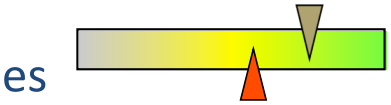
10

Work Management Processes



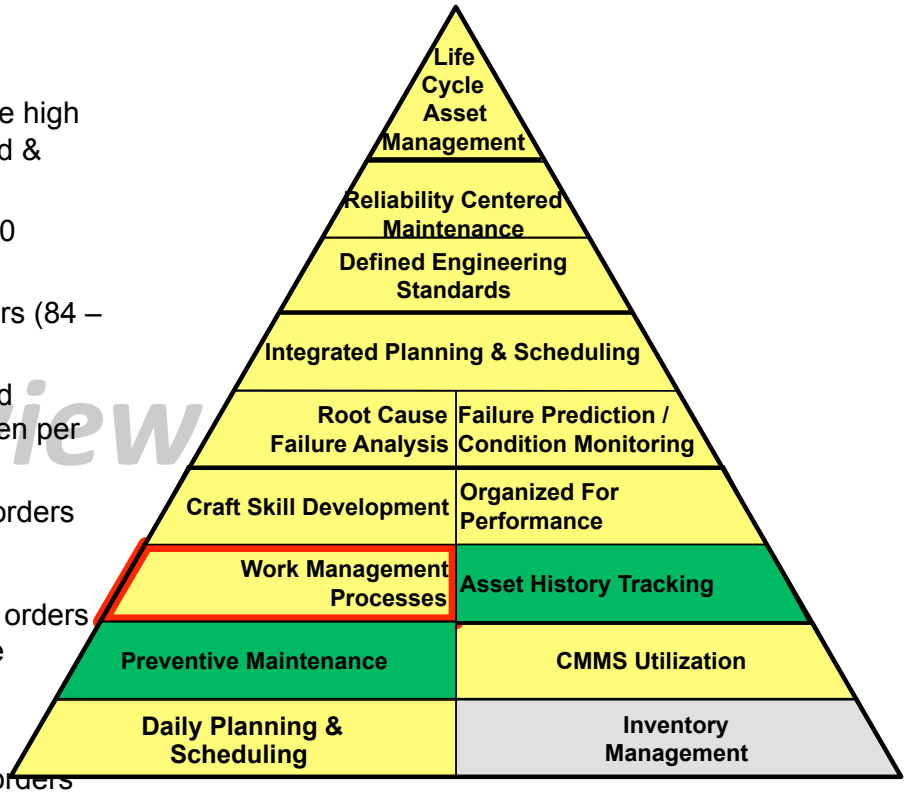
Level 5 (Best in Class)
- > 40 craftsmen per supervisor
- Self-directed work teams execute high percentage of previously planned & scheduled work

Level 4
- Self directed work teams (18 – 40 craftsmen per supervisor)
- Most work covered by work orders (84 – 94%)

Level 3
- Moving away from command and control structure (9 – 17 craftsmen per supervisor)
- 55 -83% work covered by work orders

Level 2
- 5 – 9 craftsmen per supervisor
- 41 – 54% work covered by work orders
- 25 – 31% mechanic wrench time

Level 1
- < 5 craftsmen per supervisor
- <40% of work covered by work orders
- Mechanic wrench time < 25%



Work Management Practices Observations

General Services

- ▲ Organization aims for 75% work order coverage. Monthly backlog report is prepared and reviewed
- ▲ Customer requests are channeled through a centralized system
- ▶ Work order prioritization exists although this seems to have little practical meaning.
- ▶ The actual process for managing and tracking work is determined by the supervisor. In some cases work orders are managed by the individual technician, in others the supervisor is more involved
- ▼ Significant effort expended managing the "paper flow" of the work order
- ▼ Productivity expectations not clearly established or known

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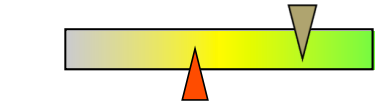
12

Asset History Tracking



Level 5 (Best in Class)

- Fully detailed asset register in place
- Includes disposal and other financial information to determine asset life cycle cost

Level 4

- More advanced register containing system criticality information as well as performance information
- History reviewed on a systematic basis

Level 3

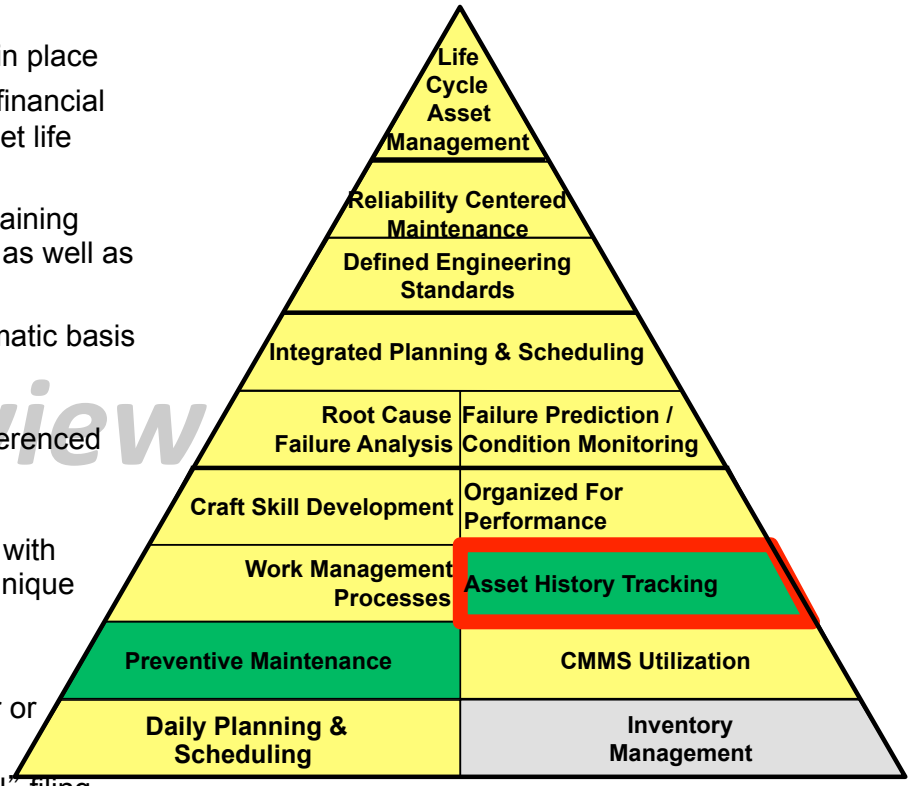
- Computerized asset history information can be cross-referenced with CMMS

Level 2

- Basic asset register in place with acquisition information and unique equipment identifier
- Centrally located register

Level 1

- No centralized asset register or equipment history
- Information kept in "personal" filing systems or tribal knowledge



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Asset History Tracking – Discussion

Description

Developing a proactive maintenance program involves optimizing a "suite" of maintenance activities to maximize asset productivity and minimize asset lifecycle cost. This cannot be done unless there is an accurate asset register, which can be referenced and updated as various acquisition, maintenance, refurbishment and disposal activities take place.

Best Practices

- *Equipment history is computerized and can be cross-referenced with the CMMS (maintenance history can be cross-referenced with asset register. Included in the asset description is acquisition information (date of purchase / installation, supplier and price information and warranty information)*
- *Equipment is tracked by serial numbers as well as location. Equipment history can be tracked when moved between locations. Assets are uniquely described using locations, description of systems, hierarchy, and criticality to system. This is a requirement for reliability centered maintenance*
- *Should cross reference engineering diagrams (e.g. P&ID, PFD, construction drawings, original equipment effectiveness, etc…)*
- *Performance information (Equipment capacity, physical condition, expected useful life, residual value, and performance measures associated with use of the equipment).-Equipment history is reviewed on a systematic basis. Premature failures or unexpected costs are tracked against plan and corrective action taken*
- *Asset register has defined information requirements with units of measure clearly stated. Should match standard used in parts catalogue. This is applicable for equipment, inventory, and locations.*
- *Additional information can include:*
  - *Disposal information (Capacity, physical condition, expected useful life, residual value)*
  - *Financial information (historic cost information, replacement value, depreciation rate and accumulated depreciation)*
  - *This complete financial information is used to determine actual and projected asset life cycle costs*

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Asset History Tracking Observations

General Services

- ▲ GS has some of the BIC Asset History Tracking activities in place
- ▲ Asset tracking capability within CMMS is utilized
- ▲ Asset maintenance hours are tracked
- ▲ Asset warranty information is systematically tracked within CMMS
- ▼ M&O parts are not tracked to the asset
- ▼ Bill of Materials (BOMs) do not exist

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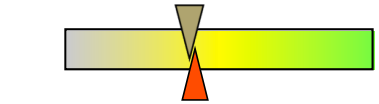
14

Craft Skill Development



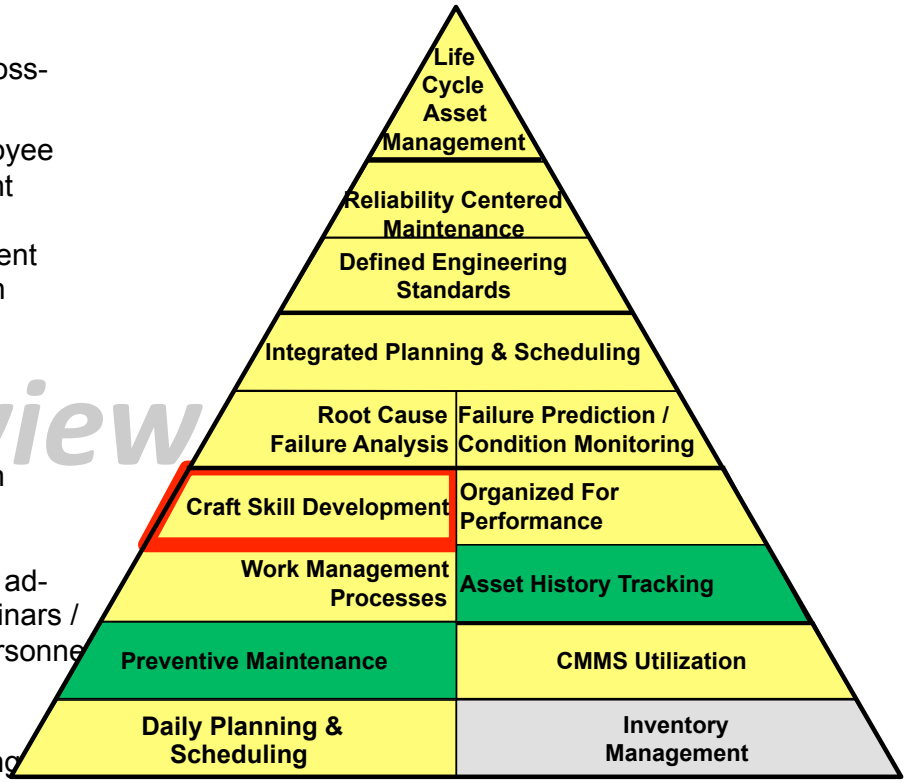
Level 5 (Best in Class)
- Emphasis on development of cross-functional skills
- Training program for each employee based on formal skill assessment

Level 4
- Customized training & development programs are developed for each technician

Level 3
- Formal maintenance skills assessment program in place
- Formal maintenance certification program in place

Level 2
- Informal, on-the-job training and ad-hoc use of 3rd party training seminars / courses by majority of facility personne

Level 1
- No formal skills standards training program in place



Craft Skill Development Observations

General Services

- ▲ There is a formal skill assessment program in place
- ▲ The organization encourages cross functional skill development
- ▲ Individuals have the opportunity to grow within the organization
- ▼ A formal skill development program does not exist

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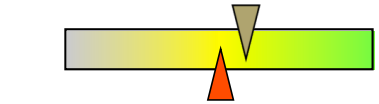
Organized for Performance



