

FROM REACTIVE MAINTENANCE TO PROACTIVE PREVENTIVE MAINTENANCE SYSTEM

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Summary: A maintenance system is presented in this paper that has been implemented in a number of companies. The system has four key elements. The first element is specifying all equipment to be maintained in a hierarchical system, covering issues such as criticality of equipment. The second element is development of an efficient but comprehensive maintenance procedure database. The next key element is provision of a master maintenance schedule that ensures all registered equipment is covered by an appropriate procedure. The last element is implementation of the maintenance system through load-up to a computerized maintenance management system (CMMS) of choice. The main outcomes from introducing the proactive preventive maintenance system includes moving the site from breakdown maintenance to preventative maintenance, ensuring that all statutory compliance obligations are met, eliminating frequent causes of loss of reliability and reducing the cost of maintenance.

Keywords: Maintenance System, Breakdown Maintenance, Preventative Maintenance, Scheduling, Change Management.

1 INTRODUCTION

In a typical reactive system most of the effort of the maintenance team is spent on responding to breakdowns. There is little or no planned maintenance activity, and work is prioritised in a random manner (responding to breakdowns) with no regard to the business drivers. Such a regime keeps the organization operational, but at a very high cost. The cost is high due to the unplanned stoppages in production that are frequently associated with time lost in obtaining spares to complete the repair. In such a regime it is difficult to complete preventive maintenance procedures (PM) as maintenance staff are constantly responding to breakdowns (BD). Very little if any time is allocated to PM work. The unpredictable and random nature of breakdowns does not allow work to be planned. Frequently such systems do not keep records of work done that would enable reliability engineers to attack major reliability issues.

A proactive maintenance system is not free of breakdowns, but the breakdown can be related to the organization's business drivers via assigned criticalities. A piece of equipment that has a low criticality assigned to it can be scheduled into next weeks planned activities. A proper managed maintenance plan allows capacity to attend to urgent breakdowns, i.e. those with a high criticality. It also allows the maintenance team to control the maintenance activity, rather than to be controlled by it. Equipment that receives adequate maintenance is less likely to fail, which makes it possible to have planned maintenance down time. Planned down time is far less costly than unplanned down time and does not have the associated loss and poor quality product associated with a BD. If a breakdown occurs on equipment that has been regularly maintained, the damage is generally not as bad as that on poorly maintained equipment. Apart from eliminating the operational inconvenience associated with a breakdown regime, a proactive maintenance system also results in a more cost effective maintenance system. This paper describes the four key elements of a proactive maintenance system, as the authors have implemented in a number of organizations and in a variety of industries.

2 PLANT DICTIONARY

The level of detail that is necessary for adequate maintenance systems design is quite extensive. This is often a major problem to the improvement team given the poor state of documentation and local knowledge regarding some machines, despite their criticality to the process.

Cluster mapping is an important technique for the team to understand the scope of a machine/process and its maintenance requirements. It is a means by which a complex machine is broken down into a logical hierarchy of maintainable items. A maintainable item is defined as an item for which an inspection is warranted.

Cluster maps are also there to ensure that the team does not waste time by delving so deeply into the machine that the team does not take advantage of both the trades competency of the people who maintain at the component level and the fact that much of the machine is designed to last until its end of life.

An example of a cluster map used in a food factory maintenance improvement process is shown below (1):

