Maintenance Audits

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Abstract

This paper is intended to provide the reader with the basic understanding of necessary techniques to conduct an internal review of maintenance effectiveness. The technique of information mapping is described, which is intended to assist with analysing internal relationships or relationships between operations client and maintenance service provider. The need for a quantitative approach for the audit is described and a simple five point ranking is discussed with case study examples.

1. Introduction

The general benefits of the audit and strategy development process include:

1. A company may evaluate a process of quantifiable maintenance management and condition assessment associated with an improvement process that can be rolled out in subsequent projects to their field staff. New concepts and approaches may be promoted in the field in a non-threatening way.
2. Greater exploitation of condition and maintenance information to optimise planning of maintenance and capital expenditure. The project will review a number of data sources and introduce new techniques through check sheets and supporting analysis systems.
3. The company may establish the design requirements for a corporate maintenance system which can demonstrate due diligence, plus assist in planning and auditing both operational and capital expenditure. A specification for a more comprehensive system may be formulated based on the known capability of staff to exploit such a system, [1]. The project will highlight cultural as well as technical barriers to such dramatic change in asset management.

The issues to be addressed in the audit are set out pictorially in Figure 1.1. These cover the spectrum of concerns and areas for improvement, each of which will contribute or enhance a specific improvement task over in another area.

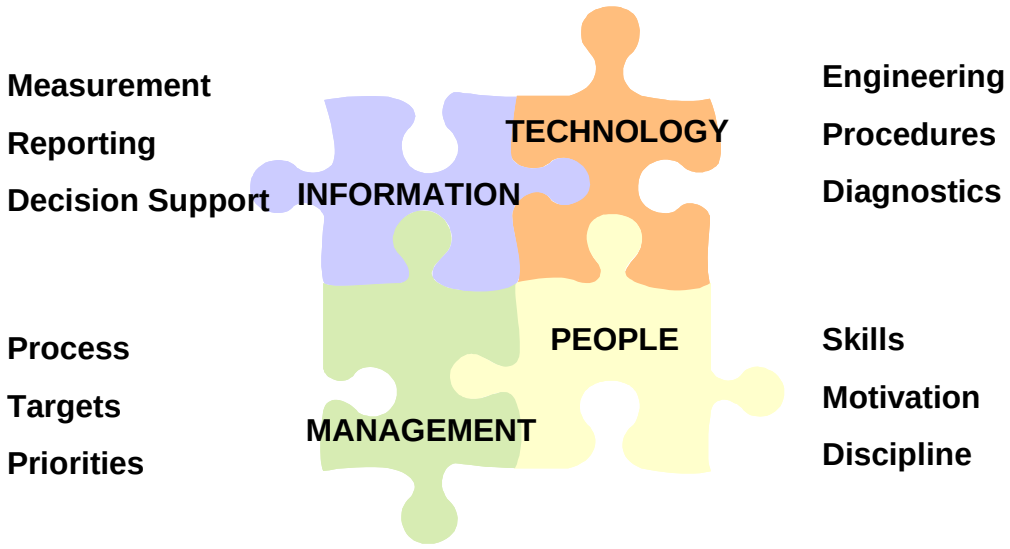

Figure 1.1 Issues to be addressed in the audit

Currently, a typical organisation has the perception that:

1. There is good field knowledge on the part of the trades staff.
2. The business is lean enough in numbers, so that people are not concerned for their job.
3. Plant availability is good.

Typical problems that are encountered include:

- Poor technical management systems – organisation of work to improve efficiency and output of work
- Poor use of information systems – too much time in data entry and no time in analysis
- Limited understanding of how to analyse equipment condition
- Limited use of operational reliability statistics – but some sectors can be quite good
- Inadequate training in maintenance strategy – exposed to the buzz word syndrome
- Need to broker communication paths between maintenance managers and operational managers

However, despite the above problems, the auditors have to keep their perspective, remembering:

- At the shop floor level most people are competent at what they do and there is at least reasonable if not excellent communication.
- We are starting to capture information in the maintenance information system (CMMS).