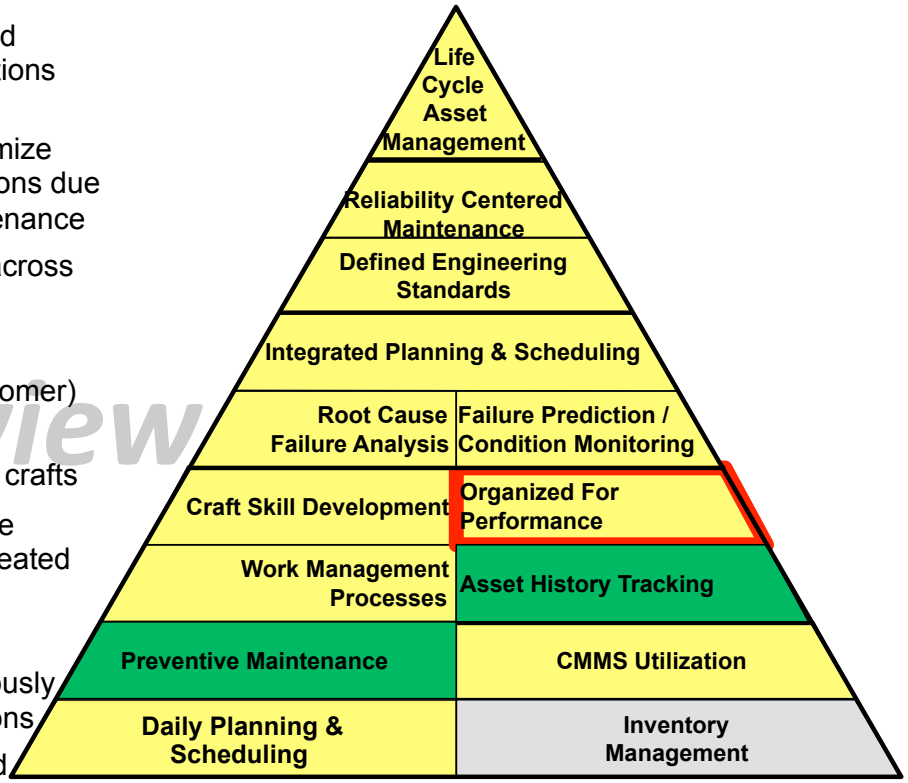
Level 5 (Best in Class)
- Best practices information shared across difference company locations on a formal basis
- "Fix-it-now" teams used to minimize maintenance schedule interruptions due to corrective / emergency maintenance

Level 4
- Informal best practices sharing across location

Level 3
- Inter-departmental teams (engineering, maintenance, customer) to resolve problems
- Predominate use of multi-skilled crafts

Level 2
- Basic recognition system in place
- Departmental teams routinely created to resolve problems or attack opportunities

Level 1
- Work is done according to rigorously & narrowly defined job descriptions
- Many layers of management and narrow spans of control



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Organized for Performance Observations

General Services

- Work is done collaboratively across the work force
- Trades are enabled to develop needed skills branch out from core job function
- Teams are created to address maintenance issues
- Supervisors are working supervisors
- Organization does not have "fix it now" teams to address customer requests thus minimizing interruptions to daily work
- Local technicians' skill level is not high enough to deal with the broad nature of calls they face

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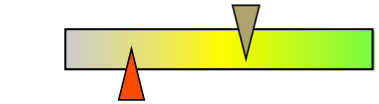
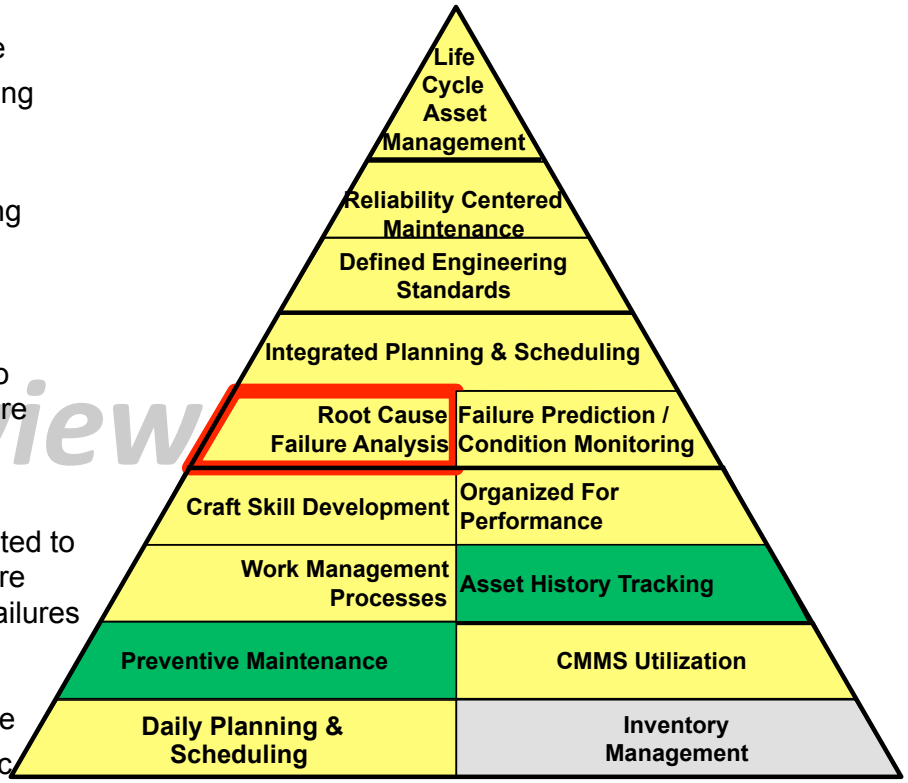
Root Cause Failure Analysis



Level 5 (Best in Class)	• Multi-step RCFA system in place • Comprehensive downtime tracking system to prioritize chronic as opposed to sporadic failures
Level 4	• More advanced analysis including fishbone diagrams utilized • Corrective action taken to rectify underlying cause of failures
Level 3	• Systematic analysis of failures to determine primary cause of failure • Maintenance personnel formally trained on RCFA techniques
Level 2	• Some technical analysis completed to determine primary cause of failure • Action taken to prevent similar failures on the same piece of equipment
Level 1	• No formal RCFA process in place • Analysis performed on an ad hoc basis after failure of key equipment



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Root Cause Failure Analysis – Discussion

Description

RCFA is a simple, yet disciplined process used to investigate, rectify and eliminate equipment failure, and it's most effective when directed at chronic breakdowns…approximately 80% of a typical maintenance budget is stored away for chronic failures, meaning that these events cost far more, in aggregate, than major breakdowns. So it makes sense that the greatest savings comes from applying RCFA to routine breakdowns.

Best Practices

Systematic analysis of failures to determine root cause of failures. (Fishbone diagrams, 5 whys, Kepner Tregoe etc…).
Corrective action taken to rectify underlying cause of failures
Identified root causes could be engineering, process or training related – issues not "indigenous to the piece of equipment itself"

"Standardized Problem, Cause & Action tracking (PCA) codes in-place. I.e. leaking seals, excessive vibration & poor alignment. This is used to systematically identify similar failure modes across different pieces of equipment. Standardized PCs exist for each equipment class (i.e. pumps, valves, compressors etc…). This requires active participation by the mechanics to provide structured feedback as to their analysis of the cause of failure. The action codes should be the immediate remedy. The collection of action codes should identify subsequent root cause activities. (i.e. Problem :noisy pump, cause: misalignment, action: laser alignment, root cause: insufficient mechanic training on alignment procedures, remedy: retrain mechanics)

A multi-step RCFA system in place that includes a failure modes and effect analysis; the preservation of failure information; the organization of an analysis team; the actual analysis; sharing the findings and making recommendations; and tracking the results. A comprehensive downtime tracking system enables the organization to focus on systematically prioritizing and addressing chronic, as opposed to sporadic failures.
Remedial actions are developed on a "business case" basis – all cost considerations of proposed actions (versus inaction) are considered in choosing course of action.

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Root Cause Failure Analysis Observations

General Services

- ▲ Mechanics will self identify premature equipment failures
- ▼ CMMS system is not used to identify and analyze potential chronic failures. Current level of data capture is insufficient to support this level of analyses
- ▼ No structured RCFA Program in place at GS, nor are the dedicated reliability resources in place to execute such a program

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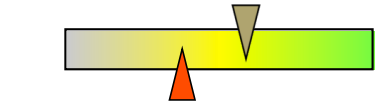
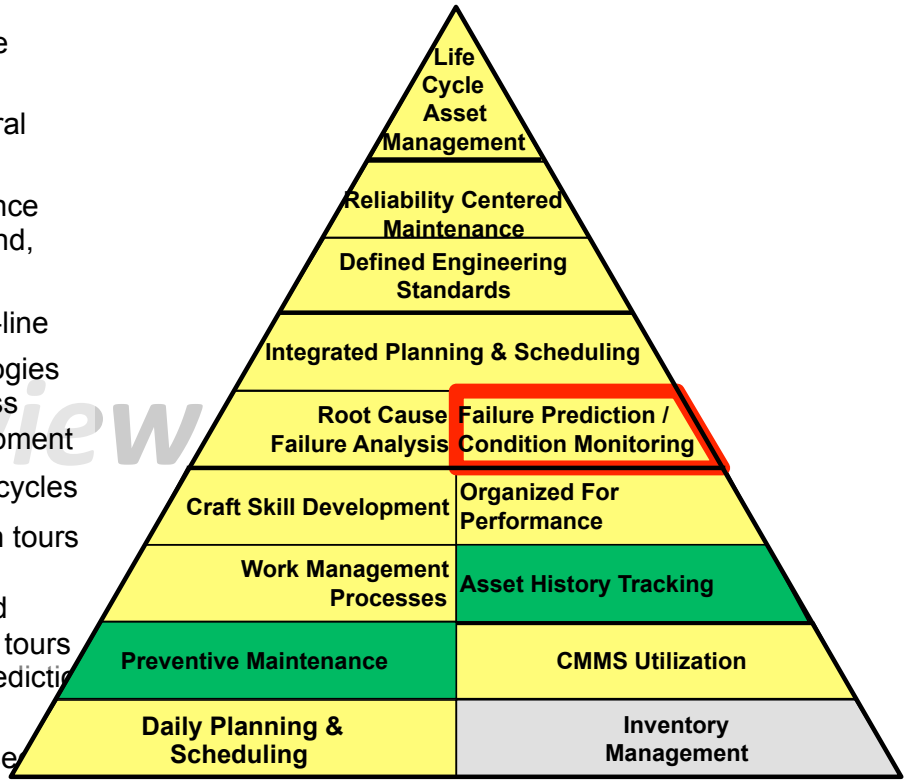
Failure Prediction / Condition Monitoring



Level 5 (Best in Class)	• Monitoring rates based on failure distribution statistics • Results incorporated into a central condition monitoring program
Level 4	• Full suite of predictive maintenance technologies (vibration, ultrasound, infrared, etc.) use • Critical equipment monitored on-line
Level 3	• Predictive maintenance technologies used on a regular basis to assess condition of essential plant equipment • Biweekly or monthly monitoring cycles
Level 2	• Scheduled equipment inspection tours are developed and carried out • Maintenance schedules adjusted based on findings during routine tours
Level 1	• No formal monitoring / failure predicti activities performance • Equipment condition reports base on observations during routine activities



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Failure Prediction / Condition Monitoring Observations

General Services

- ▲ Infrared Thermography and oil analysis predictive maintenance measuring techniques are in Limited use
- ▶ Online monitoring of critical system predictive parameters is not used
- ▶ Vibration analysis techniques are not currently in use
- ▼ Predictive information is not used to optimize preventative maintenance activities

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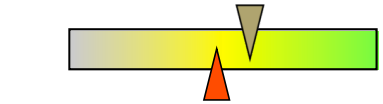
Integrated Planning & Scheduling



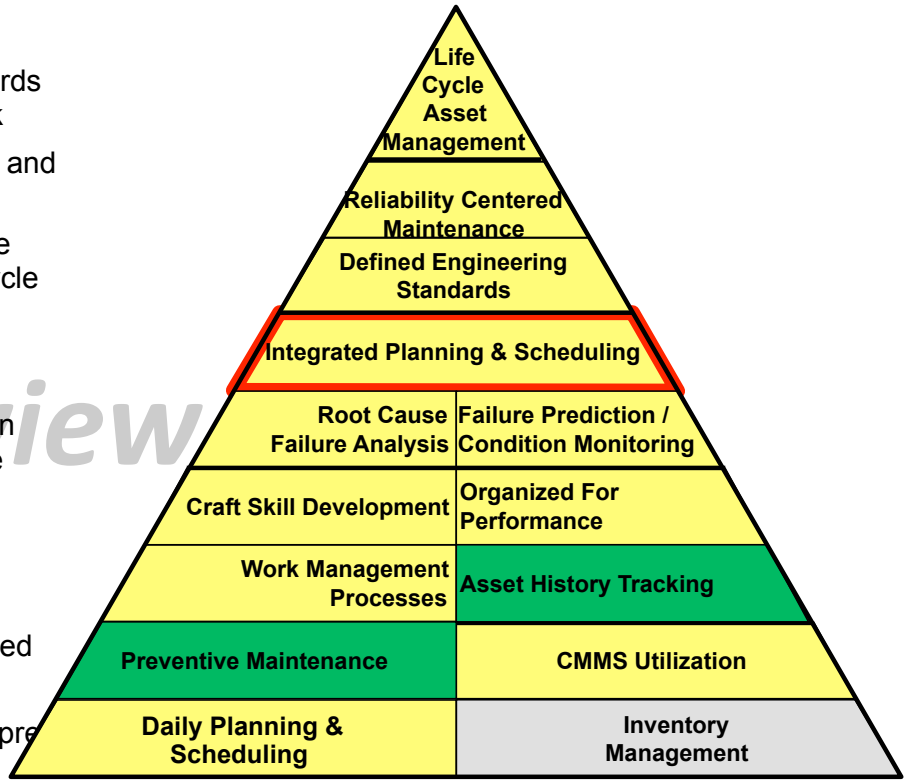
Level 5 (Best in Class)
- Engineered performance standards are used to accurately plan work
- Schedule deviations are tracked and analyzed regularly

Level 4
- Performance based maintenance activities are used to optimize cycle maintenance schedule
- 85 – 94% of work is planned

Level 3
- Maintenance planning systems in place feeding a master schedule
- 79 – 84% of work is planned

Level 2
- Daily scheduling adjusted for emergencies and absenteeism
- % scheduled completion is tracked
- 66 – 78% of work is planned

Level 1
- Daily scheduling derived from a pre existing weekly schedule
- 50 – 65% of work is planned



Integrated Planning & Scheduling - Discussion

Description

The key elements of an integrated planning and scheduling program are a cycle schedule for each Major System, A Look-Ahead Scheduling Process at the Weekly and Daily levels and disciplined performance expectations for operations and work groups.