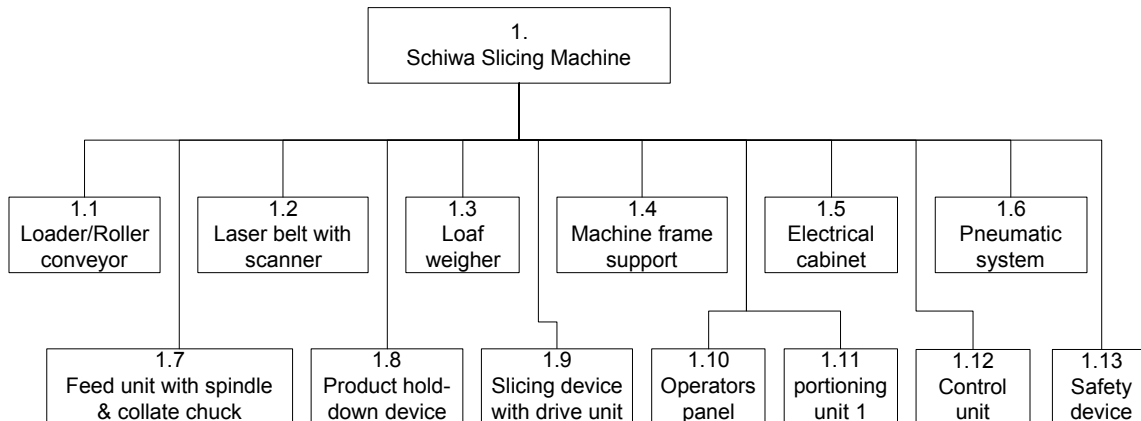


Figure 1 A Typical Cluster map

The system shown is a slicing machine. By tracking the system it is possible to simply determine a number of issues:

- Lowest maintainable units to be covered by the PM system
- Guide document to facilitate the criticality assessment process
- Identification of common types of equipment to facilitate the use of Standard Job Procedures

We recommend a three-tier policy for generating the plant dictionary:

1. The top tier is a multiple layer of levels assists in identifying the system or machine
2. The second tier may be one or more levels that are used to logically identify a group of maintainable items – the PM work order covering one or more inspections is assigned to an entity at this level. We try to use the minimum possible number of levels (i.e. one).
3. A maintainable item that needs to be checked or inspected – a PM work order is not usually provided for an item at this level but is more normally associated with a singular task such as a corrective maintenance work order or a breakdown.
4. The plant dictionary is structured according to a parent-child hierarchy outlined by the cluster maps. The plant dictionary includes important equipment information such as manufacturer, date of supply, serial number, criticality, equipment and location identifiers.

With respect to setting up the plant dictionary in a CMMS PMs (preventative maintenance work orders) will be attributed to level 2 items so these definitely need to be in the CMMS plant dictionary. However we may want to assign breakdown and corrective maintenance tasks to the level 3 items, so these also need to be loaded into the plant dictionary – this is a decision for the team putting the system together. There is often a tendency to attribute corrective work too high in the plant dictionary so that failure modes cannot be easily identified from the maintenance history. Hence an effective plant dictionary is one where a corrective task attributed to a child dictionary item clearly indicates the instance of a type of failure that may then be amenable to improvements in the maintenance plan.

3 MAINTENANCE PROCEDURES AND ROUTINES

This section is concerned with the identification and specification of Maintenance Strategies. These are procedures that specify a range of tasks for a specific type of maintainable item. The strategies set will be consequently allocated to many incidents of the same type of equipment across the site.

The procedures are divided into three levels:

Level	Attributes of the level	Expected personnel to conduct the level
1	Regular inspection that does not require the maintainable item to be opened up or, in most cases, halted for the work to take place.	Either Trades competent maintenance staff or local operating staff
2	Detailed trades procedure. Normally requires the maintainable item to be stopped and access allowed.	Trades competent maintenance staff
3	Expert or third party inspection of the maintainable item, commonly associated with condition monitoring. Can also refer to an expert NDT inspection, inspection by the machinery supplier or an external expert.	Scientific experts or 3 rd party personnel

Table 1 Three Levels of Procedures

The system does not specifically cope with the following types of tasks:

- **Daily checks** – these are considered to be parts of the Standard Operating Procedure.
- **Non-routine refurbishment or rebuilds** – these should be treated in a long-range maintenance plan, which can be provided under an asset management plan product.

