PROACTIVE VERSUS REACTIVE MAINTENANCE MEASUREMENT/IMPROVEMENT

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Summary: successful maintenance improvement projects in large organisations require a systematic and well-founded approach to ensure tangible technical outcomes. A structured maintenance data analysis has been developed to address key maintenance objectives known as proactive maintenance, backlog management and failure mode analysis.

Maintenance data (i.e. work orders) for one fiscal year 2002/2003 in a large Alumina refinery is investigated in an attempt to established short, medium and long-term maintenance improvement strategies. Data set included more than 61,000 individual work orders with a total amount of actual cost recorded as high as $63m with more than 330,000 hours of actual work registered in the CMMS.

Such a structured analysis has led to specific set of recommendations for improvements in planning and scheduling of works, PM strategies for number of critical assets, new backlog management strategy and engineering investigations into major failure modes. Since delivering the full report, several of these improvement initiatives have been successfully implemented, and few others are being considered for implementation.

Keywords: Maintenance Improvement, PM Strategies, Backlog Management, FMEA

1 INTRODUCTION

Cost cutting and efficiency improvement initiatives in maintenance departments are persistent concerns for maintenance and engineering managers. The effect of these decisions in larger organisations could amount to the tens of millions of dollars savings in yearly budgets if defined and implemented well. Therefore, it is of prime importance to be able to finely define improvement targets with stepwise strategies to achieve specific goals.

There are different approaches to tackle this issue. One approach is to go through organizational change and define a path from “As it is” condition to “As it should be” situation. Although we do not endorse such exercise, we do not comment on this approach either. This paper, however, presents a more technically oriented approach with its associated developed methodology. This has enabled us to define specific, technically viable and achievable solution strategies based on a systematic interrogation of the Computerised Maintenance Management System (CMMS).

The methodology, process and its technical outcomes have been presented and future improvement initiatives arising from this investigation are explained.

2 METHODOLOGY

Alumina refineries, designed and operated based on Bayer process (1), are consisted of four distinct process areas, being Digestion, Clarification, Precipitation and Calcination (apart from its Bauxite mine and Powerhouse). In another classification, Digestion and Clarification areas are commonly referred to as “Red side” and Precipitation and Calcination areas are called “White side”. This is due to the colour of the product in each part of the plant, which transforms from red to white as the process flow passes through facility.

The investigation, therefore, was divided into four sections to represent the true nature of operation and its associated failures. For each area, following points were investigated:

- Reactive vs. Proactive maintenance

- Criticality analysis
- Backlog management
- Maintenance improvement initiatives

A data file containing work order history for 2003/2004 fiscal years was prepared and downloaded from the CMMS. This file contained more than 61,000 individual work orders for both Red side and White side with more than 330,000 actual working hours recorded against all work orders.

3 REACTIVE VERSUS PROACTIVE MAINTENANCE

The first step in assessing the technical compliance of a Preventive Maintenance (PM) strategy is to measure the relative magnitude of Reactive works (driven by the plant) versus Proactive works (driven by human management of the plant). The Covaris (2) classifications for these types of works are:

Reactive work

Breakdown and/or unplanned jobs– no control of timing of the work

Corrective – no control of the timing of the work, and driven by a non-scheduled event

Proactive work

Scheduled – control of the timing and initiated by either calendar time or metered time, typically used for inspections

Condition based – control of the timing and initiated by a scheduled event such as an inspection result

It is worth to mention that a work is also considered to be reactive if initiated as a result of a condition monitoring activity, but cannot be scheduled (i.e. urgent action required).

There are different work types associated with work orders in different CMMSs. In SAP (3) terminology there are two major work order types:

PM01 – non-routine maintenance

PM02 – System generated maintenance work orders

Although PM01 work orders are defined as non-routine maintenance jobs, they are not a true indicator of reactive maintenance work type. Table 1 presents the definitions used to categorise work types in a SAP environment. All PM01 work orders with priorities 4, P and S are allocated to proactive maintenance due to the ability to plan these types of PM01 work orders in advance. PM02 work orders contribute the major proportion of the proactive work type.