Proper execution increases worker productivity, reduces missed opportunities for repairs and increases overall plant efficiency.

Best Practices

- *Multi-week look-ahead schedule is prepared (3 or more weeks)*
- *Assets & resources schedules are coordinated, maintenance schedules are coordinated with production scheduling*
- *Complementary Maintenance planning systems in place:*
  - *Outage / Forced Outage Maintenance Schedule*
  - *Cycle Maintenance Plan*
  - *Weekly Maintenance*
  - *All three systems (weekly maintenance, cycle maintenance, shutdown maintenance) feed a master schedule*
  - *Performance based maintenance analysis (i.e. proactive maintenance activities) are used to optimize cycle maintenance schedule*
  - *>85% work is planned*
- *Backlog is driving shut down / turnaround events (ensuring work is driving shutdowns, not dates)*
- *Engineered performance standards (i.e. RS Means) are used to accurately plan work*
- *Performance standards are updated based on analysis of actual performance*
- *Schedule deviations are systematically tracked and analyzed to determine cause of deviations*

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Integrated Planning & Scheduling - Observations

General Services

- ▲ GS has developed and implemented work plans
- ▲ Asset maintenance plans have been developed in implemented for all assets
- ▶ Supervisors have a good understanding of the work flow and work load as well as priority of the work for assigning work daily
- ▼ No weekly or daily schedule is created
- ▼ GS has not made significant progress developing a look-ahead work scheduling process which identifies and "load levels" all preventative maintenance work
- ▼ Schedule compliance can not be tracked in a meaningful way

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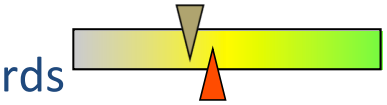
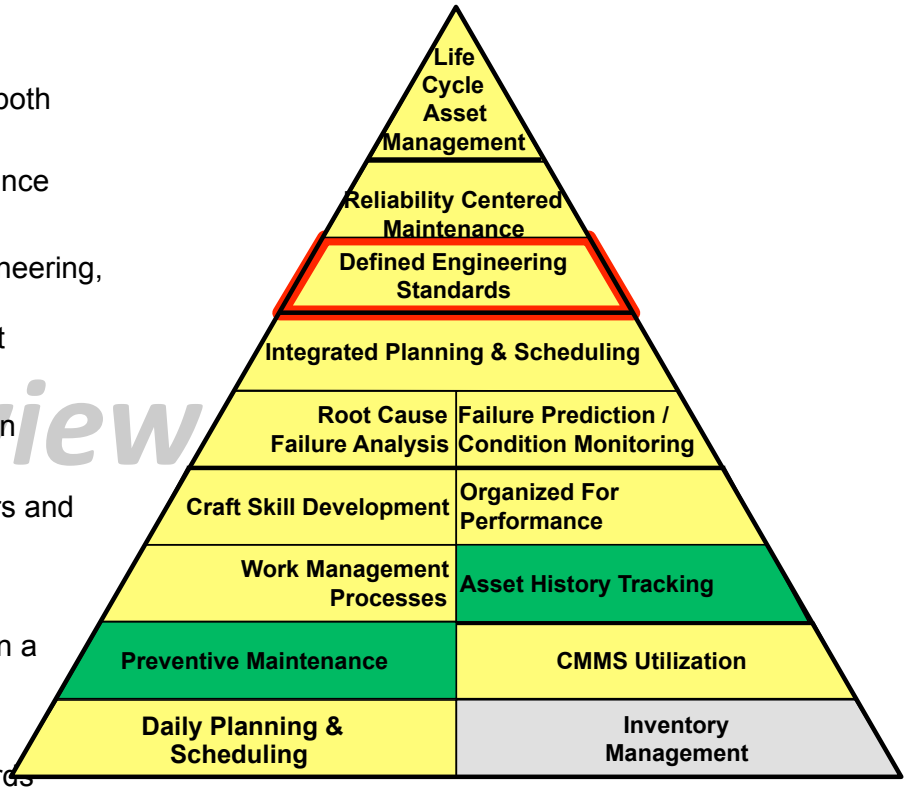
Defined Engineering Standards



Not Implemented — *Fully Implemented*

Level 5 (Best in Class)	• Defined standards matched to both asset and application • Specifications include performance standards
Level 4	• Systematic involvement of engineering, operations, maintenance, and purchasing in setting equipment standards
Level 3	• Equipment standards have been defined for most facility assets • Consistent use of manufacturers and models
Level 2	• Equipment selection made by individual project engineering on a case by case basis
Level 1	• No defined engineering standards



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Defined Engineering Standards – Discussion

Description

Defined engineering standards ensure that there are standard specifications and manufacturers for new equipment, equipment inspections and equipment rebuilds. This ensures consistent equipment performance, minimizes requirements for MRO supplies, minimizes training requirements and enables more effective PM program management. Specific elements of Defined Engineering Standards include:

- *Approved manufacturers & models for plant equipment (i.e. Motors, valves, controls).*
- *Selection based on price, equipment performance and maintenance history.*
- *Specifications and design standards for new / rebuilt equipment.*
- *Precision rebuild, certification & verification (specification for rebuilds are defined, shops certified to standard required to execute rebuilds, testing program for rebuilt assets).*
- *Standardized costs for new equipment rebuilt equipment and exchanged equipment (exchange for rebuild).*

Best Practices

- *Defined standards for equipment rebuild. Standards are matched to both the asset and the application. Spec includes performance standards / validation for rebuild equipment (i.e. rebuilt valve must pass 600psi hydro testing)*
- *Precision rebuilds. Specifications to MIC tolerances and match fit rotating equipment.*
- *Vendor participates in RCFA process and provides input as to appropriate rebuild standards, asset usage and new asset standards.*
- *Vendors help identify appropriate & cost effective asset applications (and misapplications).*
- *Standard / known costs for various asset replacement options (replace new, replace rebuilt, rebuild same asset)*

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Defined Engineering Standards Observations

General Services

- ▲ Maintenance personnel are involved with the equipment selection decision
- ▲ GS strives to consistently use like manufactures and models
- ▶ A systematic process needs to be developed to manage the selection and procurement of assets that insures all appropriate are involved in the equipment purchase decision
- ▼ Equipment standards need to be developed for the purchase and rebuild of assets

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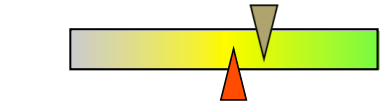
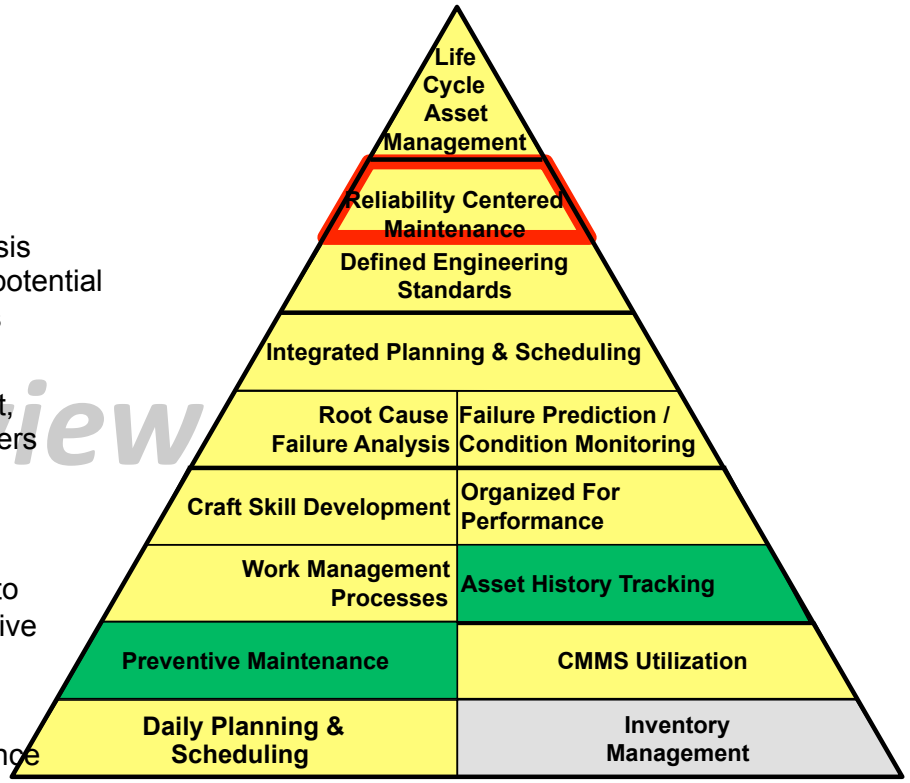
Reliability Centered Maintenance



Level 5 (Best in Class)	• Failure management policy developed, implemented, and regularly checked and updated
Level 4	• Failure modes and effects analysis (FMEA) follows identification of potential sub-optimal operating conditions
Level 3	• Performance parameters (output, speed, etc.) defined by asset users
Level 2	• Critical systems identified • Maintenance program modified to ensure that critical systems receive priority attention
Level 1	• No reliability centered maintenance program in place



Reliability Centered Maintenance – Discussion

Description

Reliability Centered Maintenance (RCM) is a maintenance strategy that logically incorporates into a maintenance program the proper mix of reactive, preventive, predictive, and proactive maintenance practices. Rather than being used independently, the respective strengths of these four maintenance practices are combined to maximize facility and equipment operability and efficiency while minimizing required maintenance time, materials, and consequently, costs. For example, a small pump might be run to failure, a gasoline engine might be placed on a 1,000-hour PM program, and a critical turbine might be monitored with on-line diagnostic sensors.

This strategy often includes performing a statistical analysis of historical data related to failures to determine the optimal investment of maintenance resources and risk assessment methods, called "Failure Mode and Effects Analysis (FMEA), " to identify those processes or systems that statistically exhibit the greatest chance of catastrophic failure. The equipment is then modified or replaced accordingly. Thus, the result is a shift in maintenance resources to areas of greatest mission consequence.

Best Practices

Users asset expectations are defined in terms of performance parameters such as output, throughput, speed, range and carrying capacity. Where relevant, users requirements in terms of risk, quality, control and comfort, are also defined. This information is then used to prioritize systems and optimize maintenance.
Operating equipment effectiveness (OEE) standards are defined. Failures occur when equipment cannot achieve OEE standards. (i.e. pump rated for 100 gpm delivers 80 gpm)

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Reliability Centered Maintenance – Discussion Continued

Best Practices Continued

Warranty requirements are considered in the development of PM routines.

For the previously identified systems, ways by which systems can fail to live up to expectations are identified. This is followed by an FMEA (failure modes and effects analysis), to identify all the events that are reasonably likely to cause each failed state. This information is then used to select optimum maintenance strategies.