The auditors should never lose sight of the fact that in general the production demands have been met by motivated and knowledgeable individuals, and that the company is in business to use the assets and not to maintain the assets – it is not a perfect world and trade offs are essential. The art of auditing consists of:

- Listen and be patient
- Sift the complaining for solid fact
- Remove all prejudice and empathise with those interviewed – see it from their point of view
- Do not hide poor capability under the "cultural" carpet
- Look for the positive aspects:
    - Support
    - Systems
    - Training
- Work towards a road map for improvement that is not "borrowed" from somewhere else

There are many variants of maintenance audits in place through the commercial offerings of a variety of consulting practices and larger engineering firms. This document seeks to offer a selection of concepts from the author's experience plus the results of current literature. It is up to the delegates to take those pieces of advice and demonstrable good practice away with them, to test them in their own work place and to follow a path to improvement consistent with their people's capability.

2. Information Mapping

To better understand the operation of the organisation structure, an analysis should be completed that closely models the interaction between all positions across the field crews and maintenance engineering support, in order to achieve a One Team approach, [2]. Information mapping clearly identifies the reports that a person will receive from other members of the team.

The information map is provided as a matrix, which may be explained by the following diagram. It is important to appreciate that the design of the maintenance team clearly integrates all company staff into a single team, with internal lines of communication. The technique can be extended to include local contractors, once the teams are finalised. Hence line managers are able to see where they need to provide guidance and maintain control of the overall process, plus also where their feedback is coming from.

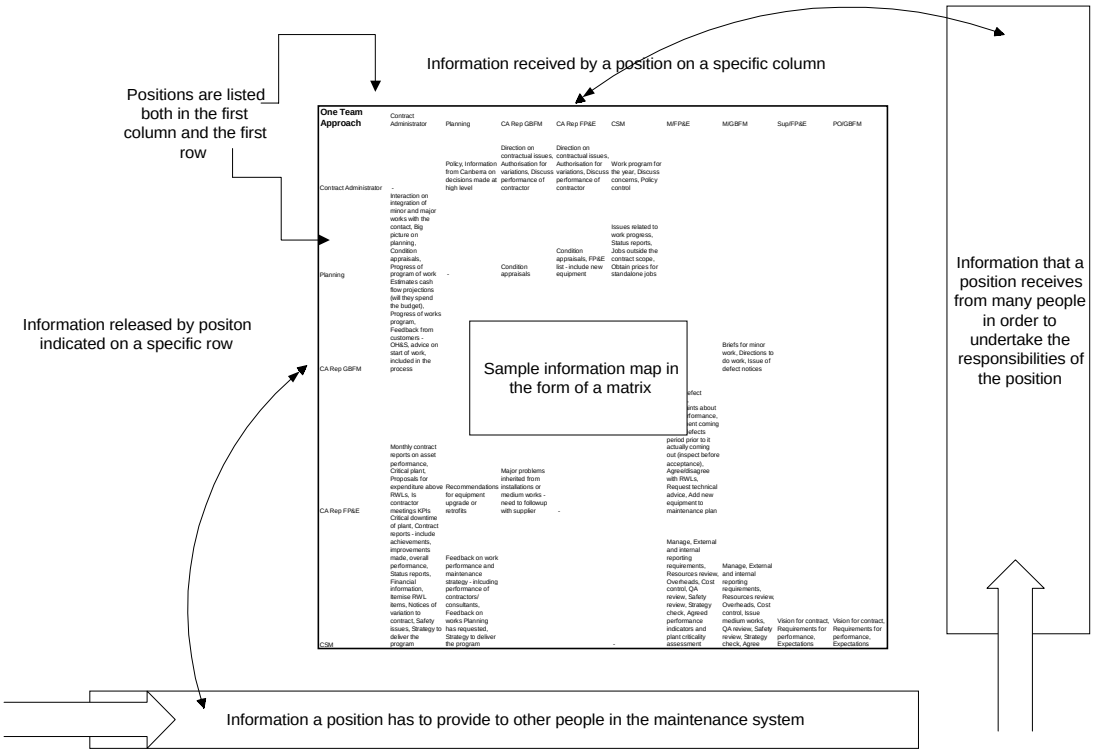

Figure 2.1 Information Mapping process

An extract from the information map for the proposed One Team Approach for one company is tabulated below:

