



ENTERPRISE ANALYTICS

Driving better decisions.

REDUCING THE COST OF PREVENTIVE MAINTENANCE

Deryk Anderson
Business Analyst - Maintenance
Oniqua Enterprise Analytics
deryk.anderson@oniqua.com
T: +61 7 3859 9523

SUMMARY:

Lean Manufacturing and Lean Maintenance target the identification and elimination of waste through continuous improvement. The problem of under-maintaining assets is often addressed through loss elimination and continuous improvement programs. The problem of over-maintaining by comparison receives little attention. Left unattended the over-maintaining of assets silently and continuously squanders precious maintenance resources.

Industry has been conservative in its approach to setting preventive maintenance intervals. On some sites:

- 80 % of Preventive Maintenance costs are spent on activities with a frequency 30 days or less.
- 30 to 40% of Preventive Maintenance costs are spent on assets with negligible failure impact.

This paper explores the impact of frequency on the over maintaining problem and proposes, with the use of a case study, low risk methods for reducing Preventive Maintenance costs.

Keywords: Preventive Maintenance, Waste Elimination, Activities, Frequency, Analysis, Cost Reduction.

INTRODUCTION

Buell and Smedley (1) define Lean Manufacturing as "a systematic approach to identifying and eliminating waste through continuous improvement". Waste is further defined as "anything that adds no value to the manufacturing process. Common sources of waste in manufacturing are identified (2) as:

- **Overproduction** – Producing product quantity in excess of requirement or demand.
- **Inventory** – Producing levels of end product or work in progress above the optimum.
- **Waiting** – Delays in the production process.
- **Transportation** – Transporting end product or work in progress unnecessarily.
- **Motion** – Unnecessary motion of workers, assets or materials associated with production.
- **Processing** – Redundant steps or activities in the production process.

- **Defects** – Producing defective products

The application of the term “Lean” to maintenance similarly aims to target waste. Bever (3) estimates that between 18% and 30% of every dollar spent on maintenance is wasted. Greg Folts is reported (4) as observing that maintenance operations may be wasting up to 25 percent of available labour and that up to 60 percent of this waste results from activities that add no value to the performance of the plant.

Similar categories of waste identified for Lean Manufacturing can be applied to the exploration of Lean Maintenance. Building on a list developed by O’Hanlon (3), seven categories of waste in maintenance are summarised as follows:

- **Overproduction** - Performing preventive and predictive maintenance activities at intervals more often than optimal
- **Inventory** – Overstocking maintenance spares with slow moving parts and secret inventories.
- **Waiting** - Waiting for tools, parts documentation, transportation, etc.
- **Transportation** – Time spent walking, running, driving, and flying associated with maintenance work
- **Motion** – PM performed that adds no value to the prevention of downtime.
- **Processing**– Opportunity to improve the quality of repairs in reactive or breakdown maintenance.
- **Defects** – Asset failure caused by under-maintaining assets or maintenance rework.

Waste in maintenance can be considered as a problem of strategy, planning and control. This paper is specifically concerned with waste arising from strategic decision making. This particularly targets maintenance waste associated with “overproduction”, “inventory” and “motion” from the above list. These three topics are referred to specifically as over-maintaining.

THE PROBLEM OF OVER-MAINTAINING

Under-maintaining assets is characterised by:

- Preventive activities not performed or performed at too long intervals
- Ineffective or non-existent preventive activities

Under-maintaining assets leaves an evident waste trail as it often results in frequent and long breakdowns, high levels of unplanned work and lost production and output. Under-maintaining is a regular target of continuous improvement programs.

Over-maintaining is characterised by:

- Performing preventive maintenance activities at more frequent intervals than necessary
- Performing preventive maintenance activities that add no value to the output
 - ~ PM activities are ineffective at detecting failure and are a waste of time
 - ~ PM Activities are redundant (i.e. duplicate other effort)

Over-maintaining assets leaves a less obvious waste trail. We are inclined to believe that our preventive maintenance activities are effective if we are not constantly rectifying breakdowns. When left unchallenged over-maintenance silently, constantly squanders precious maintenance resources that impact on direct costs, and the profitability of our businesses.