Maintenance strategies are designed to match equipment reliability, operational costs and life-cycle costs with business unit strategy.

Standardized maintenance routines available for different classes of assets. Different routines are available based on asset criticality and application.

Actual maintenance routine is optimized for individual assets as opposed to asset classes.

A failure management policy for systems under management is developed. Failure management policy options include:

- *predictive maintenance*
- *preventive maintenance*
- *failure-finding*
- *change the design or configuration of the system*
- *change the way the system is operated*
- *run-to-failure.*

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Reliability Centered Maintenance Observations

General Services

- Maintenance system has been optimized to insure critical assets receive high levels of maintenance
- Critical assets operate with high reliability
- A formal Failure Modes and Effects Analysis program is not in place
- Equipment maintenance strategy has not been implemented to optimize equipment reliability, operational cost and asset life cycle

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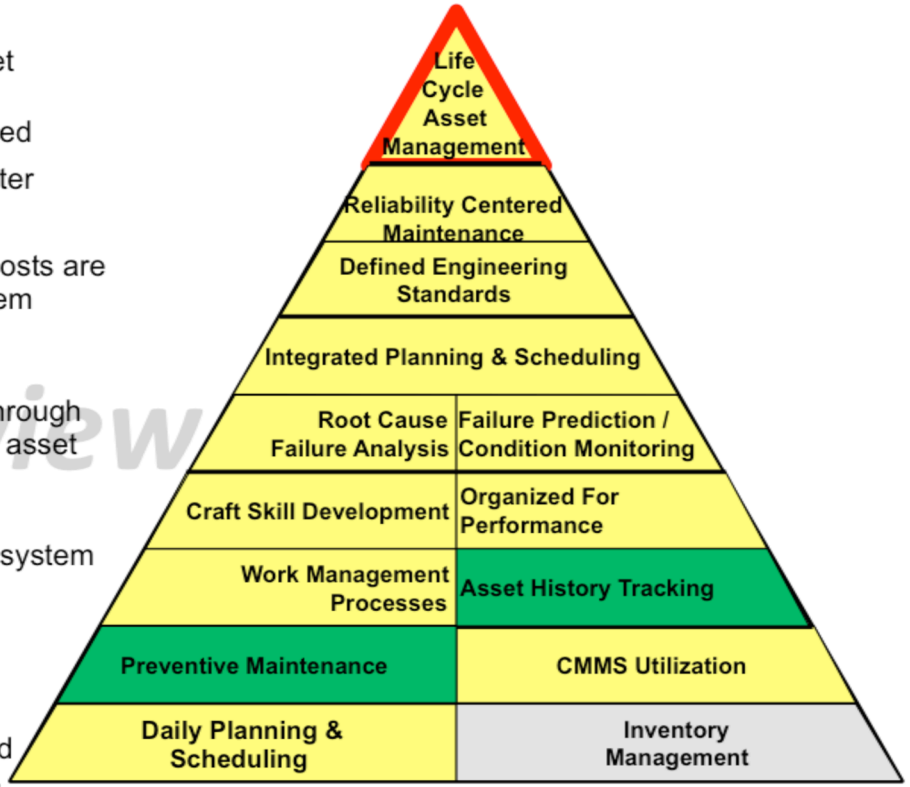
Life Cycle Asset Management

Not Implemented — *Fully Implemented*

Level 5 (Best in Class)	• Full costs from planning for asset acquisition through operations through asset disposal are tracked • Costs available from asset register
Level 4	• All maintenance and operating costs are tracked through work order system
Level 3	• All maintenance costs tracked through work order system and linked to asset register
Level 2	• Cost of major refurbishments to system are tracked • Asset investments also include purchase and installation costs
Level 1	• Not practiced -- Purchase & installation costs only are tracked • Asset investment decisions made on a pure cost basis



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Life Cycle Asset Management – Discussion

Description

Life cycle cost analysis considers the full cost of an asset from acquisition through to disposal. Costs, which must be included, are those relating to acquisition, operations, production impacts, maintenance, and disposal.

Effective asset management involves using life cycle cost information to inform the coordination of maintenance strategy (operational spending), capital budgeting & business planning.

Capital budgeting processes and tools are a critical element of an effective Life-Cycle Asset Management program

Best Practices

- *Full costs from planning for asset acquisition, through to asset disposal are tracked. Costs are available through the asset register.*
- *Asset acquisition decisions made on the basis of life cycle costs and productivity. (Expected availability, throughput, improved quality etc.)*
- *Life-cycle building requirements are considered in the development of both capital and operational (maintenance) plans. Maintenance plans are optimized to consider expected capital refurbishments*

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Life Cycle Asset Management – Discussion Continued

Best Practices Continued

- *Capital budgets subjected to "portfolio optimization" to ensure that optimum basket of possible project is chosen.*
- *Value of deferred maintenance (asset degradation) is tracked and considered in the development of maintenance and capital plans*
- *Structured risk assessments are performed as part of maintenance and capital planning*
- *There is full coordination of maintenance plans & capital spending plans. Capital projects justified on Maintenance reductions result in maintenance budget reductions. Maintenance plans are optimized based on expected building life-cycle plans and business performance requirements.*
- *Focus is on optimization of the total asset spend, matching to longer term business plans while finding the optimum trade-off between operational costs, life-cycle costs & performance (reliability)*

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Life Cycle Asset Management Observations

General Services

- ▲ GS is in the preliminary stage of Life Cycle Asset Management practices
- ▼ Lacks sufficient asset part use history, actual work hour history on asset repair
- ▼ Lacks integration with Toyota Real Estate and Financial Strategy

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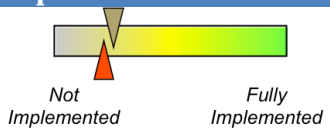
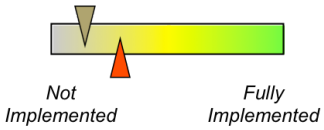
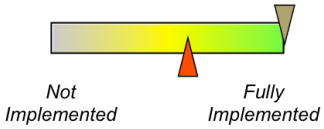
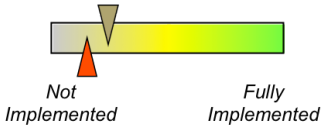
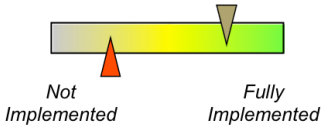
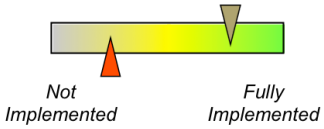
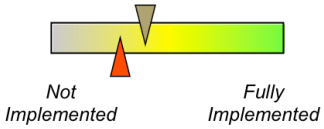
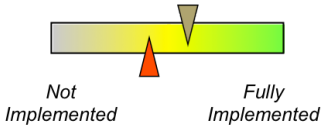
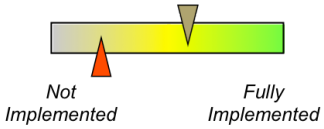
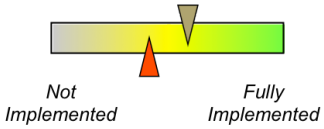
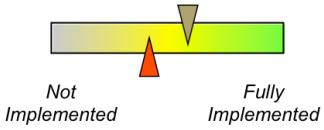
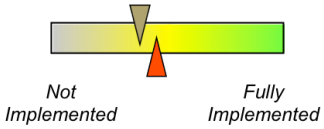
Element No.	Maturity Element	Graphical Evaluation
1	Daily Planning and Scheduling	
2	Inventory Management	
3	Preventive Maintenance	
4	CMMS Utilization	
5	Work Management Processes	
6	Asset History Tracking	
7	Craft Skill Development	
8	Organized for Performance	
9	Root Cause Failure Analysis	
10	Failure Prediction and Condition Monitoring	
11	Integrated Planning and Scheduling	
12	Defined Engineering Standards	

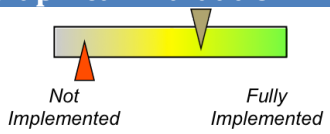
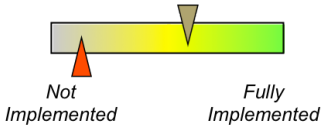
Element No.	Maturity Element	Graphical Evaluation
13	Reliability Centered Maintenance	
14	Life Cycle Asset Management	

Figure 16: Community Services MMM Summary

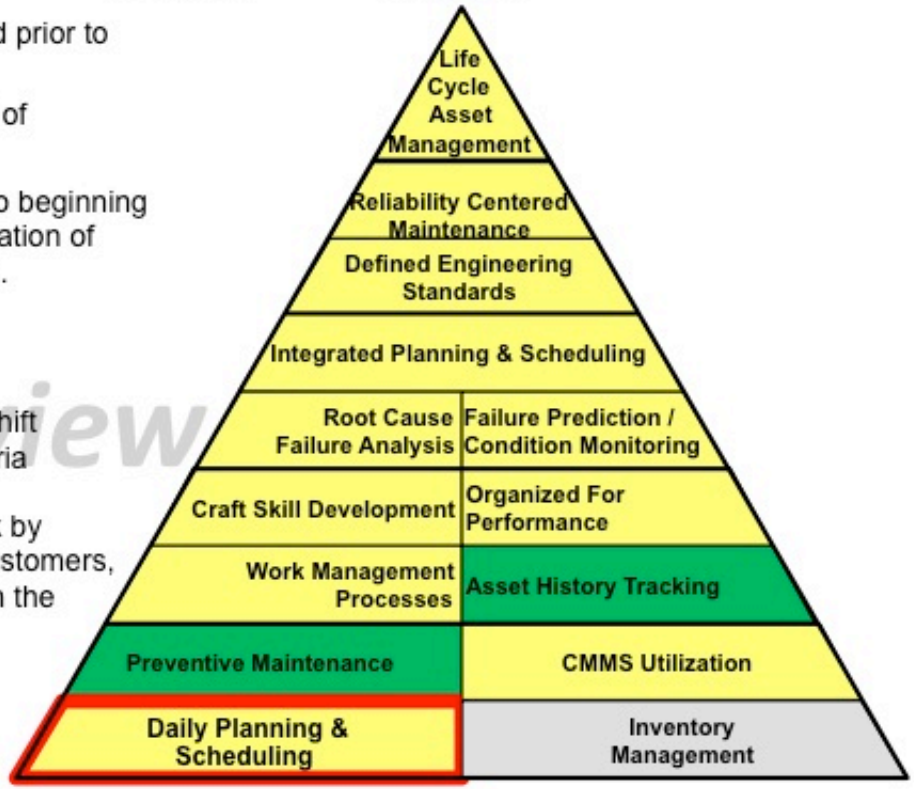
Community Services: Maintenance Maturity Model; The Detail

For each Division, (General Services and Community Services, Jorgensen uses a maintenance maturity model presenting the fourteen evaluation elements in a pyramid structure.

The detail evaluation for the Community Services organization is presented on the following pages:

Daily Planning & Scheduling

Level 5 (Best in Class)	• Daily work schedule is created prior to beginning of work shift • Schedule targets 110 – 120% of expected workload
Level 4	• Daily Schedule created prior to beginning of work shift based on prioritization of outstanding work requests (i.e. emergency, urgent, routine).
Level 3	• Work is assigned by priority • Work is prioritized at start of shift using some independent criteria
Level 2	• Employees are assigned work by supervisor as requested by customers, or on an ad hoc basis, through the course of the workday.
Level 1	• Daily schedule is not created • No systematic method of prioritizing work exists.