	Process Manager	Scheduler	Analyst	Maintenance Manager	Operations	Dispatcher	Team Leader	Trades
Process Manager	-	Manage, Priorities of plant, System reports on starts/stops	Manage, Priorities of plant	Long term work packages, Dollars necessary for work program, Compliance to package issues, Machines we have outages on, Machines that are critical		Market issues, need for plans, why decisions are made the way they are	Mentoring in plant issues, Market issues, need for plans, why decisions are made the way they are	Mentoring in plant issues, Market issues, need for plans, why decisions are made the way they are
Scheduler	2 year schedules, Revised risk profiles, Budget tracking, Identification of root cause of failure analyse, Planned versus unplanned, Backlog, Commitment to programmed work, Compliance to package	-	Requirement statement on how data is to be provided in order to assist maintenance planning, Machine outages, when routines are coming up - oil, vibration, PDA	2 year schedule, Identification of root cause of failure analyses, Supply of provisional outage plan for comment on time allowances and procedures, Outage needs to be changed, Long term planning - condition assessments, Machine outages likley in next 2 years	2 year schedule	Job package exists, Priority needs to be explained, Timing, Access time limits, AES work list in CMMS, Preliminary priorities, Packages of work (fortnightly), Motional $ cost of project packages	Outcome expected from work, PM procedures to be reviewed when they are scheduled, Risk assessment of the job, Changes made to job procedures as requested, What is necessary for building a job, awareness of standard activities in CMMS	What is necessary for building a job, awareness of standard activities in FMM
Operations		Operating condition of plant		Operations training requirements	-	Operator availability		Info from System Control on machines start/stop on daily basis

Mapping the information flow provides a detailed insight into how the maintenance strategy will be implemented. The matrix identifies responsibilities and assistance to specific positions. The individual's capability is removed and replaced by the position description.

It is possible to map the interaction between teams of people through information mapping and communicate the expected manner in which interaction should occur through simple feedback such as in Figure 2.2

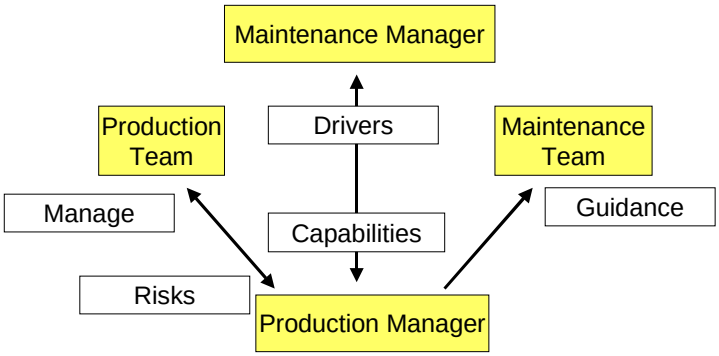

Figure 2.2 Simple Team Interaction

Details are critical to the success of information mapping. For example in one exercise, "Work" consisted of:

Job package exists, Priority needs to be explained, Timing, Access time limits, AES work list in CMMS, Preliminary priorities, Packages of work (fortnightly), Motional $ cost of project packages
Operating hour triggering of work, Triggering of condition monitoring results
Outcome expected from work, PM procedures to be reviewed when they are scheduled, Risk assessment of the job, Changes made to job procedures as requested, What is necessary for building a job, Awareness of standard activities in CMMS
Explain why CM is necessary or what procedure is trying to do, Advice on spare parts type and holdings, Feedback on research, What information is needed - what quality and how much, Feedback on condition of plant

As shown in Figure 2.3, the information mapping exercise is guided by the corporate intentions locked up in the formal position description documents.

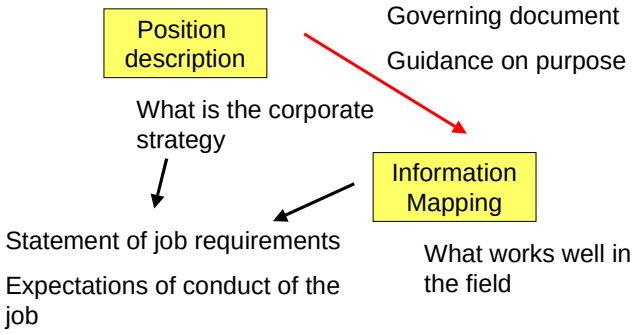

Figure 2.3 Relationship of Position Descriptions to Information Mapping

Information mapping is quite different from process mapping. In the author's experience no one reads the process maps, people bypass the agreed process systems, and detail can be absent. However, specific circumstances need to be process mapped, and include details. These include safety issues such as permit to work systems Process maps can be good for general communication if kept simple and relevant. Information maps have a wider appeal since they can be used to track gaps in the overall system, and assist in communicating the vision of an organisational structure to deliver improvement.