PREVENTIVE MAINTENANCE

In this paper, the term Preventive Maintenance refers to any activity that is designed to:

- Predict the onset of component failure,
- Detect a failure before it has an impact on the asset function,
- Repair or replace asset before failure occurs.

Preventive Maintenance has two features, an activity to be performed, and a frequency at which the activity is performed. A reduction in waste in Preventive Maintenance can target either the Preventive Maintenance activity or its frequency.

Preventive Maintenance Activities

In many businesses, Preventive Maintenance activities have been established over time with little technical discipline supporting the decision process. This has resulted in Preventive Maintenance activities that:

- Are ineffective in detecting the onset of failure,
- Duplicate the effort of other preventive activities,
- Are missing for critical failures.

A review of Preventive Maintenance activities requires an assessment of the modes and consequence of failure contrasted with the effectiveness of the proposed or actual activity.

One method of performing a review of Preventive Maintenance activities is by hypothetical failure analysis. Analyses in this category develop Preventive Maintenance activities based on an analysis of failure risk. Analyses in this category are typified by RCM II after Moubray (5), however there are many derivatives of this approach in practice. This type of approach generally ignores the existing Preventive Maintenance activities and compares results with existing maintenance programs after the analysis is complete.

Hardwick and Winsor (6) describe the development of new maintenance standards for Energy Australia based on the application of RCM principles. Regarded as a successful technical and change management project, there were significant benefits estimated on 25000 Pole and Kiosk Substations. The traditional maintenance program had demanded an annual budget \$6.875M per year. Typically \$3.75M per year had been budgeted for, with the budget shortfall showing as work backlog. As a result of the project, new maintenance standards were developed. These changes did not affect the period or frequency of the preventive maintenance, but only the methodology or activities. The resulting maintenance program demanded a budget of \$2M per year. With full implementation of the new program, a payback period for the project is estimated to be 4 months. This example clearly demonstrates the extent of the over-maintaining problem as well as the effectiveness of a successful review of preventive maintenance activities by hypothetical failure analysis.

Another method of performing a review of Preventive Maintenance activities is a “Reverse RCM” process in which each activity is reviewed and tested for its purpose, value and possible duplication against other activities. In this case the existing Preventive Maintenance activities are not ignored and provide the basis of the review process.

Turner (7).describes an approach called PMO that reviews Preventive Maintenance activities in a nine-step process. The results of a typical PMO review are shown in Figure 1.

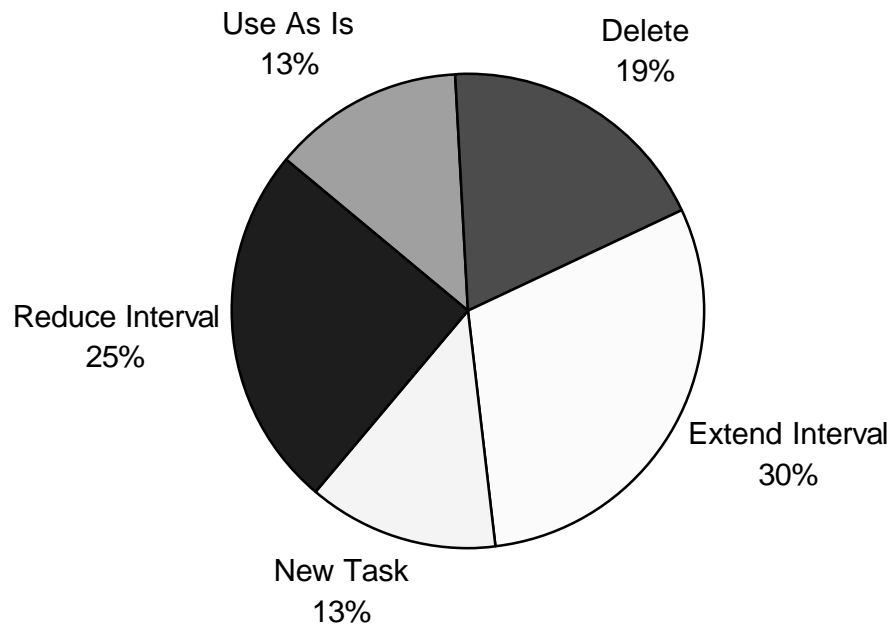


Figure 1 – Results of a Typical PMO Review

Figure 1 shows that:

- Only 13% of existing Preventive Maintenance activities were considered worthwhile
- 19% of Preventive Maintenance activities were a waste of time
- 30% of Preventive Maintenance activities were carried out too frequently

This example also demonstrates the extent of the over-maintaining problem and shows the effectiveness of a review program in addressing the Preventive Maintenance activities.

