Improving Return from Maintenance

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Abstract

This paper is a contribution to the principal issues in formulating maintenance strategy and the integration of resources to conducting a wide range of tasks. The strategy relies on the implementation of rigorous systems and the use of information technology for decision support. An aspect of maintenance support is value add work where asset performance is to be enhanced through related studies, such as the case in this paper which focuses on the exploitation of inspection data and life forecasting.

1. Introduction

Improvement on return from maintenance commences with joint planning, and technical and strategy communication between production/maintenance and management groups. In particular large companies need to pay attention to integration of systems across different production centres, while taking account of local efficiencies generated by slightly different approaches to asset management.

There needs to be a meeting series for the local managers to ensure that the company acts as a single business, and to allow dissemination of good practice. This can be particularly beneficial when senior appointments are made with people who have come from outside the company culture. We rarely advocate internal engineering conferences since it is not clear that continuous conferences of this type would be of sustained value. However local managers need to cut across a mix of engineering, business and financial issues that need to be shared in order for the company to retain a single business focus.

By not directly encouraging such cross company communication, the local managers are often driving separate businesses, with separate culture and inward focused engineering development, which is not, in our opinion, in the best interests of the overall company.

The strategy proposed in our work to improve return from maintenance is based on a combination of maintenance engineering improvement and information technology. As a consequence this paper includes a number of standard reports taken from past work, which are intended to guide people towards focusing on what is important and justifying investment to prevent ongoing losses. It is common that companies are resource limited, and as a consequence attention needs to be focused. Avoidance in investment in useful information systems that lead to effective reports will mean gross inefficiencies and the tying up of precious analyst and trades labour.

2. Improving Return from Maintenance

Differences can exist across a large company in the following areas:

Structure of the local management.
Culture – senior people recruited from outside the company or division.
Culture – a particular group have focused on raising the level of maintenance analysis. Information is normally the means by which culture is altered or modified.
Engineering development – use of risk management, and detailed plant or process knowledge.
Labour planning – team-based strategies versus highly skilled individuals with extensive plant knowledge.
Business management – systems and team development, individual skills and development, use of long term staff and reduced turnover of people.

In one case study, two sets of facilities were compared:

	A	B
Strength	Information focused business models Risk assessment Clarification of purpose for employees – they know where they are headed Dedicated local level work schedulers who will develop and optimise their work allocation – this will lead to cost savings in the long run	Good plant knowledge in key individuals Introduction of condition monitoring limits Preliminary analysis of maintenance data Divisional/regional policy on use of the CMMS including training Good training of fitter/operators High level of functional testing observed (but was not well related to condition monitoring with discrepancies reported)

Common Weakness	Need to be more company focused rather than divisional/regional focused Poor focus on cost tracking, e.g. $ maintenance/output for each facility Poor management of materials tracking with no link between work orders and stores booking Communication between local managers across regions Sharing of technical expertise Need to develop a common CMMS development strategy Cohesive and joint application for targeted services from corporate, e.g. 30 year plan, technical services, risk management Extremely poor training and development of professional engineers Need for HR profiles on individual's training needs Need for improved quality control of documentation, manuals and drawings	
Weakness	Many development targets set including maintenance analysis, scheduling, condition monitoring, work systems High turnover of staff, e.g. many people at one station very new to the job Rapid expansion of procedures set to cope with new personnel – what are they learning from experienced northern personnel? Low level of functional testing observed – will lead to unforeseen capital hits Inward looking to cope with the many projects and changes	Inconsistent support for the CMMS Poor data entry and information management for unmanned power stations Inability to measure their management of risk Need to reconsider their approach to local level scheduling – will they ensure long term cost minimisation in the development and dispatch of work packages

This table describes two very different styles of operation within the one company. Each style is quite generic: one with an improved systems focus and the other arguably more lean. It is often fascinating to observe how the one company can evolve very different cultures through lack of cross-communication and limited capability in implementing effective and useful corporate systems.