Priority	Required action	Reactive/Proactive
1	Immediate action	Reactive
2	Must be done within 24 hours	Reactive
3	Must be done in current week	Reactive
4	Low Priority work	Proactive
P	To be planned	Proactive
S	For shut down plan	Proactive

Table 1. PM01 work order classification

Therefore, Reactive and Proactive work orders are defined as follows:

Proactive work orders = All PM02 + PM01 (with priorities 4, P and S)

Reactive work orders = PM01 (with priorities 1, 2 and 3)

This interpretation of work orders produced following results in terms of the % of actual time spent on work orders in four major process areas as shown in Figure 1.

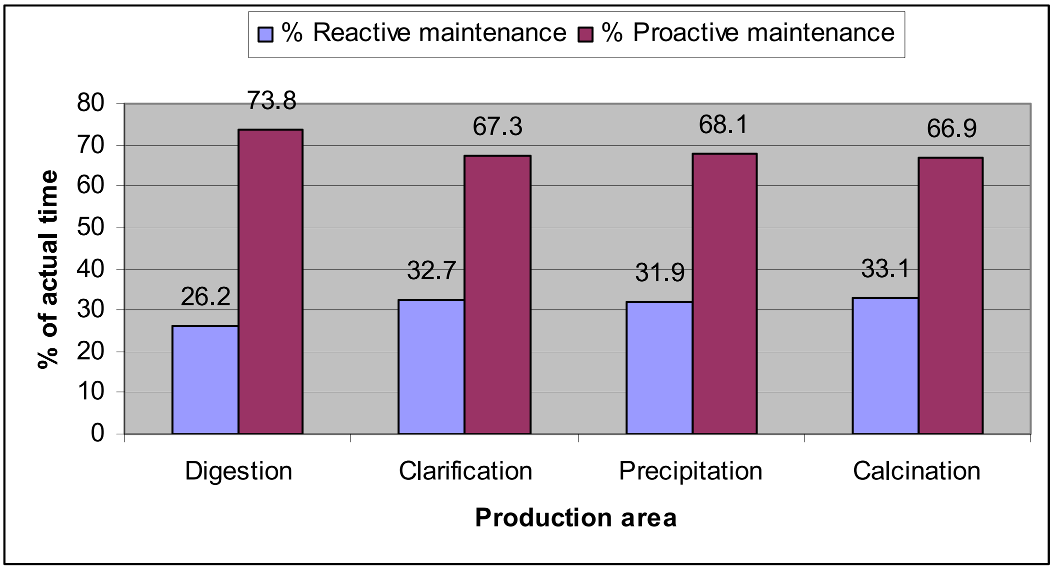

Figure 1. Maintenance planning indicator in 4 major process areas

This figure indicates that the maintenance planning is influenced by unplanned events with magnitudes of 26.2%, 32.7%, 31.9% and 33.1% of the total maintenance time recorded in Digestion, Clarification, Precipitation and Calcination production areas respectively.

A ratio of 85% planned work to 15% unplanned work as a target value is considered to be a good maintenance practice for this indicator (4). Therefore, there is a need to reduce the quantity of reactive maintenance by greater than half in most production areas. However this metric does not portray the full picture. Additional issues need to be considered including:

- We need to ascertain why the quantity of PM02 work is not driving down the PM01 work – this is a matter of addressing failure modes in the plant and can be either a design issue or an improvement in the repair tasking, both of which represent engineering improvements that need to be progressed.
- The metric does not portray estimated labour productivity, which can be impacted by wait time. If the actual time on refurbishment of equipment within the work order is increased (i.e. wrench time) then not only is it likely that reactive work can be relieved, but total costs can be reduced.

Plant area	Reactive works (%)	Proactive works (%)	Improvement Opportunities (%)
Digestion	26.2	73.8	11.2
Clarification	32.7	67.3	17.7
Precipitation	31.9	68.1	16.9
Calcination	33.1	66.9	18.1
Average	31	69	16

Table 2. Improvement opportunities in planning and scheduling of works

Table 2 shows the improvement opportunities for different areas of the plant, which can be achieved by the following:

- Refinement of the maintenance strategy so that the reactive work is better anticipated, possibly through improved analysis of trends in inspection results.
- Re-design or improvement of materials – it was noted that at this site practices in assessing effectiveness of materials are not consistent across the plant types with better assessments conducted for some plant types compared to other. It was found, for instance, that material selection for Valves had better engineering understanding of the process requirements than that of Pipes in the same part of the plant.