3. Conduct of the Audit at the Site

Check sheets can be used to collate some baseline data.

For example, in one type of audit, which is more engineering focused than strategy focused, an agenda for each stage in the process may look like:

1. Meet with site team member for improvement program
- issues at the site
- identifiable targets for improvement
- overview of people, systems and interaction at the facility
- layout of the factories, including provision of drawings of factory layouts
- naming of key manufacturing process lines

2. Site inspection
Walk around assets, check house keeping, assess knowledge of process on part of guide, learn of major issues. The check sheet used in this type of walk around is shown in Figure 3.1.

		Condition	Surveillance Option	Criticality	Critical Component 1	Critical Component 2	Critical Component 3
	Air Blowers						
	Air Preheater						

Figure 3.1 Sample check sheet for assessing equipment condition

The ranking system for the equipment condition scores is tabulated:

	Condition	Surveillance Option	Criticality
A	Good to excellent condition	Visual inspection – audit only	Level 2 item may need to stop
B	Work needed	Advanced inspection type – audit only	Level 1 item will need to stop
C	Significant availability hazard	Visual inspection and report – frequent operations	Level 1 item stops

		requirement	
D	Major process hazard. Loss of capital. Closure of business unit.	Operations audit performance regularly	Facility will need to stop
E	Personnel hazard. Major environmental hazard. Closure of facility.	Permanent monitoring of performance	Facility stops immediately

During the course of the inspection, the host will provide a continuous stream of comment on reliability and maintenance issues with respect to the equipment being observed. As much as possible, key information regarding this description should be noted down for further consideration, both in terms of the plant engineering and the knowledge the plant people have of their systems.

This walk around is extremely useful for identifying priority concerns that will benefit from maintenance improvements

3. Meet with Production representative
- standard production reports that we can take away
- organisation chart for production teams
- skills capabilities of production teams in understanding their plant
- willingness to be involved in maintenance
- current common problems
- high cost areas
- high risk to production areas - high frequency/low consequence, low frequency/high consequence
- reliability issues

4. Meet with Maintenance representative
- manner in which work is raised
- concept of work orders
- tracking of work
- information systems used
- planning of work
- reports on performance issued
- annual budget preparation papers
- capital works in hand
- org chart
- OH&S systems, sample minutes from committee
- use of condition monitoring, sample reports, use of data
- vision for improvement
- key reliability areas
- planning for overhauls

5. Sampling of information
- where are manuals, drawings, PLC software kept
- what manual and computer systems are used
- asset register
- numbering system of plant (if any)

- inspection reports
- overhaul reports
- overhaul contracts (if any)

6. Meet with Technology representative
- what information is collected
- export requirements, documentation
- critical issues - plus current problems
- sample reports we can take away
- involvement of equipment reliability, integrity in export license audits

7. Baseline check with shop floor supervisors
   - refer next section for the 5 point audit

8. Review and cross check
- have we got all of the information we need

4. 5 Point Audit

The perception of the adequacy of the maintenance system may differ between the senior levels of management and the shop-floor. It is important to capture both groups' impressions of how the system is performing. This can be done with the type of check sheet shown below. In such an interview it is important that there are two people conducting the interviewing, and the number of people being interviewed at the same time can be more than one, but should be no more than three.

The means by which a score is allocated is by the interviewers each ticking off on a separate score sheet their impression as to the credibility of the answers using a five point scoring process. We have adapted this process from an environmental scoring process developed for environmental auditing.