Targets for improvements in return from maintenance include:

1. A simple overview on maintenance strategy to include type of work, response to type of work, planning of type of work and relevant priorities of type of work.
2. Production targets and criticality levels for assets whereby such levels dictate speed of response and level of care.
3. A life assessment review of critical assets as specified to be critical under item (2).
4. A maintenance training program in simple aspects of maintenance: service life, design-based issues, damage modes, inspection, risk management, work

procedures design, work management, reporting and KPI's, planning (short term and long term), contractor management, and quality systems.
5. CMMS (computerised maintenance management system) reporting – client reports, management reports, all staff reports, planning reports, performance monitoring, compliance reports.
6. Overhaul of maintenance planning methods and effective use of the CMMS.
7. Development of a PM (preventative maintenance) program that is thorough, rigorous and breaks down past inefficiencies

3. Improvement in Plant Reliability through Focused Analysis

Downtime monitoring is a means by which priorities may be set for inspections and corrective planning. The identification of key threats to the production process should be the basis of cost justification for capital and maintenance project work. The publication of the data is useful in awareness raising and goal setting for staff. A facility needs a partial loss of availability tracking system that will track every event where a facility cannot provide its requested output. The data should be made available to all production and engineering groups to assist in optimising scheduling and work practices.

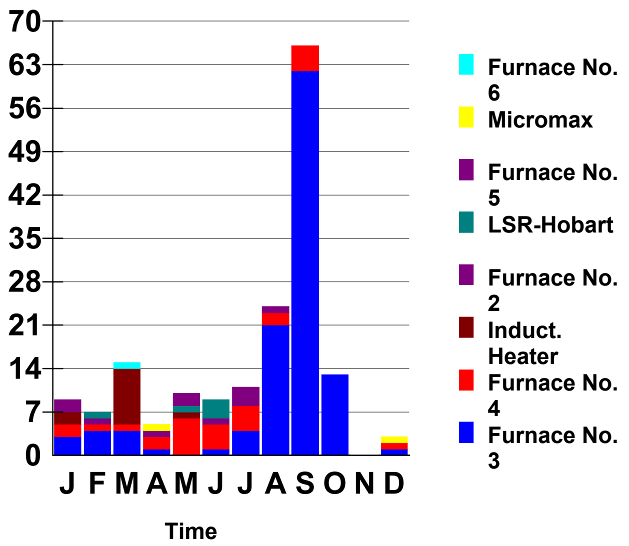
For a single production line, a machine failure typically represents a four figure monetary loss per hour due to the high-speed nature of modern processes. In the event that increasing the holding capacities of buffers is employed to smooth over the perturbations, the line will become less flexible so that the control of the process becomes sluggish. In a manufacturing environment where many types of product design are manufactured this can be unacceptable. Hence an initial step in production improvement is the monitoring of line performance and diagnosing causes for forced stoppages.

The information required when developing a tracking and diagnostic system for machine stoppages is a list of probable causes of forced stoppage attributed to each of the machines entered in the Plant Dictionary.

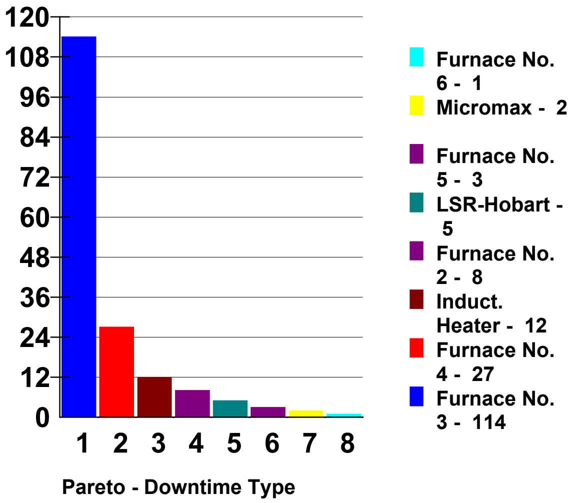
This sample set demonstrates the specific detail of information required at this stage.

Hence the process may commence at a top level study of the key issues afflicting production efficiency, but it must swiftly devolve down to specific, plant-focused problems that can be diagnosed by a check of the state of relevant equipment. These conditions represent a current state that has considerably moved away from the preferred design state.

Top level reports that may be produced are shown in Figure 3.1



Time based histogram of failure types



Pareto analysis

Figure 3.1 Analysis of downtime trends

Attempting to understand the features of the dominant failure modes requires drill-down reports such as shown in Figure 3.3. In this example a dominant weakness with a key machine is clearly identified by the Pareto reporting, justifying a major project to overhaul this critical module.