Total actual cost throughout the refinery for the analysed data set was $63.5m. As a rule of thump, an unplanned maintenance work is at least 50% more expensive than a planned one (over labour, material and overhead cost components). Therefore, there is a possibility of maintenance cost reduction by a magnitude of $275K on average for each 1% reduction in unplanned works from the current level of 31% (see Table 2).

Consequently $4.4m reduction in maintenance costs can be expected by achieving the target value of 85% planned work orders on average throughout the plant.

4 CRITICALITY ANALYSIS

Equipment criticality codes used at this site (consistent with general SAP definitions) are shown in Table 3.

Code	ABC indicator text
A	Immediate production loss
B	H/Potential production loss
C	Potential production loss
D	No production impact/H cost
E	Low production impact/L cost

Table 3. Equipment criticality index

The actual time recorded for PM01 work orders with high priorities (*i.e.* priorities 1, 2 & 3) indicates the amount of reactive workload on maintenance crews. This indicator is shown in Figure 2.

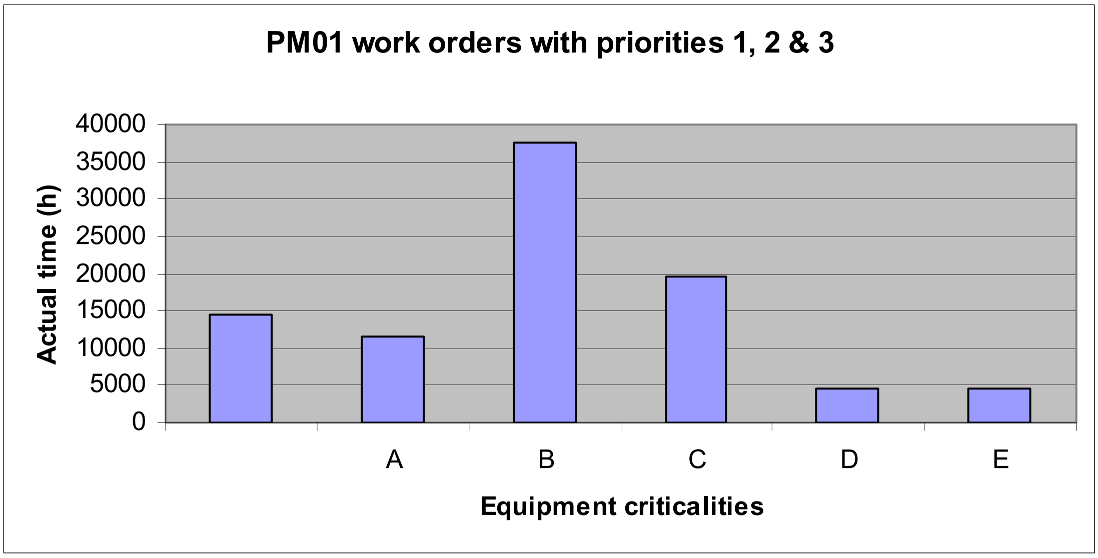

Figure 2. Actual time recorded for PM01 work orders with high priorities (Reactive)

A total amount of 92,469 hours is recorded for PM01 work orders with priorities 1, 2 and 3 (*i.e.* unplanned works imposed to the weekly plan). This analysis reveals the following points:

- High criticality plant, which had a reliance on urgent corrective maintenance. This reflects on both client's understanding of plant condition as well as the maintenance strategy for these assets.
- Urgent responses in maintenance to low criticality assets are somehow puzzling. In some cases these may be justified where safety issues have arisen, but such rapid response should be assessed if they are causing unnecessary pressure on the scheduled work program.

5 BACKLOG MANAGEMENT

At the time of the analysis a total number of 5,205 work orders were in backlog. Figure 3 shows the distribution of work orders based on equipment criticalities throughout the refinery.