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1

Daily Planning & Scheduling Observations

Community Services (Parks)

- ▲ Work is generally assigned by location with secondary dispatch based on craft
- ▲ Community Services (CS) is very customer focused and responds quickly to customer requests
- ▲ Supervisors have a good sense of what work needs to be done and the priority of the work
- ▶ SBC employee customer calls are frequent and a very quick response is expected in most cases interrupting daily work routines
- ▶ The squeaky wheel definitely gets attention. There are "direct call" numbers for going around the facility service center directly to the facility service center supervisor
- ▶ The technicians and supervisors do not focus on the assigned priority of the work
- ▼ CS does not use a formalized system base schedule. Work such as PMs are planned but they are not scheduled
- ▼ Work is not scheduled based on craft, parts or equipment availability
- ▼ CS craftsmen often have to leave jobs to attend to call outs
- ▼ No consistent structured process for setting and defining daily schedules

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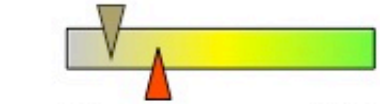
Inventory Management



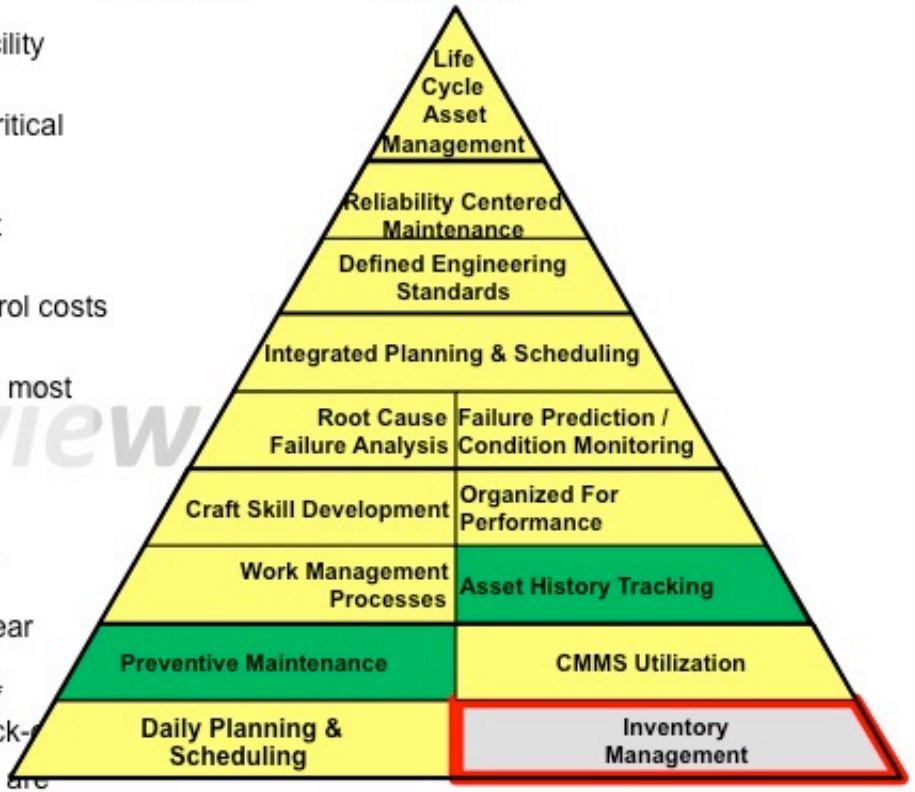
Level 5 (Best in Class)
- Stock accounts for <0.5% of facility replacement value
- Separate Stock-out targets for critical spares and non-critical spares

Level 4
- Inventory ordering based on part criticality
- Use Just-in-Time models to control costs

Level 3
- Minimum order quantities set for most parts with computerized controls
- 1 – 1.5 inventory turns per year

Level 2
- Centralized tracking of inventory
- Some private Stashes
- Less than 1 inventory turn per year

Level 1
- No central monitoring/tracking of inventory – parts ordered by stock-
- Unofficial "stashes" of inventory are common



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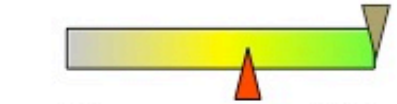
Inventory Management Observations

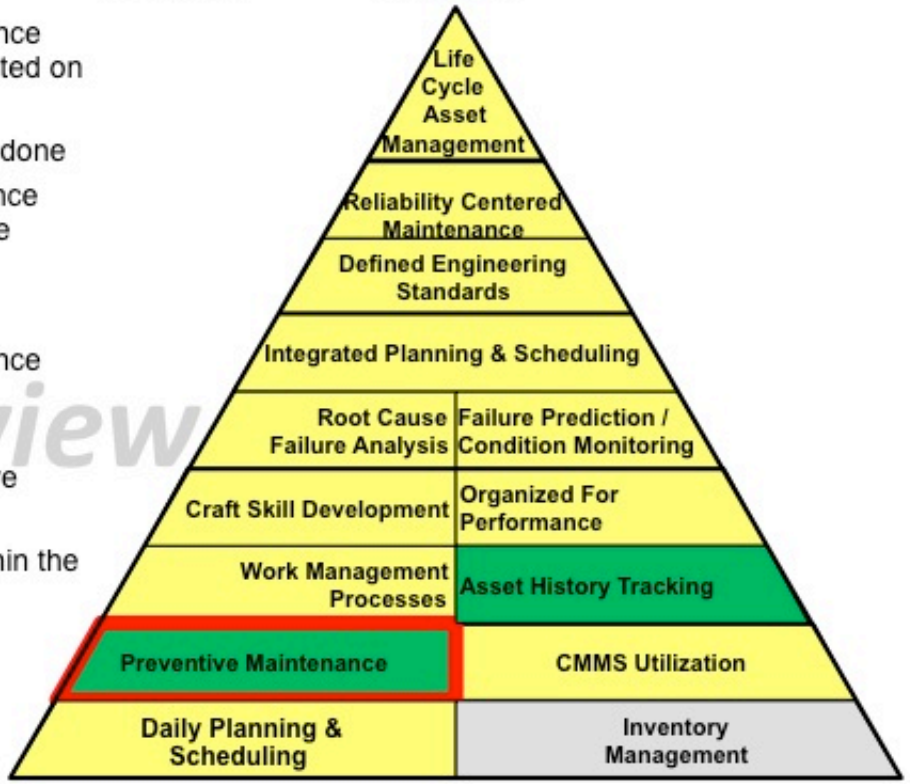
Community Services (Parks)

- ▲ CS Staff works to negotiate best pricing for commodity parts
- ▼ There is no controlled parts stock room
- ▼ There is no centralized purchasing of M&O parts
- ▼ Spare parts are not tracked using a CMMS system
- ▼ Not leveraging the capabilities of CMMS to automate parts ordering
- ▼ Verbal confirmation only of order acceptance. No proactive notification of parts arrival.
- ▼ Supervisors and technicians cannot electronically check parts availability – this can particularly hamper productivity when the stores and shops are not co-located.

Preventative Maintenance



Level 5 (Best in Class)	• Formal preventative maintenance program is reviewed and updated on a regular basis • Documented basis for al work done
Level 4	• Formal preventative maintenance optimization processes in place • Asset criticality, age, and cost performance are all measured
Level 3	• Formal preventative maintenance program in place • Highest priority asides from emergency work is preventative
Level 2	• Preventative maintenance is performance, although not within the context of a site preventative maintenance program
Level 1	• No preventative or predictive maintenance is performed • Only breakdown and corrective maintenance



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Preventative Maintenance Observations

Community Services (Parks)

- ▲ CS has a paper-based (at the time of the evaluation) PM program, (for equipment in the asset inventory)
- ▶ The window for completion for PM's is very wide which leads to skewing the % complete number high
- ▶ PM performance against planned schedule not well known by supervisors and technicians
- ▼ PM routines not typically printed and included with work orders. Mechanics perform most preventive maintenance routines from memory

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CMMS Utilization

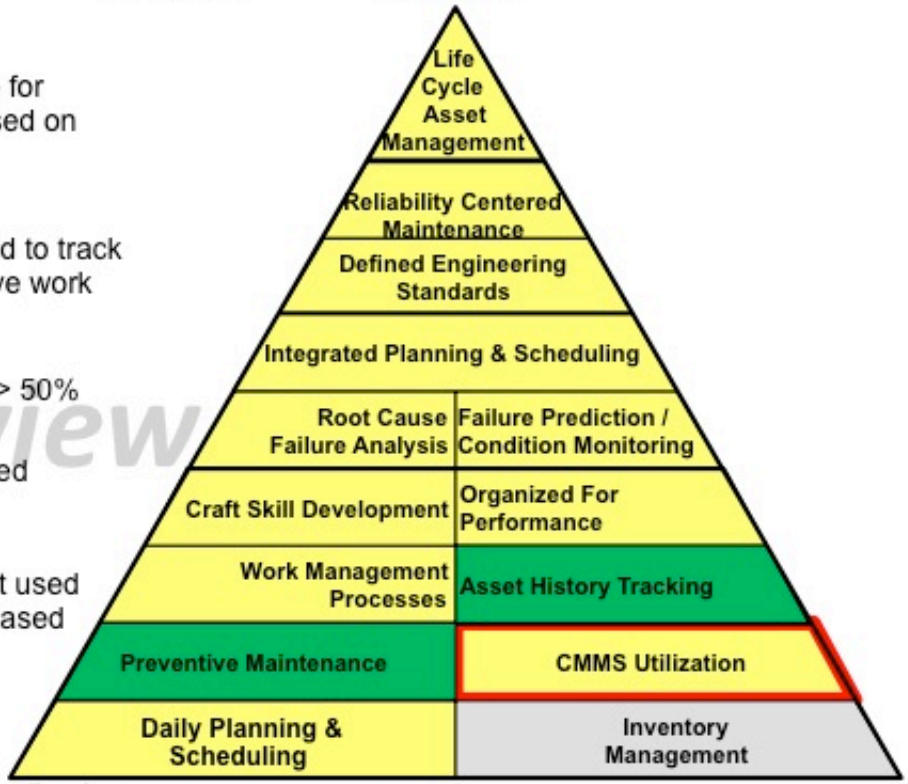
Level 5 (Best in Class)
- CMMS system fully responsible for daily planning & scheduling based on inventory, asset criticality, etc.

Level 4
- CMMS system fully implemented to track preventative as well as corrective work orders

Level 3
- Computerized system handles > 50% of work order tracking
- Work orders delivered and closed electronically

Level 2
- CMMS system implemented but used solely for tracking limited data based on paper reports

Level 1
- No CMMS system in place
- Paper-based system is not centralized



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CMMS Utilization Observations

Community Services (Parks)

- Hand held device technology has not been implemented
- Craft technicians work off paper work orders
- CMMS system not used for inventory control or parts ordering

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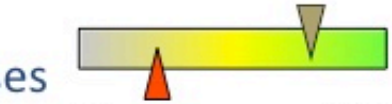
Work Management Processes



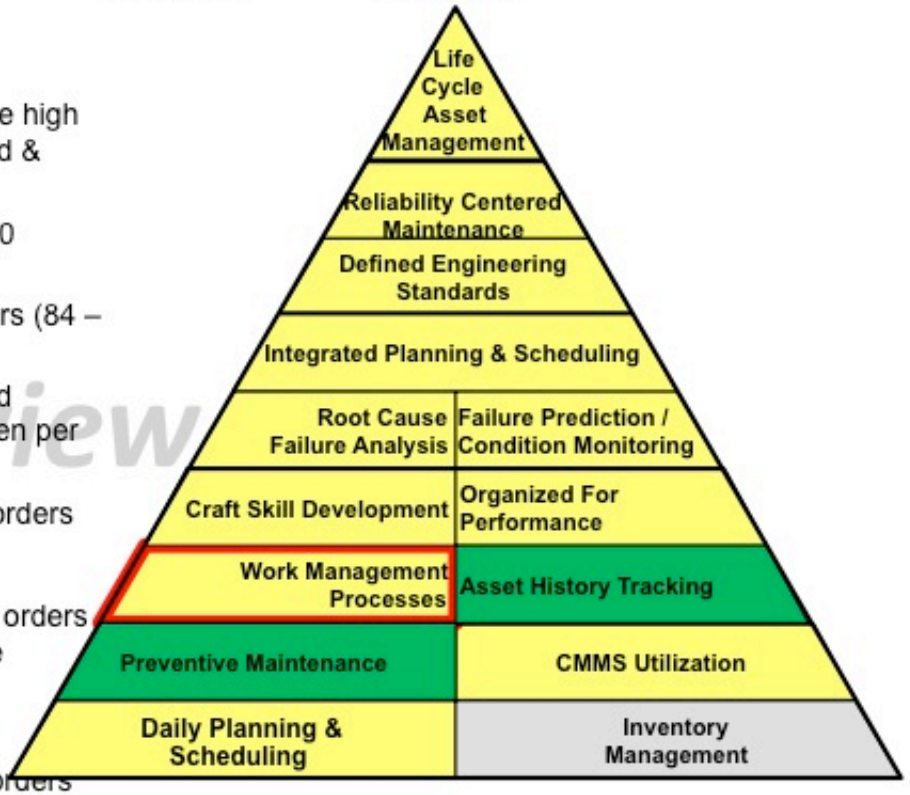
Level 5 (Best in Class)
- > 40 craftsmen per supervisor
- Self-directed work teams execute high percentage of previously planned & scheduled work

Level 4
- Self directed work teams (18 – 40 craftsmen per supervisor)
- Most work covered by work orders (84 – 94%)