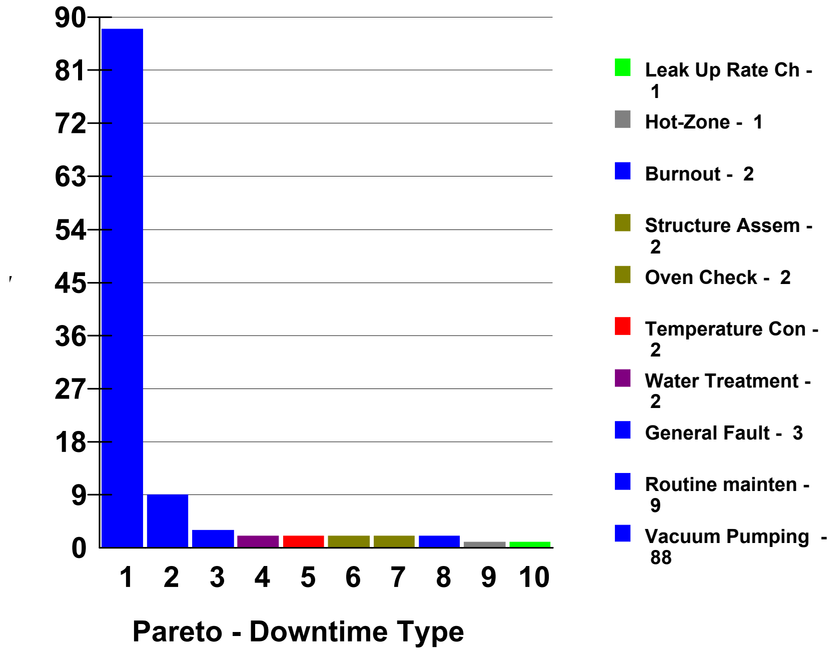


Figure 3.2 Key failure mode for most frequently failing machine

4. Converting Maintenance Performance Data into Business Risk Analysis

A risk program has three distinct stages:

1. Identification and ranking of risks
    - Non compliance with statutory regulations
    - Non compliance with good industry practice
2. Analysis of high current risks
    - Identification of easy to implement solutions
3. Development of life cycle risks to contain hazard
    - Safety audits (ongoing)
    - Environmental audits (ongoing)
    - Statement of investment opportunity (ongoing)

A common formula for risk is:

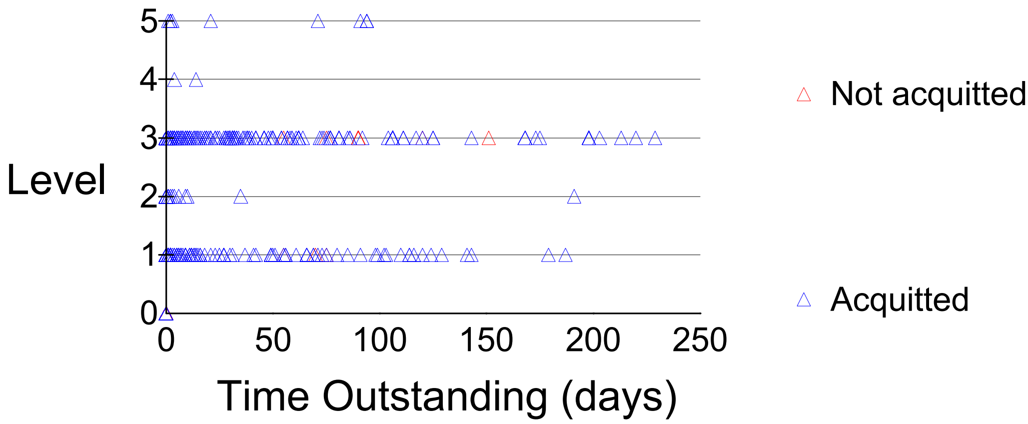
$$\text{Risk level} = \text{Consequence of failure (hazard)} \times \text{Probability of failure}$$

The common problem with the pragmatic use of risk as a measure of what is good, bad or some priority is how to report something more meaningful than the usual human judgement on a case-by-case basis. All maintenance managers are risk managers, called upon to choose between conflicting priorities. What is more useful is to present the overview of general decision-making and to manage the outliers, where decisions have obviously been poor.