The relationship of maintenance strategies to procedures and routines is identified below:

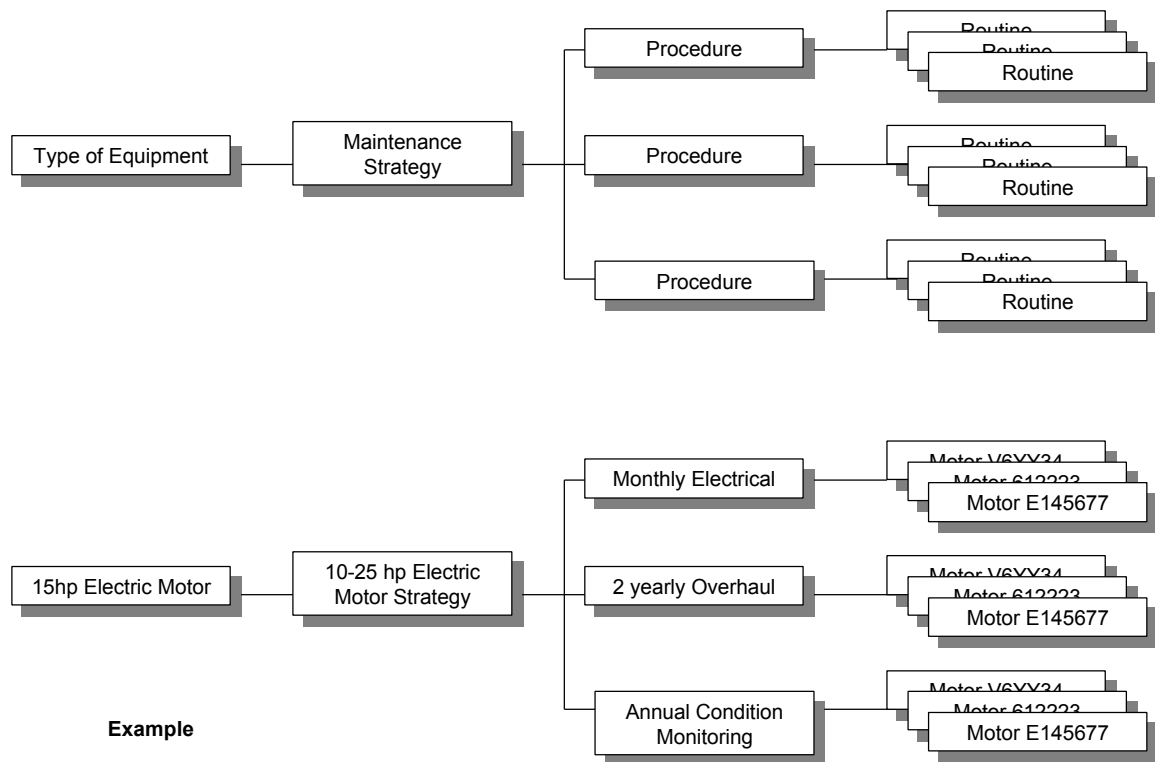


Figure 2 Maintenance Strategies

3.1 Procedure Design

The process for designing a procedure is as follows (see Figure 3):

1. Ascertain that no other procedure is relevant to the type – allowing for the fact that we may need more than one procedure for a type, based on variances in manufacture or design.
2. Identify the scope of the procedure based on elements on the plant dictionary – note that a procedure can cover more than one element. For each of the following steps work around each of the elements in a consistent manner.
3. Review the failure modes that are amenable to simple inspection and list suitable inspection tasks – action plus location of inspection. These tasks should include all external observations.

4. Note all internal checks that are required for inspections. List tasks according to area of access – what has to be stripped down to allow access. Determine if task is electrical or mechanical (note that all structural checks are considered mechanical). These tasks are also requiring trades expertise so calibration checks can be included here if undertaken by a trades person and not an external expert. If an external expert is required, refer the job to Level 3.
5. Determine task frequency and expected duration of the work – used for scheduling purposes.
6. Identify all functional testing that should be conducted – exercise of machine, exercise of alarm, exercise of limit switches, etc.