These examples demonstrate that Preventive Maintenance activities have a significant impact on the effectiveness and cost of the Preventive Maintenance program. The review of Preventive Maintenance activities can be successful in terms of the technical activities developed, but face challenges in the selection of optimal activity frequencies.

Preventive Maintenance Frequency

Preventive Maintenance frequencies can be varied according to deterioration and failure rates, operating strategy, (i.e. windows of opportunity), the cost of performing the activity and the penalty associated with asset failure.

Decision models for timing of inspection, repair and replacement based on asset failure data are described, for example, by Jardine (8). Collecting accurate failure data for optimising frequencies for a wide range of assets is regarded as problematic. In the absence of data for

such decision support, the setting of frequencies by “personal judgement” is widely recommended and practiced.

A straw survey of industry supported by published maintenance frequencies (9, 10) shows a distinct preference for certain intervals when specifying Preventive Maintenance frequencies. These are:

- Monthly
- Quarterly (3 Monthly)
- Semi Annually (6 Monthly)
- Annually

This observation supports the contention that maintenance frequencies based on “personal judgement” are heavily influenced by monthly and annual calendar cycles. If each of these frequencies was extended by just one week most maintenance facilities could realise a 20% reduction in the direct cost of their Preventive Maintenance Program.

If Preventive Maintenance activities are allocated to the preferred frequency intervals above in a conservative manner it is easy to imagine a situation for many activities of over-maintaining by a factor of up to 200%. The resulting over-maintaining adds little or no value to the detection or prevention of asset failure.

Impact of Preventive Maintenance Frequency on Reliability

It is assumed that as Preventive Maintenance frequency increases (i.e. the interval between Preventive Maintenance activities is reduced) the cost of performing the Preventive maintenance activity increases. It is also often assumed that the probability of failure reduces with increased Preventive Maintenance frequency. The relationship between Preventive Maintenance frequency and the probability of failure prevention (assumes that the Preventive Maintenance activity is successful and the penalty costs are avoided) is shown in Figure 2.

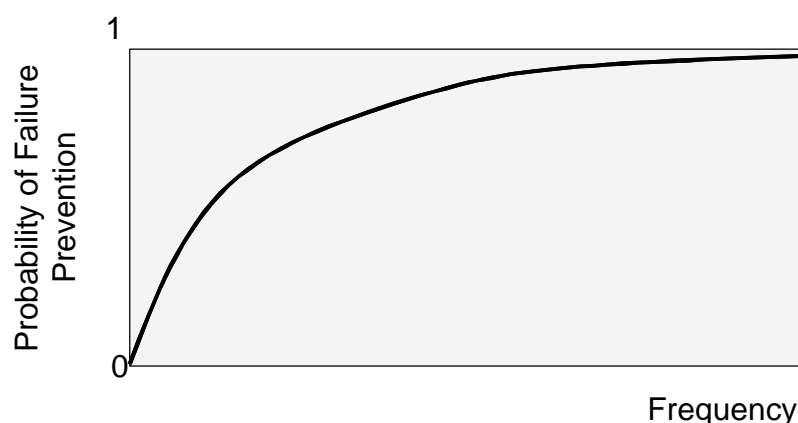


Figure 2 – Probability of Failure Prevention

Figure 2 shows a diminishing return in relation to probability and frequency of Preventive Maintenance. If the correct inspection frequency for a bearing is 6 weeks then there is very little to be gained by carrying out the inspection 4 weekly or 2 weekly.

It cannot be assumed, however, that the benefit of carrying out the Preventive Maintenance activity increase in all cases. In the case of intrusive Preventive Maintenance where assets is opened, adjusted, or otherwise handled, there is a chance that assets will be returned to service in a worse condition than when it was received. This means that as maintenance frequency increases the probability of a maintenance induced failure increases and the overall probability of success of the preventive maintenance activity is reduced as demonstrated in Figure 3. Figures 2 and 3 provide the basis of an argument for avoiding high frequency Preventive Maintenance activities.