Level 3
- Moving away from command and control structure (9 – 17 craftsmen per supervisor)
- 55 -83% work covered by work orders

Level 2
- 5 – 9 craftsmen per supervisor
- 41 – 54% work covered by work orders
- 25 – 31% mechanic wrench time

Level 1
- < 5 craftsmen per supervisor
- <40% of work covered by work orders
- Mechanic wrench time < 25%



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Work Management Practices Observations

Community Services (Parks)

- Work order prioritization exists although this seems to have little practical meaning.
- The actual process for managing and tracking work is determined by the supervisor. In some cases work orders are managed by the individual technician, in others the supervisor is more involved
- Significant effort expended managing the "paper flow" of the work order
- Productivity expectations not clearly established or known

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Asset History Tracking

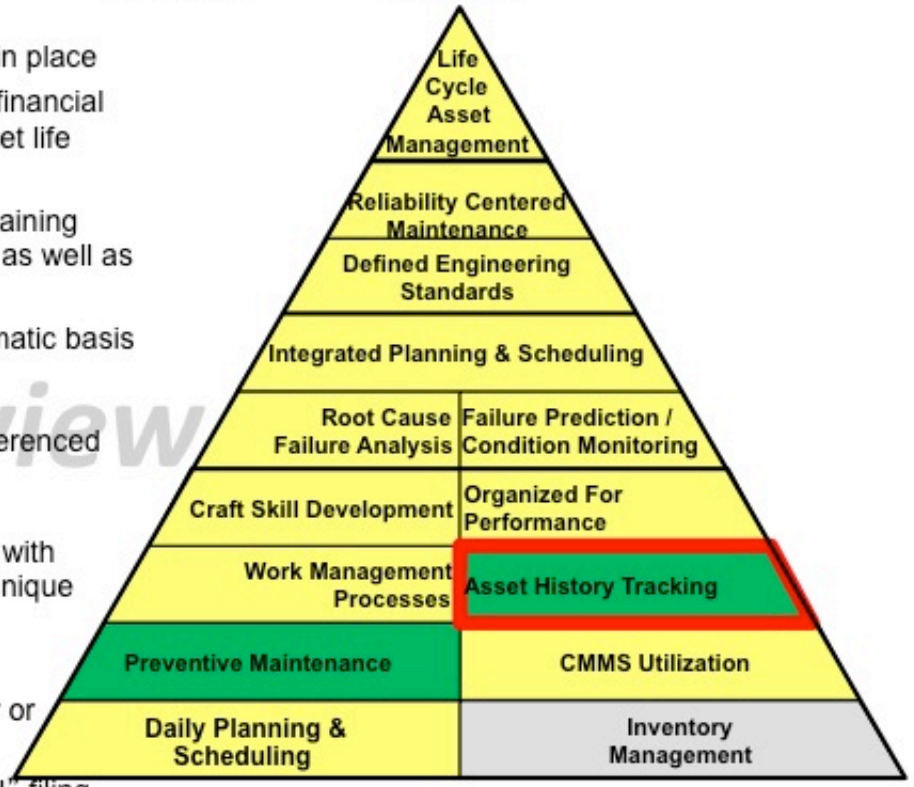
Level 5 (Best in Class)
- Fully detailed asset register in place
- Includes disposal and other financial information to determine asset life cycle cost

Level 4
- More advanced register containing system criticality information as well as performance information
- History reviewed on a systematic basis

Level 3
- Computerized asset history information can be cross-referenced with CMMS

Level 2
- Basic asset register in place with acquisition information and unique equipment identifier
- Centrally located register

Level 1
- No centralized asset register or equipment history
- Information kept in "personal" filing systems or tribal knowledge



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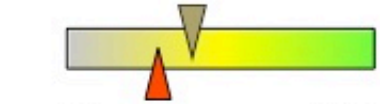
Asset History Tracking Observations

Community Services (Parks)

- ▲ CS has a very basic asset history tracking activity in place
- ▼ M&O parts are not tracked to the asset
- ▼ Bill of Materials (BOMs) do not exist

Craft Skill Development



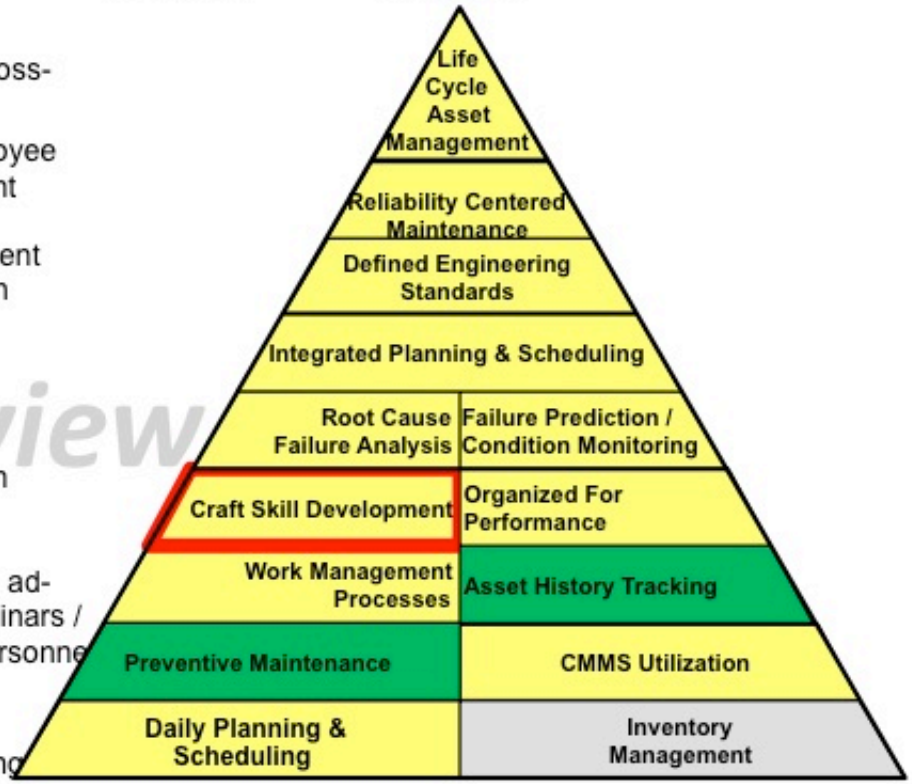
Level 5 (Best in Class)
- Emphasis on development of cross-functional skills
- Training program for each employee based on formal skill assessment

Level 4
- Customized training & development programs are developed for each technician

Level 3
- Formal maintenance skills assessment program in place
- Formal maintenance certification program in place

Level 2
- Informal, on-the-job training and ad-hoc use of 3rd party training seminars / courses by majority of facility personne

Level 1
- No formal skills standards training program in place



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Craft Skill Development Observations

Community Services (Parks)

- ▲ There is a semi-formal skill assessment program in place
- ▲ The organization encourages cross functional skill development
- ▲ Individuals have the opportunity to grow within the organization
- ▼ A formal skill development program does not exist

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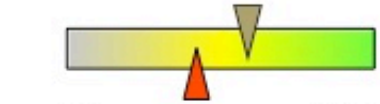
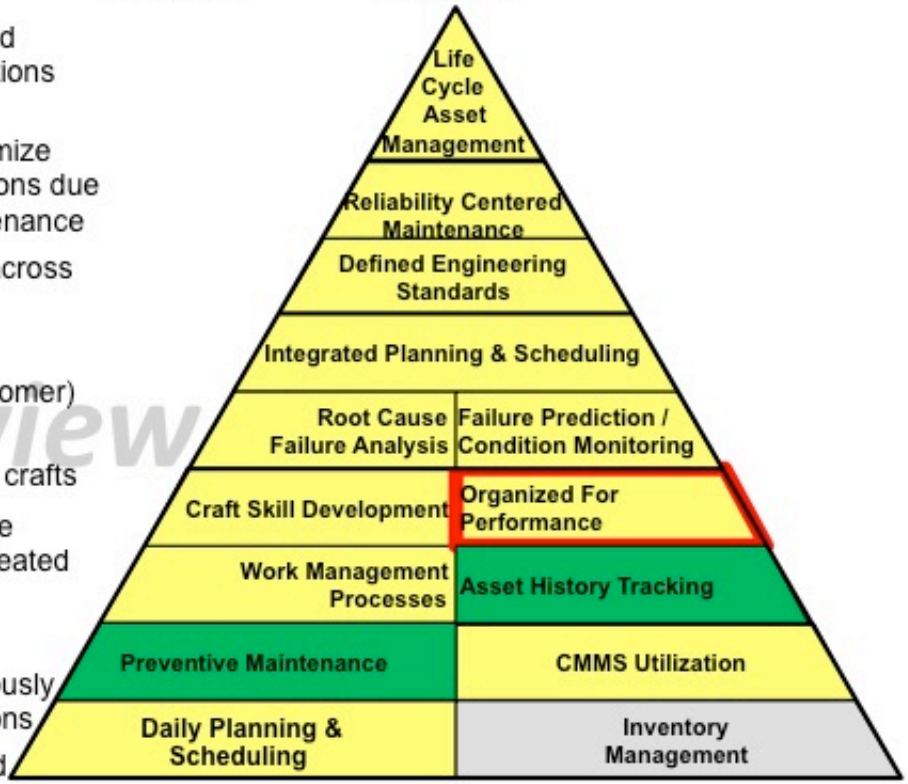
Organized for Performance



Not Implemented — *Fully Implemented*

Level 5 (Best in Class)	• Best practices information shared across difference company locations on a formal basis • "Fix-it-now" teams used to minimize maintenance schedule interruptions due to corrective / emergency maintenance
Level 4	• Informal best practices sharing across location
Level 3	• Inter-departmental teams (engineering, maintenance, customer) to resolve problems • Predominate use of multi-skilled crafts
Level 2	• Basic recognition system in place • Departmental teams routinely created to resolve problems or attack opportunities
Level 1	• Work is done according to rigorously & narrowly defined job descriptions • Many layers of management and narrow spans of control



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Organized for Performance Observations

Community Services (Parks)

- Work is done collaboratively across the work force
- Teams are created to address maintenance issues
- Supervisors are working supervisors
- Organization does not have "fix it now" teams to address customer requests thus minimizing interruptions to daily work
- Local technicians' skill level is not high enough to deal with the broad nature of calls they face

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Root Cause Failure Analysis

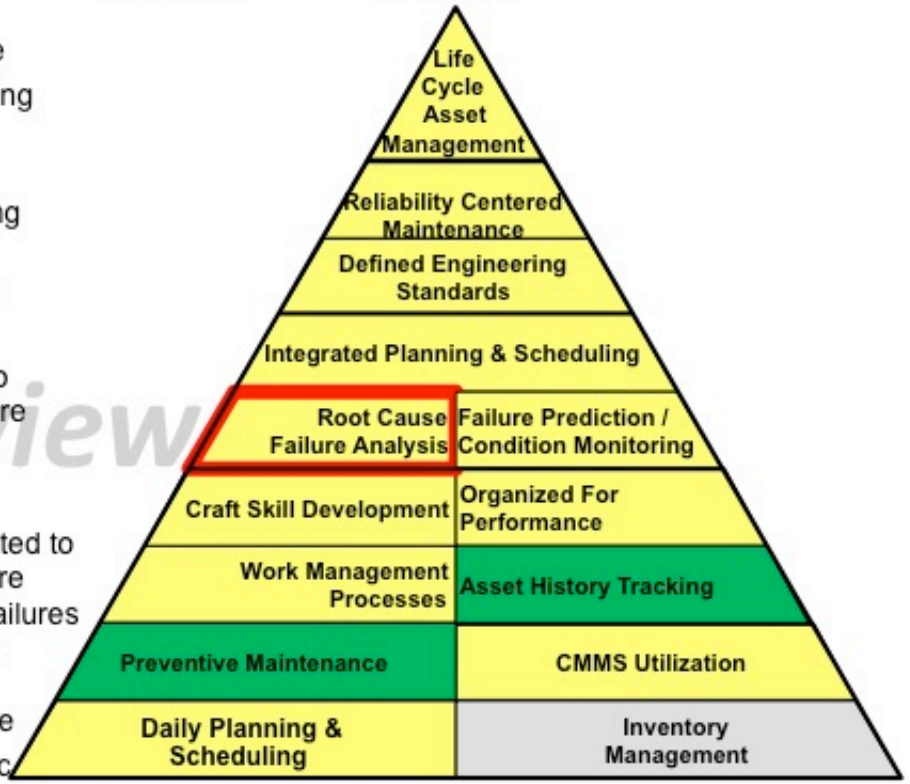
Level 5 (Best in Class)
- Multi-step RCFA system in place
- Comprehensive downtime tracking system to prioritize chronic as opposed to sporadic failures