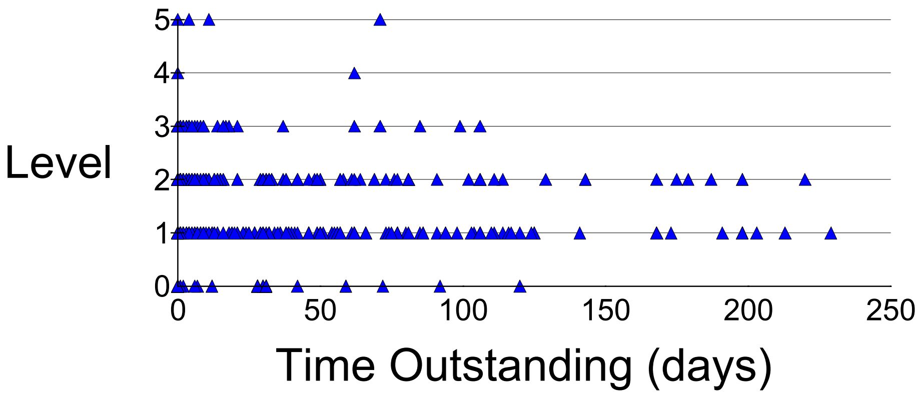
There are three characteristics upon which this work has placed some importance:

- The risk incurred if the work is not completed
- The condition of the equipment when first considered by the relevant work personnel (e.g. trades, technician, ...)
- The condition in which the equipment has been left upon the completion of the work order.

A sample plot for trending these diagnostics is shown in Figure 4.1. The reporting does not provide a detailed appreciation of every work order. It is more concerned with the overall condition of the facility and particularly, as a function of the services of the various *Business Units*. The three graphs associated with these reports are point plots where the horizontal axis is time when the work was conducted and the vertical axis some measure of the characteristic. The main point to remember with these presentations is that it is preferable if the points lie close to the lower horizontal axis: high is BAD! Where no information is supplied points are placed along the horizontal axis line and should be ignored.



Risk of work not being done



Risk ascertained in the job before work commenced

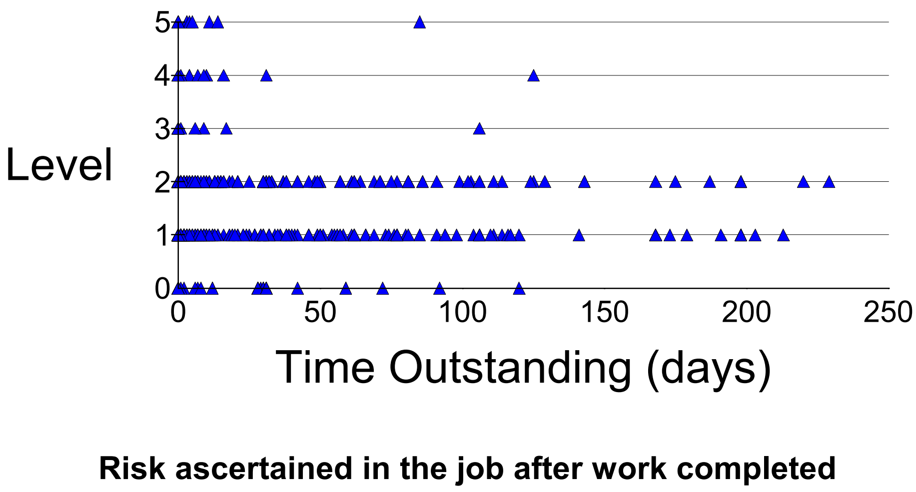


Figure 4.1 Maintenance Diagnostic Report - Risk

The relative values of risk are tabulated as follows:

	Risk of work not being done	Risk found at the start of the job	Risk left when job completed
1	None	As-new condition	Left as-new
2	Nuisance	Minor defects noted	Completely repaired
3	Availability	Significant work to be done	Work still to be done
4	Capital	Very poor condition	Band aid
5	OH&S, License to operate	Dangerous	Job not done

If a user observes a continuous line of high risk entries with perhaps 30% of the entries running along the upper levels of the graph, then there should be some concern as to whether there is an unknown hazard out in the facility, given that so many have been detected. Effective maintenance management is shown by a reduction in possible sources of hazard throughout the facility.