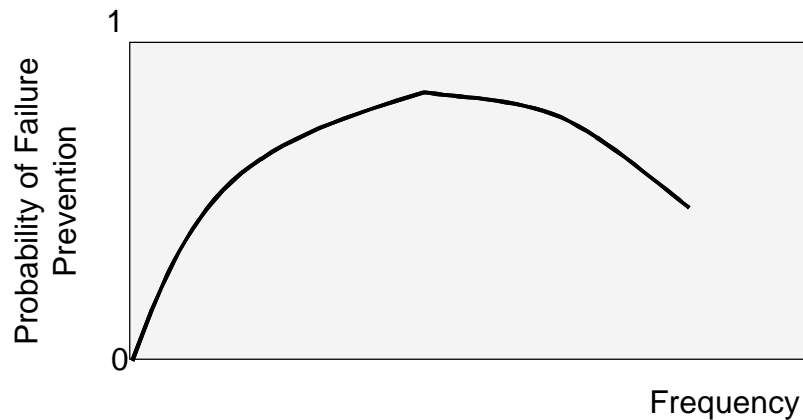


Figure 3 – Probability of Failure Prevention – Intrusive Maintenance

The graph of Figure 2 suggests that it is possible to reduce Preventive Maintenance frequency without significantly impacting on assets reliability. Figure 4 shows that a significant decrease in maintenance frequency may only result in a minor reduction in the probability of failure detection (perhaps even an increase if the graph of Figure 3 is considered).

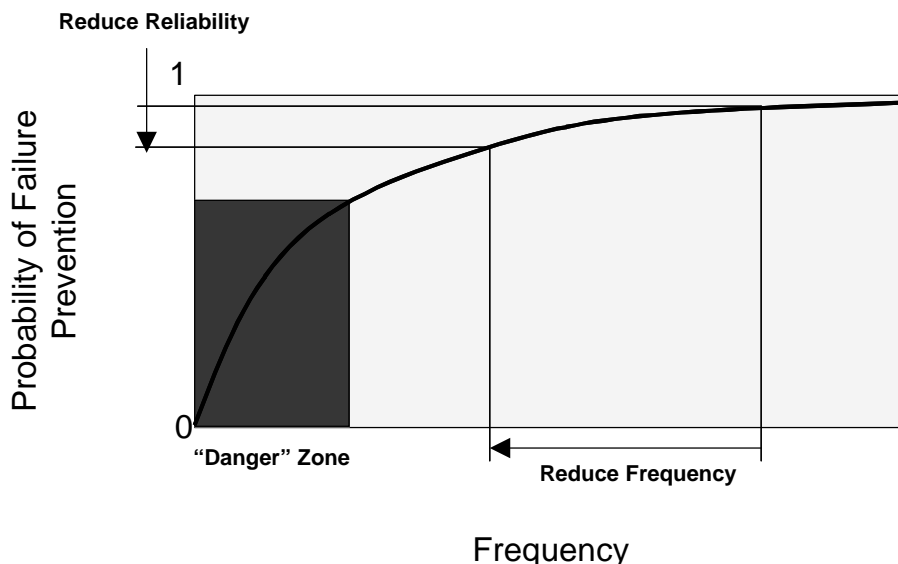


Figure 4 - Effect of PM Frequency Reduction on Assets Reliability

The challenge associated with frequency reduction is that without reasonable failure data or history, it is difficult to know where the current Preventive Maintenance frequency sits on the graph. Frequency reductions in the “Danger Zone” indicated in Figure 4, would result in

proportional reductions in assets reliability. If the current maintenance frequency is low then significant reductions in reliability may not be apparent for some time. If the current maintenance frequency were high, then reductions in maintenance frequency within the “Danger Zone” would result in more immediate reductions in reliability.

Frequency reduction may only be a reasonable strategy where the consequences of failure are low and the current frequency is high. Minor reductions in maintenance frequency with these characteristics can yield considerable returns as demonstrated in the following case study.