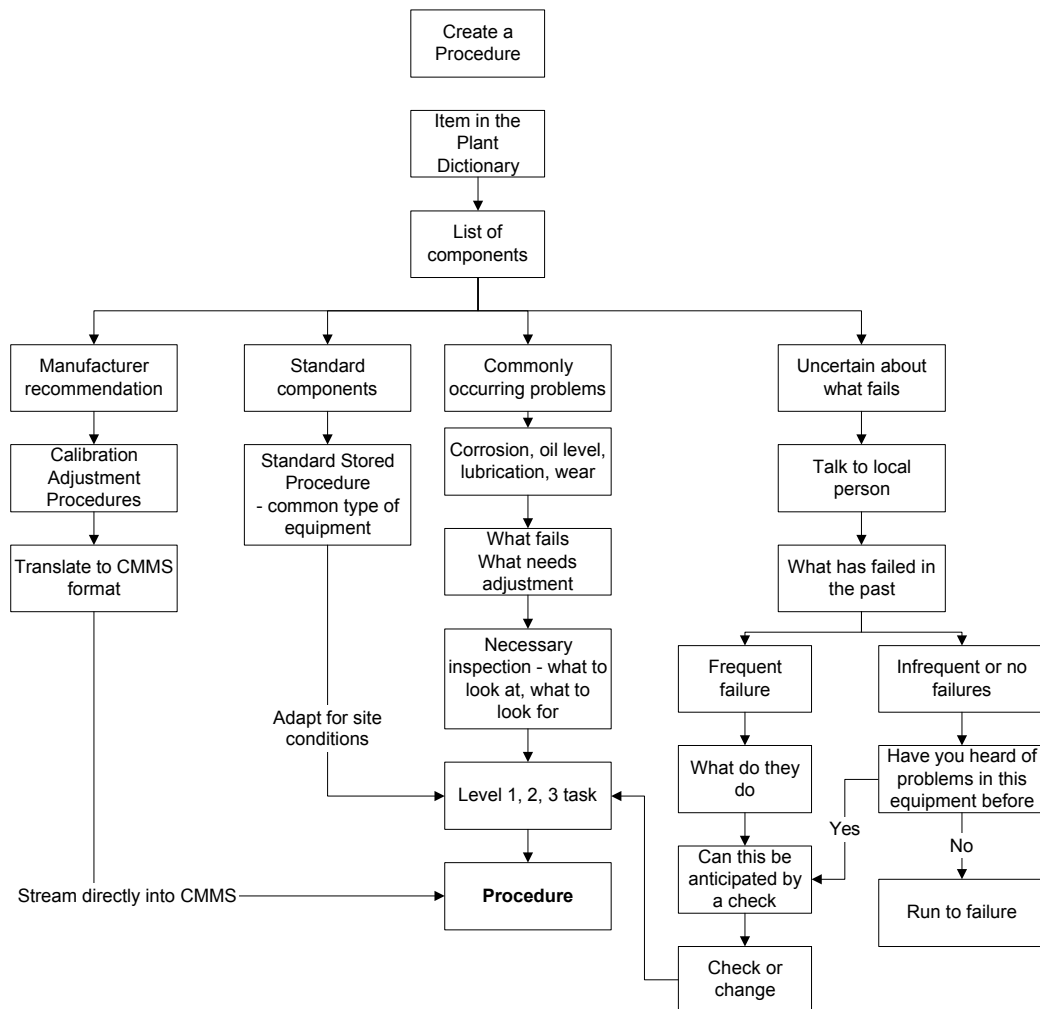


Figure 3 Procedure Design

Assigning a procedure to a specific item of equipment creates a routine. Specifying the timing of the first release of the routine as a work order is an important issue to obtain a balanced workload during the year and avoid the backlog built-up during the busy period of the year for the particular site. Adjusting the duration of the routine is required to allow for either travel or access to the equipment. Considerations in the timing of a routine can include:

Maintenance routes, e.g. lubrication rounds, where a number of routines are completed at the same time

Lumping of routines together based on the location of the equipment, eg servicing a plant room or servicing a line when it is down

Isolation requirements – how much equipment, up to the entire facility, needs to be off line

4 MASTER MAINTNENCE SCHEDULE

The previous section of this paper covered the generation of maintenance procedures and routines for maintainable items. Preventive maintenance work needs to be planned. The process for scheduling preventive maintenance work is provided in this section. This process sets out the generation of preventive work prior to it being loaded to the CMMS database.