Level 4
- More advanced analysis including fishbone diagrams utilized
- Corrective action taken to rectify underlying cause of failures

Level 3
- Systematic analysis of failures to determine primary cause of failure
- Maintenance personnel formally trained on RCFA techniques

Level 2
- Some technical analysis completed to determine primary cause of failure
- Action taken to prevent similar failures on the same piece of equipment

Level 1
- No formal RCFA process in place
- Analysis performed on an ad hoc basis after failure of key equipment



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Root Cause Failure Analysis Observations

Community Services (Parks)

- ▲ Mechanics will self-identify premature equipment failures
- ▼ CMMS system is not used to identify and analyze potential chronic failures. Current level of data capture is insufficient to support this level of analyses
- ▼ No structured RCFA Program in place at CS, nor are the dedicated reliability resources in place to execute such a program

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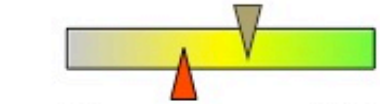
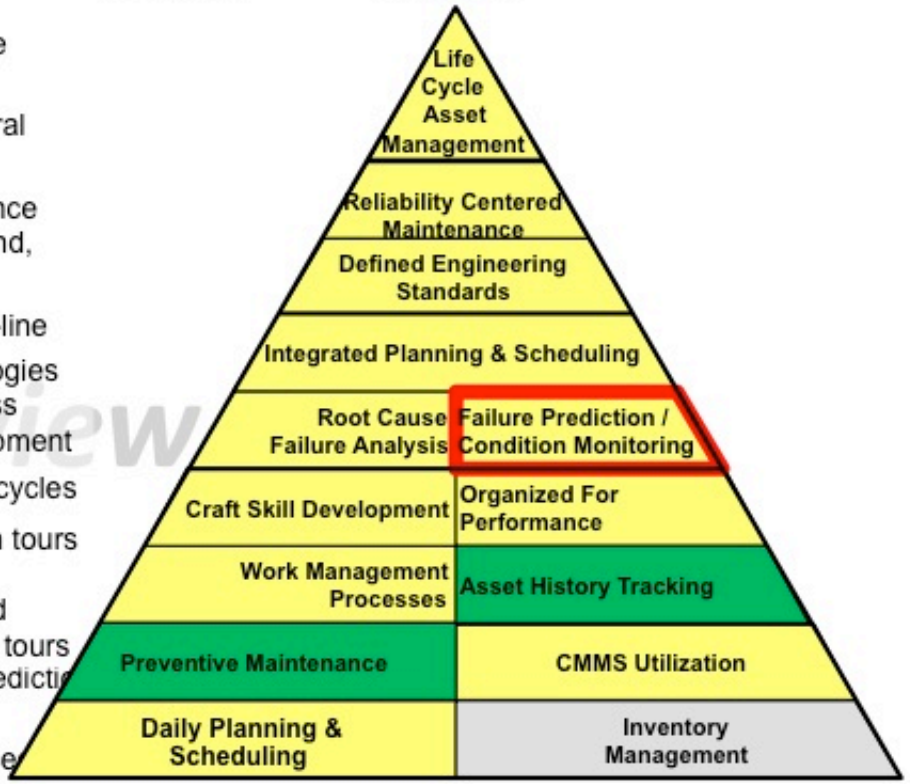
Failure Prediction / Condition Monitoring



Level 5 (Best in Class)	• Monitoring rates based on failure distribution statistics • Results incorporated into a central condition monitoring program
Level 4	• Full suite of predictive maintenance technologies (vibration, ultrasound, infrared, etc.) use • Critical equipment monitored on-line
Level 3	• Predictive maintenance technologies used on a regular basis to assess condition of essential plant equipment • Biweekly or monthly monitoring cycles
Level 2	• Scheduled equipment inspection tours are developed and carried out • Maintenance schedules adjusted based on findings during routine tours
Level 1	• No formal monitoring / failure predicti activities performance • Equipment condition reports base on observations during routine activities



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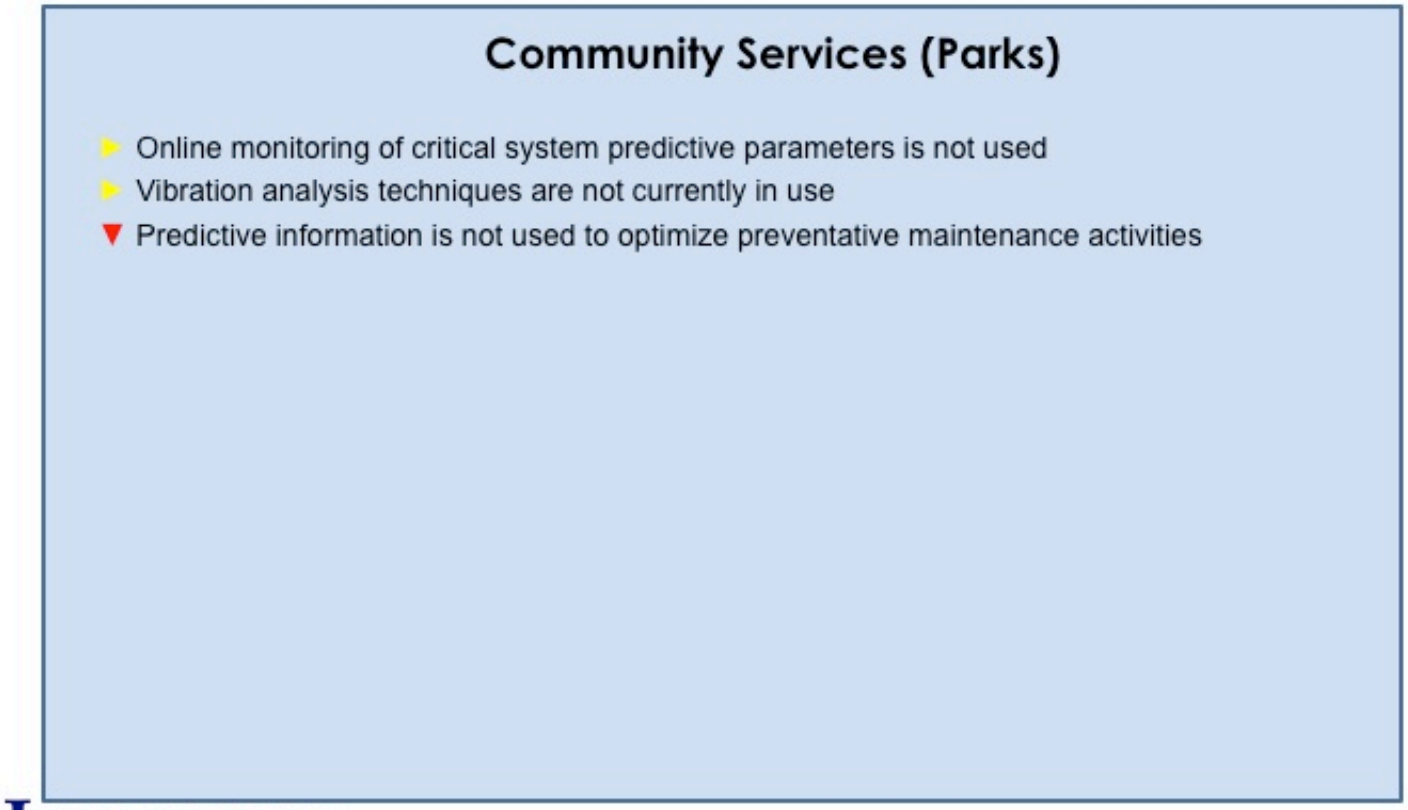
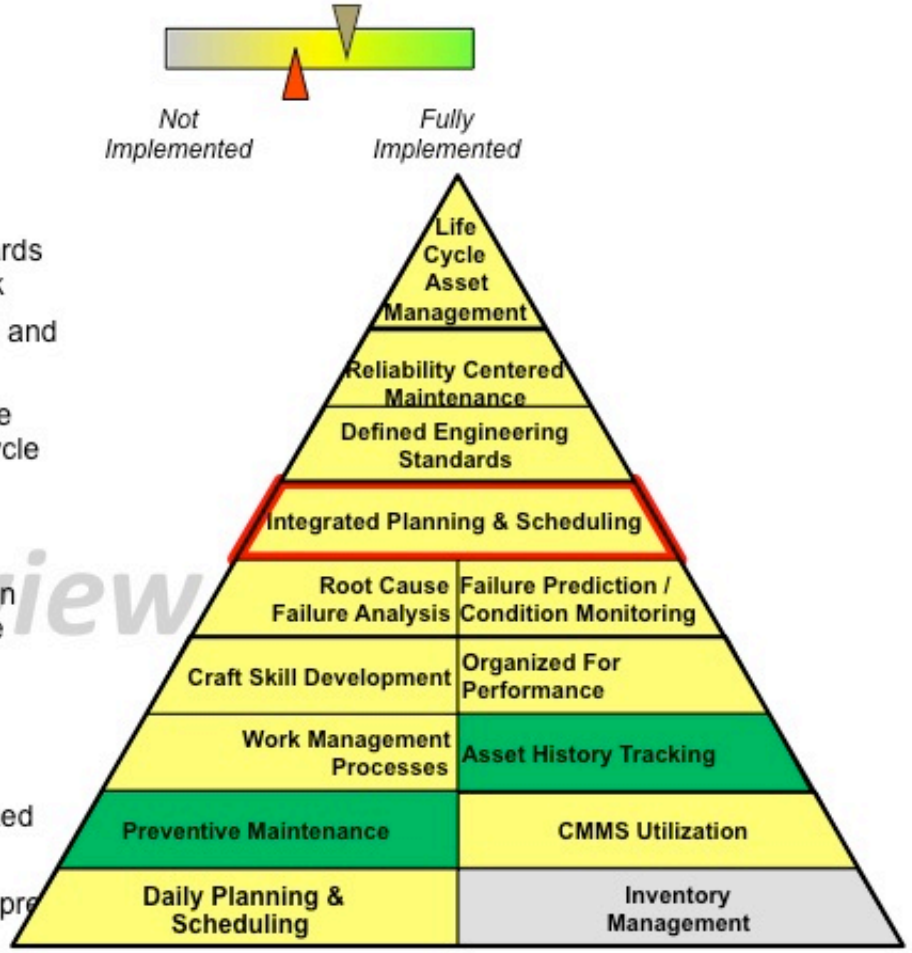
Failure Prediction / Condition Monitoring Observations



Integrated Planning & Scheduling

Level 5 (Best in Class)	• Engineered performance standards are used to accurately plan work • Schedule deviations are tracked and analyzed regularly
Level 4	• Performance based maintenance activities are used to optimize cycle maintenance schedule • 85 – 94% of work is planned
Level 3	• Maintenance planning systems in place feeding a master schedule • 79 – 84% of work is planned
Level 2	• Daily scheduling adjusted for emergencies and absenteeism • % scheduled completion is tracked • 66 – 78% of work is planned
Level 1	• Daily scheduling derived from a pre existing weekly schedule • 50 – 65% of work is planned



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Integrated Planning & Scheduling - Observations

Community Services (Parks)

- ▲ GS has developed and implemented work plans
- ▲ Elementary asset maintenance plans have been developed in implemented for all assets
- ▶ Supervisors have a good understanding of the work flow and work load as well as priority of the work for assigning work daily
- ▼ No weekly or daily schedule is created
- ▼ CS has not made significant progress developing a look-ahead work scheduling process which identifies and "load levels" all preventative maintenance work
- ▼ Schedule compliance can not be tracked in a meaningful way