CASE STUDY – WASTE ELIMINATION THROUGH FREQUENCY REDUCTION

The following case study is from the manufacturing sector. The maintenance facility had recently conducted a review of their Preventive Maintenance activities, but backlog was continuing to climb as work was deferred. Site personnel were concerned that:

- Work backlog would rise to unmanageable levels,
- Critical Preventive Maintenance activities were being neglected in the deferred work

A further review of the Preventive Maintenance activities was considered to be of little value. For this reason it was decided to target the maintenance frequencies for possible reduction.

Assets Criticality

An analysis of assets criticality was carried out. The criticality of the assets was identified with the code of Table 1.

Code	Criticality	Business Impact
S	Safety / Environmental / Critical	Safety / Environmental
10	Major impact on output of all machines/lines, contributing to long factory outages. Orders lost on all products.	Total Loss of Production
9	Major impact on output of one or more machines/lines, contributing to long machine/line outages. Orders on specific products are lost.	Total Loss of Production
8	Significant impact on output of all machines/lines. Inability to meet customer order quantities by delivery dates.	Partial Loss of Production
7	Significant impact on output of one or more machines/lines. Unable to meet specific product order quantities by delivery dates.	Partial Loss of Production
6	Minor impact on output of one machine/line. Production can be rescheduled. Unable to meet some customer orders for a specific product by delivery dates.	Partial Loss of Production
5	Loss of assets with 100% capacity backup. Failure of backup assets will affect ability to meet customer order quantities by delivery dates.	Negligible Impact
4	Loss of assets with some contingency or buffer storage. Significant impact on output of single machine/line (with no affect on ability to meet orders).	Negligible Impact
3	Loss of assets with significant contingency or buffer storage. Significant impact on output of single machine/line (with no affect on ability to meet orders).	Negligible Impact
2	Minor impact on output of single machine/line (with no affect on ability to meet orders) e.g. short reduction in production capacity.	Negligible Impact
1	No affect on output of any machine or process line within repair time.	Negligible Impact

Table 1 – Assets Criticality Rating

The criticality ratings were applied to individual Preventive Maintenance activities. The relative number of Preventive Maintenance activities in each of the Business Impact categories is shown in Figure 5. This chart shows that a high proportion of activities were directed at the prevention of “Negligible Impact” failures or failures with low levels of “Loss of Production”

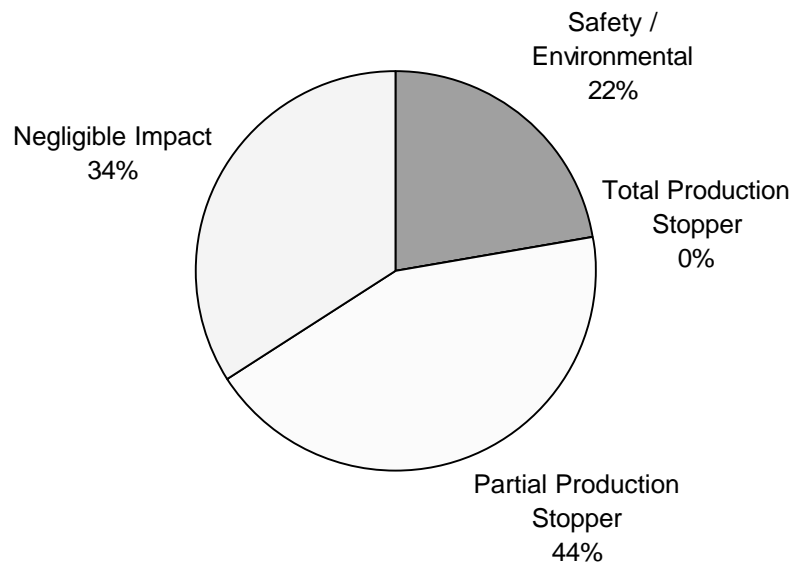


Figure 5 - Preventive Maintenance Activity against Business Impact

Frequency

The cost of the Preventive Maintenance activities was compared against frequency as shown in Figure 6.