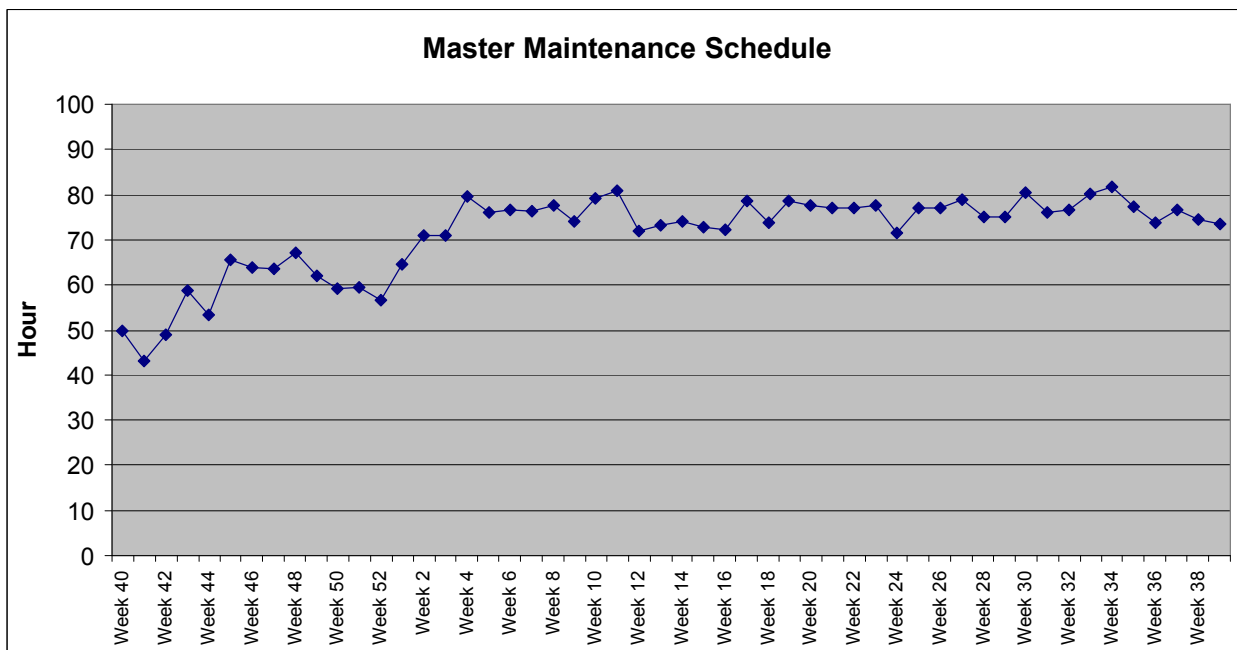


Figure 5 A Typical Workload

5 REPORTING KEY PERFORMANCE INDICATORS

A healthy maintenance management system should always be monitored with appropriate reporting system. The overall view of a maintenance planning and scheduling system is provided below. This identifies the key elements that are necessary for a well-controlled maintenance system. Two key metrics shown in Figure 6 are percentage of PM content in all scheduled work and percentage of scheduled work in total work done per week.