If people associated with work throughout the facility frequently report that they are finding equipment in poor condition, then again there is considerable grounds for concern. While from time to time some items will be found in poor condition, high levels of equipment in imminent danger of failing during production would lead to a reduced confidence in the reliability of the facility.

There are times when an item cannot be repaired or at best, left with a temporary repair. This arises when spare parts are not available, access is not possible and so on. In such cases there is good ground to close off the work order and raise a new one when convenient. At least it may be acknowledged that the work order was attended and some equipment is still in need of further attention. Where work orders are allowed to drag out because a complete repair cannot be implemented there is some confusion in reporting upon maintenance effectiveness. This is because it becomes difficult to distinguish between whether a group has not responded to a work order in a timely fashion or, it has been diligent, but cannot complete the job.

5. Forecasting the Future Life of Assets

Inspection data is commonly used in an identical way to process control data: it is read once, a decision is made, and then the information is no longer used. A sample set of inspection data taken at significant cost in a large capital plant is shown in Figure 5.1.

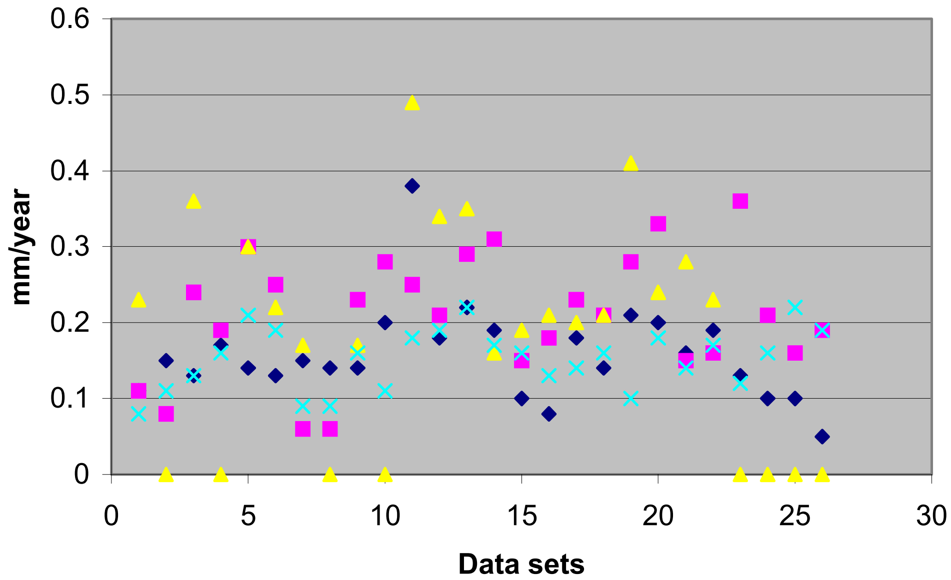


Figure 5.1 Tube thickness data – data sets refers to tube identification numbers; raw data has been converted into wear rates based on time in operation

The means for the four data sets are as follows:

	(mm/year)	Years to failure
A	0.16	1.7 x
B	0.21	1.3 x
C	0.26	1 x
D	0.15	1.8 x

The details of the data and the commercial plant it refers to have been masked for the sake of confidentiality. The point being made here is that the scatter of inspection data is so significant that there is difference in prediction of mean time to failure of the items being measured from a minimum time period to one that is 1.8 times longer. The implication of this is that significant (>$10 M) capital spending may be committed somewhere over a time period of ten years, and the review of the raw data does not assist in pinpointing the optimum time to commit within this period.

For the purposes of the analysis, the wear rates established by one survey selected on the basis of integrity and consistency of data should be taken as indicative.

Experience has found that the data sets provide an insight into the accuracy and dedication of those taking the inspections, giving substance to either selecting or rejecting data fro further analysis.

The type of life forecast that is possible from a proper analysis of such data is shown in Figure 5.2. In this case the optimum wear data has been converted into mean probability of failure plots, using insights into the fundamental damage process as a guide in the forecasting mathematics.