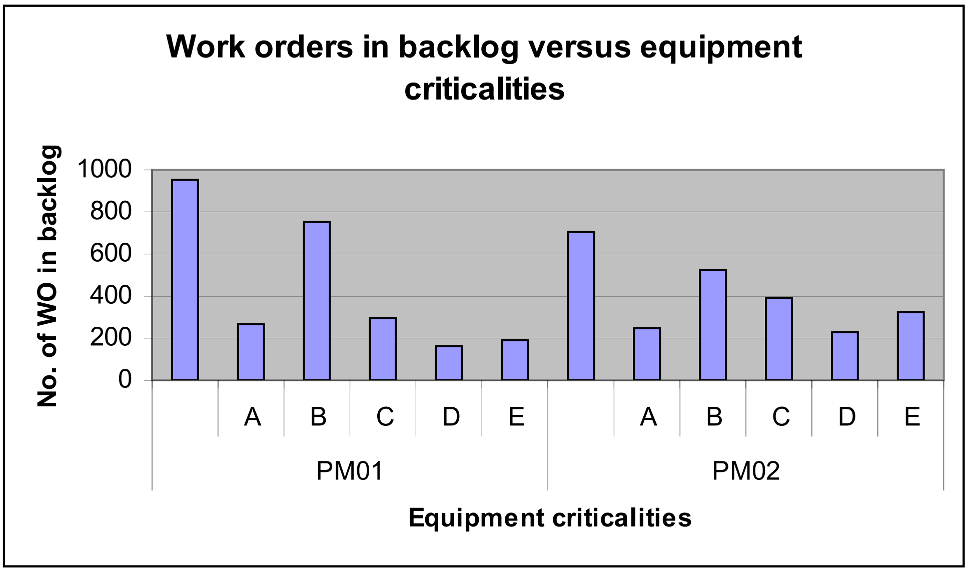

Figure 3. Backlog report against equipment criticalities

Comment on the backlog data indicates that:

- PM02 work is getting done despite the high loading of PM01 work – this may be seen as a cost driver on the labour and also troublesome insofar as the client is not seeing a good return on its investment on this labour.
- Delays in attending to PM01 work may mean that additional stress is being placed on the plant with two consequences:
    - Impact on production rates or quality
    - Growth in the size of the fault that will be eventually rectified under a PM01 work order

The existing backlog report, however, does not relate equipment criticalities to work orders priorities to produce an important indicator known to Covaris as Backlog Management Index (BMI) number.

BMI is an equivalent risk value that shows the combined maintenance priority and equipment criticality. In this analysis the following definition has been used to define the BMI:

$$BMI = (Task\ Priority) * (Asset\ Criticality)$$

The value of BMI can vary from 1 to 25. The highest number shows the highest risk to the plant. The following table shows the recommended BMI numbers.

		Asset Criticality				
Priorities/Criticalities		E	D	C	B	A
Task Priority	**1**	1	2	3	4	5
	2	2	4	6	8	10
	3	3	6	9	12	15
	4	4	8	12	16	20
	5	5	10	15	20	25

BMI is used in the backlog KPI report to show the equivalent risk. The acceptable limits for the backlog data is defined and presented in the table below (as an example for this client only). This policy will be graphically presented in the backlog report to distinguish between the acceptable performances and the risky performances. The report will also show the specific task that is a threat to the assets or has the criticality changed over time

Level	Preferred Maximum Time in Back Log	Recommended Response to Remove from Backlog
1	2 months	Review if task is necessary – delete if not; increase task criticality if it is
2	1 month	Increase task criticality to expedite attention
3	1 week	Urgent priority to address task

A typical backlog report considering BMI number is shown below.