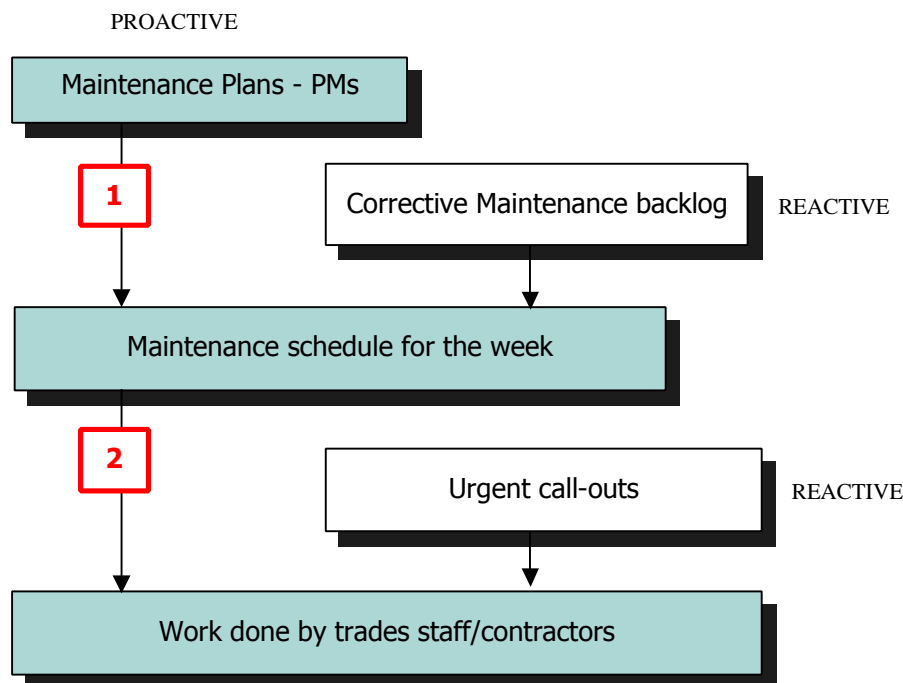


Figure 6 Overall Planning and Scheduling System

Key performance indicators (KPIs) form the basis of the monitoring process for performance-based maintenance. Use of the various KPIs will be dependant on the capability of the information system to provide accurate data for calculation purposes. Most CMMSs are capable of capturing most of the information necessary for these KPIs. Others should be developed in collaboration with production departments and require more involvement from the management to become alive (3).

Based on Figure 6 the recommended KPIs are shown in Table 2. In general both a target value and a transition value are indicated. The transition value should be adopted for the first year of operation at the site.

		Poor Maintenance	Target	Transition
1	% PM Work orders in weekly schedule	<40	85	60
2	% Work completed in a week which was scheduled the week before	<40	80	60

Table 2 Key Performance Indicators

Table 3 shows the data of a case study for the first six months of the introduction of a maintenance system (4). Both KPIs indicate the site was in a poor maintenance condition when the maintenance system was introduced. The case study shows a move from reactive maintenance to proactive maintenance in a period of six month from introduction of the maintenance system.

	January	June
BD	71	42
CM	18	25
PM	11	37

Table 3 Case Study

		January	June
1	% PM Work orders in weekly schedule	38	60
2	% Work completed in a week which was scheduled the week before	29	60

Table 4 KPIs for the Case Study

6 CONTINUOUS IMPROVEMENT

The proactive maintenance system is not the end of an improvement journey. Rather it is the first step in gaining control. Continuous improvement requires constant effort, and a good starting point is collection of reliability data, which can be stored and retrieved as required for reliability analysis. The reliability analysis of equipment should be linked to the business drivers. For example there is very little benefit in spending effort studying failure patterns on equipment that are of very low criticality to the business. The payout can be very significant however, if this energy is channelled into analysing the failure of a piece of equipment that is very critical to the business. Sometimes even a very small improvement can have a substantial impact on the business. The point is that the more critical a piece of equipment is to the business, the more attention it should receive.

The system described sets PMs up that are time based. This is not an optimum solution, but a good starting point if no other data is available. Over time, as data is available, and perhaps as some condition monitoring is implemented, the efficiency of maintenance can be improved by moving to condition based PMs. Even if the organization decides to stick with time based maintenance procedures, the intervals should be reviewed, based on criticality, and adjusted if required.

Equipment that causes problems should be identified and studied with the aid of FMECA (failure mode, effect, and criticality analysis) in order to better understand failure mechanisms and from develop more meaning checks and PMs. Special effort should be made to identify hidden failures, as these are not apparent at first and when finally identified, will cause significant failures that can result in substantial impacts on equipment availability.