5	Exceeds requirements in terms of compliance and effectiveness of control measures implemented in all aspects; doing much more than required
4	Meets all requirements in terms of compliance and effectiveness of control measures implemented in all aspects; doing sufficient to meet all requirements
3	Meets most requirements in terms of compliance and effectiveness of control measures implemented in all aspects; not doing sufficient to meet all requirements
2	Meets some requirements in terms of compliance and effectiveness of control measures implemented in all aspects; not doing sufficient to meet all requirements
1	Minimally meets requirements in terms of compliance and effectiveness of control measures implemented in all aspects; doing minimal to meet all requirements
0	Not addressed; no requirement met
N/A	Not applicable

A simpler scoring level is:

1. Non-existent
2. Minimal and inadequate
3. Doing enough to get by

4. Suitable for what is necessary
5. More than sufficient or necessary

Where the two interviewers compare notes later on and are seen to agree, this is indicative that there is a credible score for the condition of the maintenance system, irrespective of any privately held belief of the company. Where the two scores differ, and assuming that both interviewers were attentive to the point, then the lower score may well be valid since clearly the people being interviewed did not sufficiently communicate their understanding, irrespective of their actual expertise. The primary source of error in this case is any specific bias on the part of a particular interviewer who may well have a pet interest. This may have to be taken into account by the person accumulating the scores.

Sample check sheets for the interviews are shown below. The sample is taken from an actual audit and demonstrates the method of split scoring, where the interviewers may have a slight or even significant difference of opinion regarding what they are hearing by way of response. In addition comments have been left on the table where they do not conflict with commercial confidentiality, to be indicative of the type of answers one might expect.

ITEM	SCOPE OF AUDIT	CRITERIA	SCORE						
			5	4	3	2	1	0	N/A
1	**Asset Specification**								
1.1	Hierarchical model of the plant dictionary	Plant dictionary exists			2				
		Hierarchical structure					1	1	
1.2	Consistency of naming	Plant naming is clear and obvious					1	1	
		Plant naming is consistent		2					
1.3	Documentation and consistency of information	Manuals are readily available			1		1		
		Drawings are in a database and easily accessible						2	
		Drawings are in English and easy to use							2
		PLC software is well managed				1	1		
		Technical information is readily available			1	1			
		Warranties are listed and implemented			1	1			
1.4	Adding/subtracting/modifying assets	Procedure for adding new plant to the maintenance system		1		1			
		Retirement of plant is well organised		1	1				
		Retired plant is decommissioned and removed		1	1				
1.5	Design capability understood and registered	Equipment capability is understood at the time of purchase		2					
		Equipment capability is understood by maintenance staff who return it to that condition			2				
1.6	Spare parts	Availability, criticality matrix is used to ensure necessary parts are held		2					
		Supplier contracts are in place		2					
		Knowledge of parts needed for different types of work well understood		2					

2	**Work Management**								
2.1	Work order completeness	Work orders are used on the site		2					
		Date raised and date acquitted recorded	1		1				
		Who raised recorded	1		1				
		Task description clear		1	1				
		Cost area tracked						2	
		Priority system is consistent		2					
		Work type understood and recorded accurately						2	
		Item identification according to consistent plant dictionary		1	1				
2.2	Capture of history and review of history	Task outcomes clearly recorded		1	1				
		History of tasks on plant item available for further review		2					
2.3	Work flow system (BD, planned work, special work)	Work flow system defined for the facility			2				
		Registration of work is consistent and sources of work are not numerous		1	1				
		Work tracking and resource scheduling is possible		1	1				
		Acquittal of work is consistent		2					
		Work back log is tracked and managed		2					
2.4	Skills match and appropriate competency	Trades skills are well developed	1	1					
		Long experience and profound plant knowledge	2						
		Skilling and development of trades is consistent and extensive	2						
2.5	Performance tracking and identification of poor work	Position responsible for review of work	1	1					
		Repeat work identified		2					
		Work types analysed for efficiency and priorities		2					
		Report on work completed and outstanding work	1	1					
2.6	Contractors/ tracking equipment off site	Contractor work is well defined	1	1					
		Good relationship with experienced contractors	2						
		Equipment off site is tracked and followed up		2					
2.7	Forward planning	Culture of forward planning in a systematic way	1	1					
		Cyclic, one off work is well planned and efficient		2					
		PM - preventative maintenance schedules			1	1			
		BD - breakdown maintenance is rare and well managed			2				
		PDM - predictive maintenance - culture exists and integrated with work management system			2				
3	**Ability to Provide**								
3.1	Stoppage tracking system	Stoppage system in place	1	1					
		Manual system effective - operator logs are clear and read		2					
		Equipment stoppage electronically tracked, eg linked to PLC's	2						
		Product spoilage tracking system in place and used	1						1