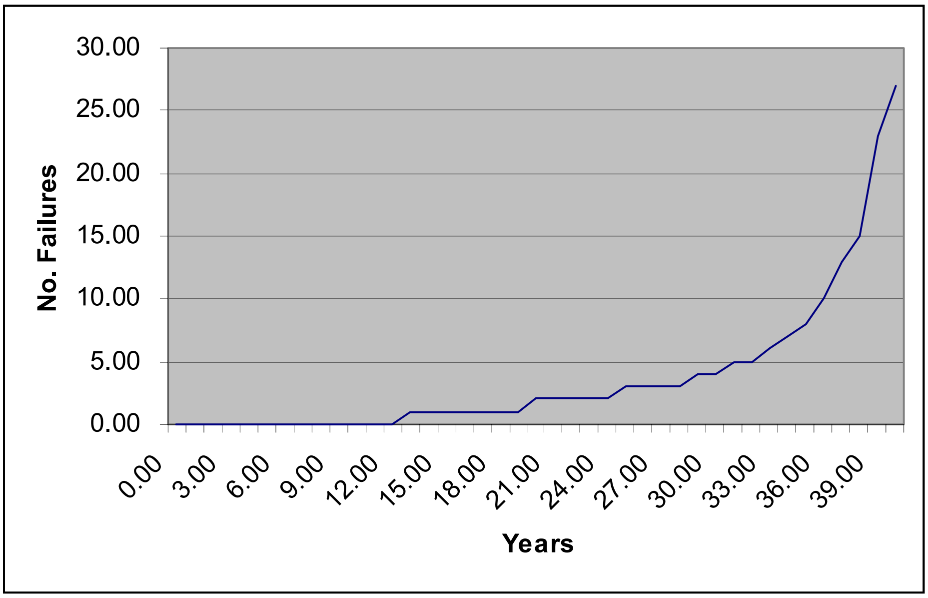


Figure 5.2 Forecast time to failure

In this case, the expected number of component failures within a large item or facility is forecast on the basis of inspection data. The optimum time to replace may not necessarily be the time of the first failure, but perhaps the notional knee point indicated in the forecasting.

This process of comparison and review of quality of inspection data, plus the inclusion of forecasting analysis based on an understanding of the likely progress of failure damage modes, will lead to a guide as to optimum time to commit capital expenditure. The problem of scatter in the data is in part handled by the range of optimum time to replacement – the knee in the plot shown in Figure 5.2 extends over a period of say three years. Hence in this case the analysis process refined a possible range in time to replacement of ten years down to three, primarily due to the rejection of incorrect or unlikely data on the basis of data quality principles, and the convergence associated with the fact that the inspection data represents one indicator that may not have a 100% dominant effect. For example, in this analysis the life forecasting also took into account future operating parameters that tended to balance the influence of current wear rate indicators.

6. Correlating Information from the Operator as well as Maintenance Sources

In developing an operator inspection regime, detailed knowledge of the equipment is gathered and then tracked by the accompanying information system. Hence there is a need to equip the operators with engineering knowledge and then to support them with a user-friendly, simple interface data collection and reporting tool. The major achievements expected of this work include:

1. An information system has been tailored for the specific needs of the local culture, work practice and conditions. This forms an example to guide the design or implementation of future systems, or may be used as a reasonable basis to expand existing systems.
2. Plant identification strategies are implemented for all areas covered in the scope of works, typically employing a four-level hierarchical model.
3. Data gathering to suit people's work practices is implemented. Breakdown, planned maintenance and plant condition data has to be accumulated for specific areas. We need to develop data-conscious work practices for the employees who support this work, which is a positive contribution to the work place culture.
4. A number of reports are issued over the introduction period, identifying equipment condition. These improve communications between managers, supervisors and operators. In some instances, these reports provide a valuable analysis tool for problems that arise.
5. The data tool typically has to be installed on the company network system, which will allow widespread access to the trend reports that should be fully automated within the system.

While the information system is an outward sign of the work completed to date, the project is more profound in terms of educating employees in improved practices through demonstration, raising awareness of the need for the company to internally measure their processes to ensure improvement in their management.

The major threats to an operator inspection system include:

1. Difficulty in ensuring accuracy in inspection of the equipment, plus follow-up of maintenance rectification. In one example a chromate tank used in a plating shop was reported as being bad in October of one year and then failed by the August of the following year. In this case we did not close the people loop to ensure effective maintenance.
2. Difficulty in capturing the maintenance work provided by external service providers to production centres. This is related to another issue whereby major production units are often dismantled for inspection and then remain in that state while parts are being bought in. There is a need to review the condition monitoring and inspection procedures that impact on this problem. Having said this, it can be very pleasing to see the reduction in downtime reported for such equipment as people start to talk about maintenance and become more focused on this work.