So far the discussion has focused on equipment availability, but operational safety must not be sacrificed. Regular safety audits should be conducted in order to ensure safety is maintained, and that all equipment complies with statutory requirements.

After maintenance efficiencies have started to improve, the next milestone should be the optimisation of maintenance strategies to develop and achieve equipment life cycle strategies that are in accordance with business objectives and goals. An example might be that in order to ensure product quality and productivity, the life cycle of a piece of equipment may be limited due to technology induced change, rather than being due to the equipment reaching its wear-out stage. Such limitation on the machine life cycle would have implications on the maintenance strategy.

Modern TQM based improvement strategies, such as quality improvement team, should not be ignored. Improvement teams can be formed with members from maintenance and from production. If such teams are given realist, achievable goals, it is often astonishing what can be done.

7 CHANGE MANAGEMENT

One thing that should not be forgotten in this discussion is that without the support of top and middle management, the best intentions and strategies will not bear fruit. Top management must provide the vision and make a commitment to support the improvement initiatives and ensure that adequate resources are made available in order to achieve agreed goals. An appropriate goal setting strategy is important, in order for goals to be achieved. Paul Meyer (5) suggest the use of SMART goals, that is goals that are:

- Specific: goals that specify what the outcome should be.
- Measurable: an agreed upon way or method to measure progress of the agreed outcome.
- Attainable: the goal must be doable within the constraints of the organization.
- Realistic: the goal set should not be too trivial, but neither should it be too difficult to achieve given the organisational constraints.
- Tangible: there should be a realistic time frame within which the goal(s) should be achieved.

The above steps in goal setting help identify obstacles, which helps in the planning and controlling of the out comes from these goals.

It is equally important for management to communicate its vision for the change and the benefits for the organization to justify pushing everybody out of their comfort zone. If no buy in is achieved, a successful outcome is highly unlikely (6).

Going into this change programme, it should be noted that there are no quick fixes. If the maintenance department is flat out coping with BDs, it is unlikely that the same team will be able to add PM tasks to its activities without additional resources. Contractors may need to be brought in help with the extra workload in the transition period. PMs should be gradually added to the workload until the weekly schedule is obtained. This may take up to 12 months to achieve. It will be noticed that over time the number of Breakdowns will decrease as the number of PMs is increased. During the transition period effective backlog management is important. Jobs that are of low priority and risk may over time, if they are kept in backlog, become higher priority and the risk factor may also increase. Managing the change to a proactive maintenance system requires a lot of upfront work in planning and documenting the system. Therefore it is good to appoint somebody who knows the organization well as a change agent to drive the changes. This person may need to be supported by an external consultant. The external consultants can help take some of the workload of the change agent, but more importantly they are also the experts to which serve as referees in implementing the system.

8 CONCLUSIONS

This paper presented a methodology that allows organizations to break away from a reactive maintenance regime, to a proactive regime that is aligned with the business drivers or objectives. Four key elements were used to achieve the successful implementation of a maintenance system. The first element is a plant dictionary that has all maintainable equipment listed in hierarchical form. The next element is the development of a comprehensive and efficient maintenance procedure database, which should also include safety procedures as they relate to maintenance tasks. The third element is a master schedule that ensures all registered equipment is covered by an appropriate procedure. The last element is monitoring maintenance management system with a reporting system. All this information is linked together in a CMMS. The CMMS will allow efficient handling of the data and appropriate planning of work to be done. The CMMS will also store equipment data that can be helpful in future review of current maintenance strategies and help identify which items can benefit the organization if further improvements are made to the maintenance system. The change can only be brought about with the support of top management and the effective communication of the organizations goals to all employees. Once the change has been brought about successfully, that is not the end but rather the beginning of the continuous improvement cycle. Further improvements are absolutely necessary. The proposed system is only the first step, and needs much more post project work such as PM improvements, the implementation of condition monitoring where appropriate. Following that, the maintenance system should evolve into a strategy that includes life cycle analysis.

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