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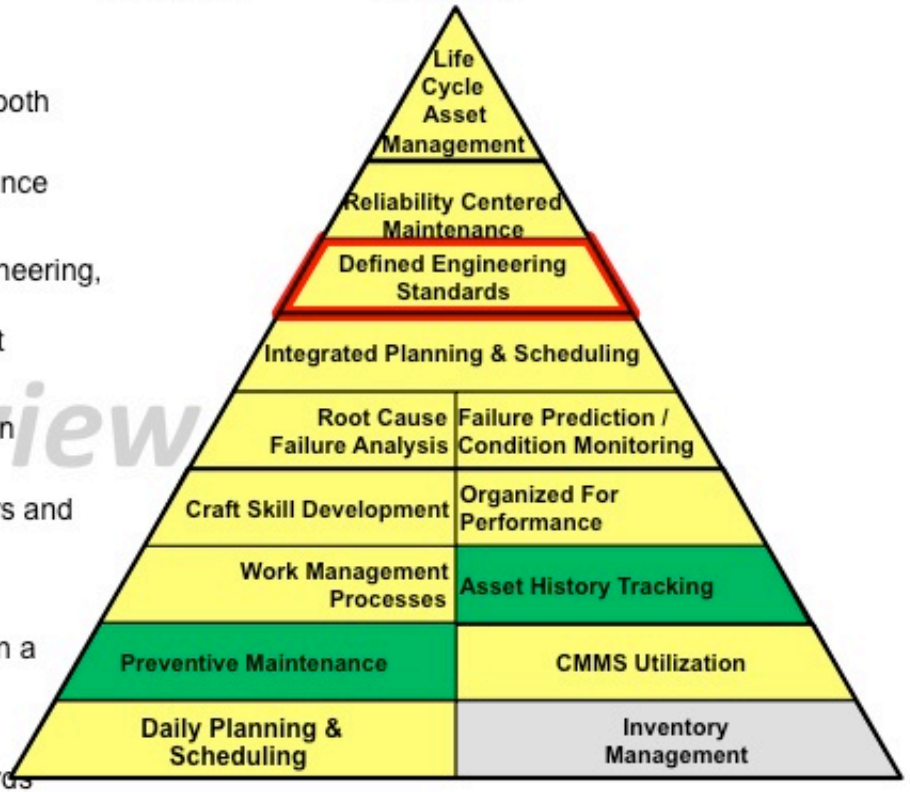
Defined Engineering Standards

Not Implemented — Fully Implemented

Level 5 (Best in Class)	• Defined standards matched to both asset and application • Specifications include performance standards
Level 4	• Systematic involvement of engineering, operations, maintenance, and purchasing in setting equipment standards
Level 3	• Equipment standards have been defined for most facility assets • Consistent use of manufacturers and models
Level 2	• Equipment selection made by individual project engineering on a case by case basis
Level 1	• No defined engineering standards



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Defined Engineering Standards Observations

Community Services (Parks)

- ▲ Maintenance personnel are involved with the equipment selection decision
- ▲ CS strives to consistently use like manufactures and models
- ▶ A systematic process needs to be developed to manage the selection and procurement of assets that insures all appropriate are involved in the equipment purchase decision
- ▼ Equipment standards need to be developed for the purchase and rebuild of assets

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Reliability Centered Maintenance

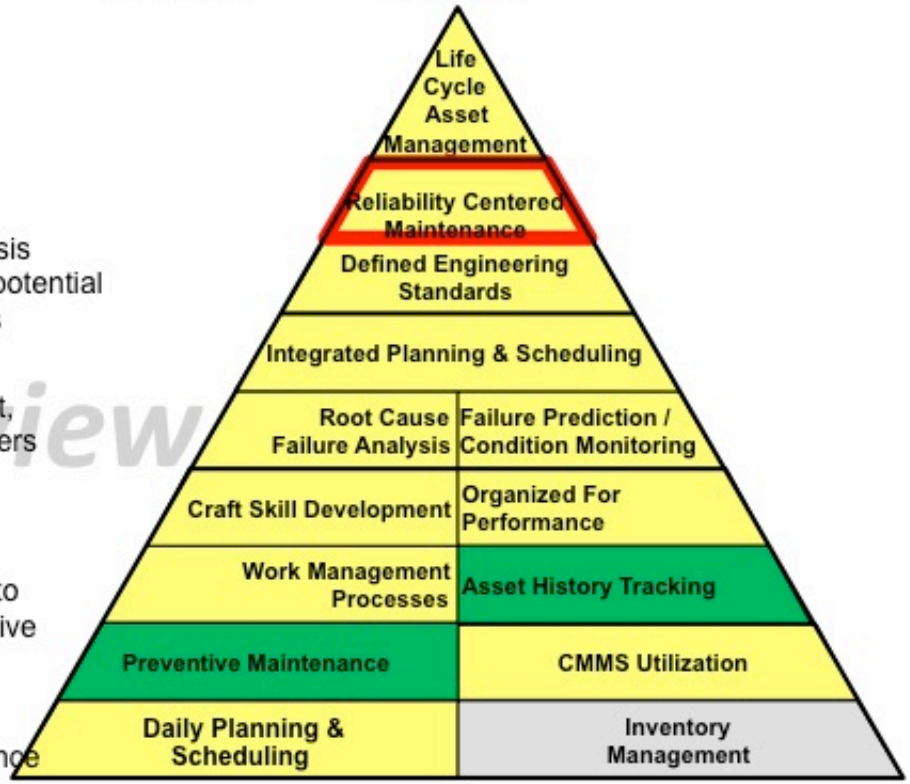
Level 5 (Best in Class)
- Failure management policy developed, implemented, and regularly checked and updated

Level 4
- Failure modes and effects analysis (FMEA) follows identification of potential sub-optimal operating conditions

Level 3
- Performance parameters (output, speed, etc.) defined by asset users

Level 2
- Critical systems identified
- Maintenance program modified to ensure that critical systems receive priority attention

Level 1
- No reliability centered maintenance program in place



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Reliability Centered Maintenance Observations

Community Services (Parks)

- A formal Failure Modes and Effects Analysis program is not in place
- Equipment maintenance strategy has not been implemented to optimize equipment reliability, operational cost and asset life cycle

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Life Cycle Asset Management

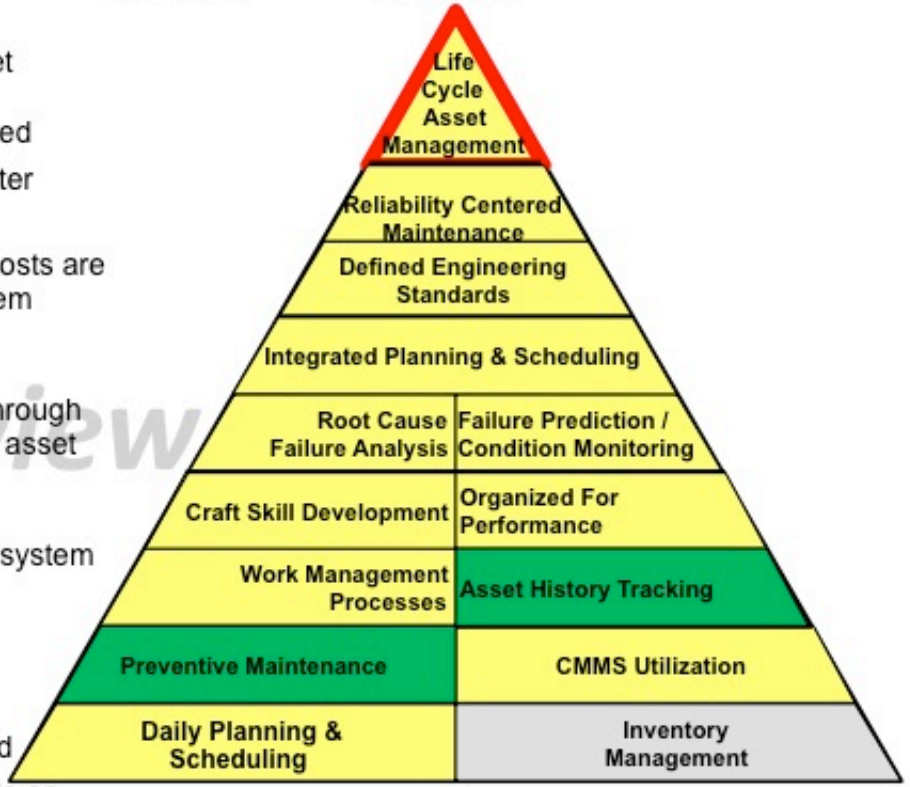
Level 5 (Best in Class)
- Full costs from planning for asset acquisition through operations through asset disposal are tracked
- Costs available from asset register

Level 4
- All maintenance and operating costs are tracked through work order system

Level 3
- All maintenance costs tracked through work order system and linked to asset register

Level 2
- Cost of major refurbishments to system are tracked
- Asset investments also include purchase and installation costs

Level 1
- Not practiced -- Purchase & installation costs only are tracked
- Asset investment decisions made on a pure cost basis



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Life Cycle Asset Management Observations

Community Services (Parks)

- ▲ CS is in the very preliminary stage of Life Cycle Asset Management practices
- ▼ Lacks sufficient asset part use history, actual work hour history on asset repair
- ▼ Lacks integration with County asset management and financial Strategy

The Annual Funding Model

The typical annual funding model, and accepted as a practice standard suggests two to four percent of the current replacement value be provided to maintain the portfolio at an acceptable service level, and ensure the portfolio meets expectation of the economic service life.

The 2% to 4% suggested annual spend is composed of:

- Operating expenses
- Project expenses
- Capital expenses

Renewal funding is obviously critical to maintaining the County portfolio and ability to provide essential services.

The total portfolio for the County is estimated to have a Current Replacement Value (CRV) of $1.1 billion dollars in current adjusted dollars.

It is important to note that although the total portfolio is estimated to be $1.1 billion dollars, the Consultant conducted a visual inspection and evaluation of approximately 73% of the County's portfolio (by square footage), or 87.7% by estimated value.

At the $1.1B CRV, the suggested annual funding would be $22.0 to $44.0 million dollars.

Current Renewal Spending and Need on Evaluated Portfolio

Jorgensen constructed an econometric model for each of the forty-seven report groups. Each model consisted of several sub models including:

- A current replacement value model
- A systems condition model
- A spend allocation model
- A capital replacement model

As a result of the modeling process Jorgensen determined the current renewal spend is approximately:

- $7.4 million dollars in General Services renewal spending
- $4.6 million dollars in CSD-Parks renewal spending
- $2.0 million dollars other departments renewal spending

The current renewal need was modeled to be:

- $19.2 million dollars (at 2% of the CRV) for the evaluated portion of the County portfolio
- $2.9 million dollars (at 2% of the CRV) on the unevaluated portion of the County portfolio

The total annual renewal funding need is $22.1 million dollars

Using a 20-year planning horizon, the long term funding is depicted on the page following.

Projection of Current Funding Model

After considering the evaluated condition of the County's portfolio, current funding levels, projected funding levels, projected rates of inflation, general facility deterioration, specific major systems deterioration, and the general aged condition of the County portfolio, the model indicates that the current funding scenario is not sustainable and will lead to an increasing level of deferred maintenance and drives a Facility Condition Index in excess of 50% at the end of a 20-year planning horizon.

The graphical relationship of the variables is presented on the page following.

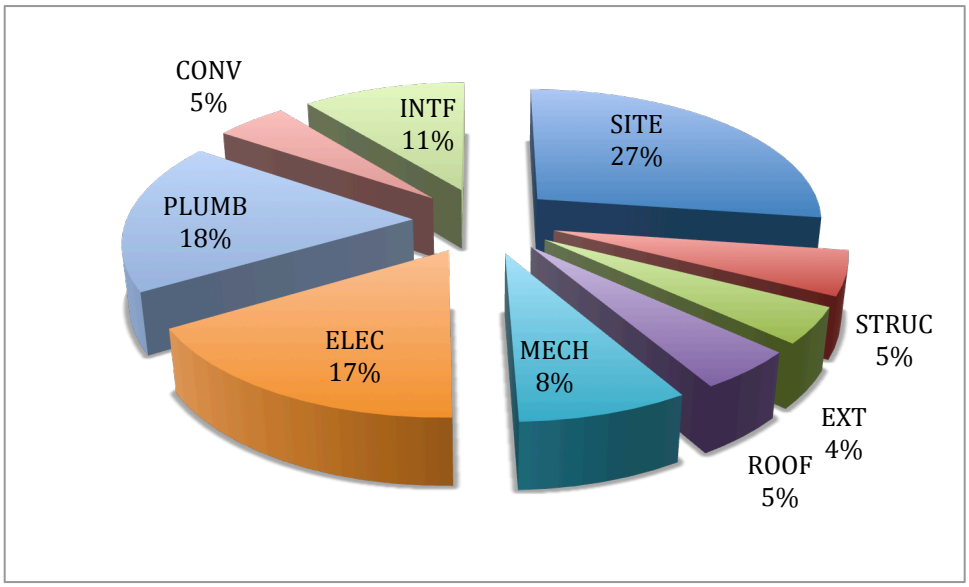

Figure 8: Funding Requirement by System Element