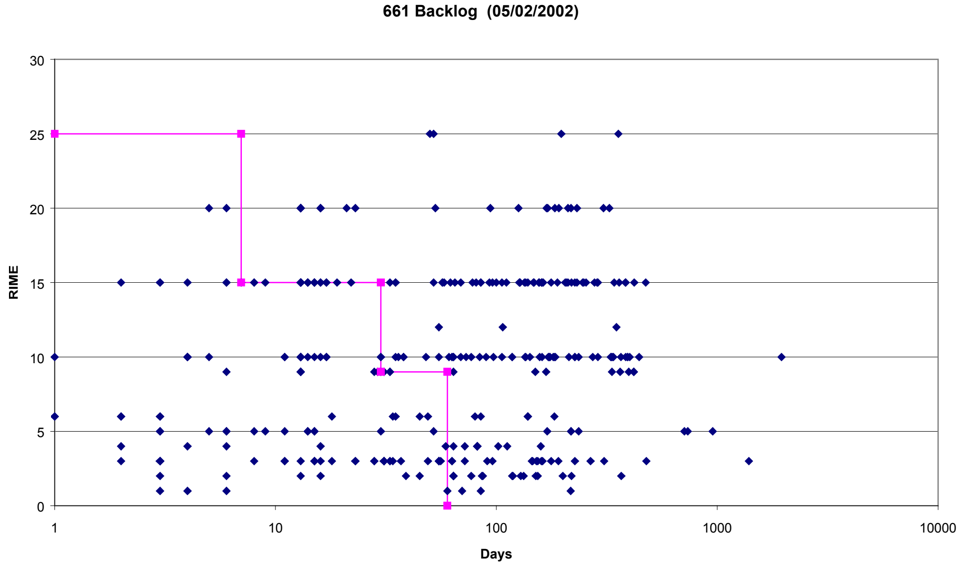

Figure 4. Sample backlog report using BMI concept

It should be noted that the broken line is a corporate policy and may slightly differ for in different organisations. All work orders in the right hand side of the broken line are unacceptable and represent a risky performance.

6 MAINTENANCE IMPROVEMENT INITIATIVES

Following detail analysis of work order histories in four production areas, the distribution of high cost assets was investigated and following conclusions were made:

1. Maintenance improvement opportunities in mill facility exist. It was found that maintenance strategies/procedures for four Bauxite mills could mot prevent mill failures and as a consequence mill reliabilities were lower than expected. A maintenance improvement study with a detailed analysis of high priority work orders (i.e. PM01 WO with priorities 1,2 and 3) was recommended for mill area.
2. Engineering investigation into fouling mechanism for heat exchanger tubes in Digestion area. Heat exchangers are originally designed to last for 90 days in operation, however, slurry deposit and subsequent erosion force operation to take them out of service in less than 60 days (even in 45 days in some cases). Heat exchangers operation suffers from this issue showing much lower than expected reliability and this issue amounts to almost \$6m extra cost to maintenance each year. An engineering investigation is certainly justified.
3. Pump wearing study in Digestion area was also found important. Cost figures for pump maintenance suggested that an improved pump design (i.e. material and internal coating) would significantly reduce frequent unpredicted pump failures.
4. Work order history analysis and subsequent review into NDT inspection regimes throughout refinery indicated different level of accuracy as well as coverage in the plant. While some part of the refinery had an acceptable level of NDT plan coverage, the lack of a technically viable NDT plan was a major contributor to pipes and valves deterioration and unplanned equipment failure. Unpredicted failures due to pipes and valves erosion and

holes contributed to more than $3m of maintenance cost. Therefore, a complete review and overhaul of the NDT plan was strongly recommended.

5. It was found that "Cause codes" were not recorded well when closing work orders and information contained in notifications could not produce a reliable set of failure modes. However, in most cases work order headers contained reliable information on what is wrong with the asset and contained proper technical data. Covaris has developed a unique tool to perform a comprehensive Failure Mode and Effect Analysis (FMEA) based on the work order history data analysis (5). Such study requires thorough engineering examination of corrective work orders and will identify failure modes, their costs effect on individual asset base and associated risks. Similar investigation for this site is strongly recommended.

7 CONCLUSIONS

In this paper, a systematic approach to analyse and evaluate maintenance data (i.e. work orders) in a large Alumina refinery is presented. Proactive maintenance is discussed and a measuring concept independent of CMMS terminology is developed. Based on this analysis short, medium and long-term maintenance improvement strategies are also presented for the case studied. Data set included more than 61,000 individual work orders with a total amount of actual cost recorded as high as $63m with more than 330,000 hours of actual work registered in the CMMS.

A refined backlog report process described in detail, which enables planners to understand and mange risks associated with works in backlog. Recommended initiatives are in different stages of implementation and improvements in some cases (e.g. initiatives 1, 2 and 4) are being realised.

8 ACKNOWLEDGEMENTS

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9 REFRENCES

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