3. We need to hand over work tracking in the areas to the process supervisors so that they can take greater control of their asset management processes. This would free up the resource in the maintenance planner to consider extending the techniques to other production areas.
4. Any inability to progress the establishment of downtime tracking referred to earlier in this paper to active areas using the inspection process. This acts as a scorecard on the effectiveness of the program.
5. The absence of maintenance policy which incorporates the operators and supervisors in a closed loop with their maintenance providers, and which guarantees that the operations staff are fully informed of the status of their equipment. In particular, the preventative maintenance program needs to be reviewed, to remove unnecessary or redundant work, and to ensure maximum effectiveness of procedures that are carried out.

Examples of what can be achieved through operator inspections is set out below in an automated report:

FAC4 Survey - Plating Shop

Printed on: 29/02/2000

Monthly report on C and B results for all of the surveys in Plating Shop.

Month of surveys: February 1999

C Scores table:

Date	Task
11/02/1999	Business Unit: New Plating Shop, Module: T11 - Sodium Hydroxide, Area: , Condition of the bottom line weld joints
11/02/1999	Business Unit: Old Plating Shop, Module: T50 - Cold Water Rinse, Area: , Check for splits
11/02/1999	Business Unit: Old Plating Shop, Module: T50 - Cold Water Rinse, Area: , Check for cracks and splits

B Scores table:

Date	Task
11/02/1999	Business Unit: New Plating Shop, Module: T8 - Cold Water Rinse, Area: , Check for splits
11/02/1999	Business Unit: New Plating Shop, Module: T8 - Cold Water Rinse, Area: , Corrosion
11/02/1999	Business Unit: New Plating Shop, Module: T8 - Cold Water Rinse, Area: , Check for panel corrosion
11/02/1999	Business Unit: New Plating Shop, Module: T11 - Sodium Hydroxide, Area: , Check for cracks and splits
11/02/1999	Business Unit: New Plating Shop, Module: T11 - Sodium Hydroxide, Area: , Check for defromation
11/02/1999	Business Unit: New Plating Shop, Module: T11 - Sodium Hydroxide, Area: , Condition of the welds
11/02/1999	Business Unit: New Plating Shop, Module: T11 - Sodium Hydroxide, Area: , Corrosion

Figure 6.1 Extract from a monthly operator inspection report; C scores refer to urgent work and B scores refer to necessary work

7. Conclusion

The path to improving the strategic management of assets is through the establishment of systems that reduce the reliance on an individual's competence to ensure a sustainable delivery of effective maintenance services. This includes the definition of workflow systems that properly account for positional responsibilities and the authorisation of expenditure. Supporting such systems will be a network of monitoring including work effectiveness, machinery utilisation, procurement accountability, and plant improvement studies.

The key benefits of the strategic planning process, and the use made of the individual information tools includes:

1. Understanding of the implications of operational behaviour on machinery integrity.
2. Options in scheduling operations which may be weighted in terms of implications to machine degradation.
3. Identification of incorrect human practices and their significance.
4. Provision of a business-planning tool that is sensitive to the fundamentals of company survival but also accounts for technical implications of business decisions.
5. Establishment of an optimum timing and budget for maintenance that is tailored to meet the likely operations of the plant.

The means to improved return from maintenance include:

1. Achieve better utilisation of the resources – address the problem of not enough people and also limited access to assets for people. This is achieved by setting priorities on the basis of fact, using some of the reports and inspection cited in this paper.
2. Obtain better access to machines such that resources are optimised and availability is maximised.
3. Maintenance engineering has finite resources; therefore it needs to allocate resources where they are best needed. This will stop access issues being a dominant factor in planning, since the resources will be where they most need to be.
4. Use anything (any method, tool or approach) that works.
5. Consider production and people issues as well as maintenance engineering.
6. Achieve better inventory control – this will help with planning to ensure that maintenance services have the right spares at the right time. This will assist the stores and ensure that they have necessary material on hand. This aspect was not covered in this paper but remains an important issue.
7. Do more inspections so that maintenance has a better feel for the plant and provide more lead-time before ordering.
8. Improve reporting to accountants and improve justification for capital expenditure to get rid of maintenance problems.
9. Document risk strategies for due diligence, including the trapping of field data as shown in this paper.

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