		for planning							
3.2	Equipment failure tracking	Downtime tracking system in place		1		1			
		Operators have a manual system to track equipment failures		1	1				
		Equipment failure electronically linked to PLC's						2	
3.3	Criteria for equipment failure or partial loss of availability	Impact of partial loss of availability understood and tracked		2					
3.4	Improvement team	Business improvement team in place and responds to reliability information		1				1	
		Management support for improvement team	1						1
3.5	Expected service lives	Service lives are forecast as part of the capital planning process		2					
		They take action on an understanding of service life		2					
		Operations/maintenance meeting reviews current status of equipment and likely threats		1					1
		Focus element for analysis of equipment availability		2					
4	**Asset Condition**								
4.1	Inspection program	Inspections are a strong part of the maintenance culture		1	1				
		Cyclic schedule of inspections well understood and followed			2				
		Method for capturing data in place and allows reporting (trending)				1	1		
4.2	Skills levels of inspectors	Inspectors of plant condition are present and knowledgeable		2					
		They are well briefed on what to look for	1	1					
		Inspectors know what happened before on the plant they look at		2					
4.3	Analysis of results	Results of inspections are available for analysis with history emphasised				1	1		
		Are they suitable for objectives					1		1
		Analysis and error checking is possible					1		1
		Results are widely available					1		1
		Results are analysed and acted upon			1				1
4.4	Technology	Company actively searches for new technologies for inspection		1		1			
		Performance review of techniques - did they prevent failures			2				
		Visual analysis is systematic and recorded				1	1		
		NDT is employed and effective		1	1				
		Condition monitoring is employed and effective			2				
		Other procedures are employed and effective (Comment on them)			1				1
		Inspeciton technology is appropriate for use			1				1
		Company understanding of results		2					
		Results are stored in a manner suitable for trending				2			
5	**Risk Mitigation**								
5.1	Strategy development	Risk mitigation strategies are published and acted upon			2				

		Risk-based priority setting of activities		1	1				
		Quality management principles in engineering work - documentation, process and measurement		1		1			
		Company unique approaches in place		2					
		Upgrade path of equipment is well understood	2						
5.2	Reduction of internal waste	The concept of waste is understood - efficiency of work, appropriate spending		2					
		Optimise total scheduled work accoridng to a plan	2						
		Reduce held inventory in a sensible fashion that does not mask critical spares		1	1				
5.3	Culture	There is strong motivation in the maintenance and operation teams to work together	1	1					
		Truth in the system on reporting on work and condition	1	1					
		Accuracy, timeliness of feedback of all data		2					
		Minimum perturbations to plans		1			1		
		Vertical communication of results	1						
5.4	People skills	Management enthuse their operations and maintenance staff	2						
		Company has knowledge in maintenance strategies	1		1				
		Training of key staff in advanced systems	1		1				
		Fault diagnosing and root cause analysis applied	1		1				
5.5	Information systems	Company uses mature, well integrated information systems			1	1			
		Wide spread reporting of results		1	1				
		Many people use the systems as part of their work		1		1			
		Complaints are monitored and addressed		1	1				
		KPI's are meaningful, people understand them			1				1
		KPI's are the basis for planning			1				1
5.6	Procedures	Procedures are integral to the planned work				2			
		Procedures are regularly updated according to good engineering analysis				2			
		Procedures are followed and checks are in place to ensure that they are followed			1			1	

5. Outcomes

Possible priorities for policy development, identified by a maintenance audit, are listed in order of significance, commencing with most significant:

1. Development of work systems – formalise how work is raised, region to local service agreements
2. Inspection management – formalise
3. Condition assessments – develop a baseline
4. Reporting – develop simple CMMS reports such as total work, backlog
5. Procedures – develop these within the context of normal work, and refine list of procedures to write to focus on high risk items as these become identified
6. CMMS – introduce due date on work order policy
7. Downtime logging – reliability assessment
8. Engineering expertise – training for professional engineers
9. Risk management – implement criticality checking on work orders

10. Reporting – develop advanced reports such as frequency of attendance, time to complete, top 10 killers per month
11. CMMS – investigate stores holdings and material tracking
12. Personnel competencies – establish training profiles, training needs
13. CMMS – investigate cost tracking
14. Advanced condition monitoring – training competencies
15. Information systems – dissemination of maintenance reports through Intranet

This list is not exhaustive but all items will need to be well in hand before a company could consider that they are approaching best practice. The tasks associated with maintenance improvement may be distributed across a company at the following levels:

Corporate - technical expert - asset strategy - information systems	▪ Long term plan ▪ Strategic risk – major capital works ▪ Strategic risk – generic plant types ▪ International knowledge ▪ Technology update ▪ Design and creation of systems ▪ Cost capture system – needs to be designed ▪ Strategic R&D
Divisional - engineering manager - engineering staff - divisional/regional planners	▪ Implementation of systems ▪ Refinement of capital plan ▪ Scheduled operational work plan - divisional/regional policy document ▪ Condition monitoring strategy and system plan ▪ Capture, analysis and reporting of costs ▪ Business support to local managers ▪ Stores management system – needs to be designed ▪ Training profiles of divisional/regional staff ▪ Period order contracts ▪ Engineering analysis ▪ Failure analysis ▪ Technology upgrades ▪ Tactical R&D
Local - local manager - local planner - generation technician - fitter/operator	▪ Maintenance implementation ▪ Short term work packages ▪ Immediate management of contractors ▪ Reliability analysis ▪ Cost capture ▪ Audit of maintenance performance, quality of work ▪ Labour training, teams development, problem solving ▪ Work systems development – requests for services, raising of work, backlog management

The elements of good practice maintenance are tabulated below. In the final report from the audit, the performance of the company is associated with each element.

	Item
1	Clear business goals and expectations of asset management, which is reflected in policy documents relevant to all groups and levels within the organisation.

2	Performance measures are reported at senior levels, technical levels and to general staff.
3	Reliability analysis is used to measure effectiveness of work plus identify forward threats to the business. Data is used in cost-benefit justification of work.
4	Functional assessment and condition monitoring.
5	Work management systems are clearly specified as organisation policy. This specifies work types, how such work is to be raised and who has responsibility for planning, execution and quality check.
6	Risk profiles are extensively used in capital plans, maintenance priority ranking and reporting on work performance.
7	Work tracking is meticulous, with minimum amortisation of work.
8	Spares inventory management
9	Failure analysis and root cause analysis is applied in the case of all breakdowns and failures.

6. Conclusion

The future of maintenance lies in its contribution to shaping the future of overall asset management. This future has the following elements:

- Increasingly diffuse sources of data which, when managed correctly, will improve the accuracy and timeliness of information, [3].
- A greater utilization of process knowledge to determine how the operations impacts on the maintenance burden.
- The dissemination of risk analysis technology so that work is initiated on the basis of an unacceptable risk rather than either a time or plant integrity condition.
- Team building and multi disciplinary problem solving which is based on a sound management of information.

The fine detail of maintenance management includes specifying all of the equipment, managing spare parts, project management and critical path analysis, and all of the minute detail that currently occupies maintenance planners, [4]. We will see information management techniques increasingly introduced which will improve the efficiency with which people will manage the detail. The new technologies indicated by the elements above will increase the focus on the common sense aspects: why do we do maintenance, when should we do it and what is causing our problems?

To sustain our progress towards this future, the objectives and scope of a maintenance audit may be summarised as follows:

- Assess status of condition and performance of the facility and provide recommendations for improvement.
- Assess the status of maintenance support performance and reliability assurance;
- Review conformance with statutory requirements including environmental and OH&S codes and licenses.

- Identification of systematic risks including environment, OH&S hazards, human health risks, and risk to major equipment or operations which would result in a critical period of lost production, and to provide recommendations for mitigating these risks.
- Provide a system and opportunity for training of plant management in self-improvement.
- Provide a foundation for immediate short-term maintenance improvement strategy as well as concepts for a strategic plan.
- Measure the success of past initiatives.

It has to take into account the strengths of past and current improvement programs, but also identify where these can be jostling for resources and management focus.

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References

1. R Blayden, Business Improvement – Analysis of Benchmarking Information provides new Insights into How to Improve Maintenance Performance, ICOMS 2000, paper 036, Wollongong 2000.
2. M. Adra, Maintenance Management & Teamwork, Strategic Maintenance ’00, Melbourne, 1999.
3. RH Clark, Data, Information and Computerised Maintenance Management Systems, ICOMS 2000, paper 072, Wollongong 2000.
4. J. Johnson, Development of Successful Maintenance Programs for Reliability and Customer Satisfaction, Mainstream 99, Sydney 1999.