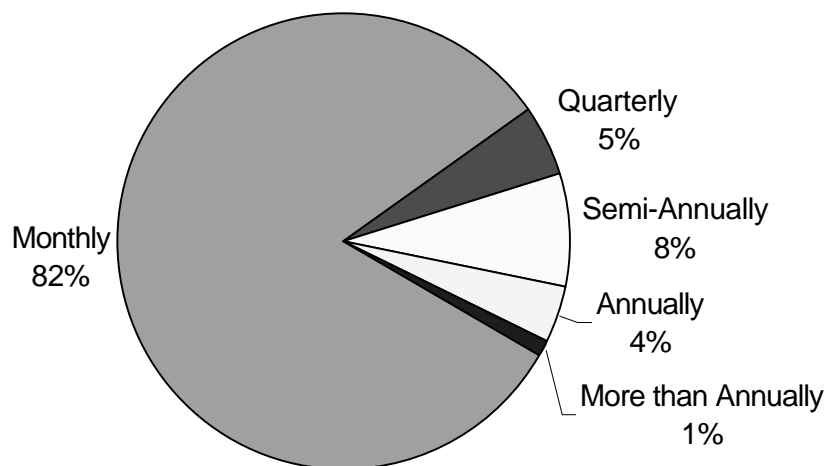


Figure 6 - Preventive Maintenance Activity Costs by Frequency

Figure 6 shows over 80% of the Preventive Maintenance expenditure on activities with a frequency of one month or less.

ABC Analysis

ABC analysis is a common method for classifying inventories aimed at identifying critical inventory items. ABC classification is based on the Pareto Principal (Vilfredo Pareto (1848 – 1923)), that a relatively few items account for the majority of any given result. ABC classification argues that a relatively small number of inventory items account for the major part of the total inventory value. When applied to Preventive Maintenance activities a similar pattern is seen.

Figure 7 shows the results of applying ABC analysis to the Preventive Maintenance activities in the case study. The graph of Figure 7 shows that:

- 70% of Preventive Maintenance Costs were incurred by 25% of the Preventive Maintenance activities
- Just under half of the Preventive Maintenance activities accounted for 90% of Preventive Maintenance costs

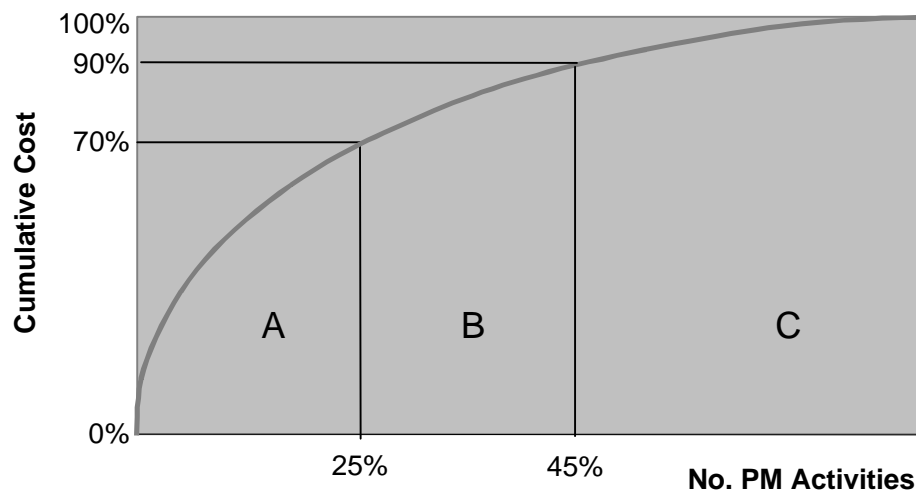


Figure 7 – ABC Analysis

Profile of Preventive Maintenance Activities

Using a combination of the Business Impact, Frequency and ABC classifications, the following opportunities were observed among 8,000 preventive maintenance activities:

- 700 activities of a high cost (Class A) with a negligible failure impact
- 1300 activities of a high frequency with negligible failure impact
- 1100 activities of a high frequency with partial production impact.

Modification to Frequencies

As a result of expected low probability of failure and the high cost of the Preventive Maintenance program, it was decided to reduce Preventive Maintenance frequencies considerably, according to assets criticality (business impact). The degree of frequency reduction is shown in Table 2.

The reduction in maintenance frequencies was performed in the Enterprise System by data manipulation. The impact of the frequency reduction on the workload is shown in Figure 8 and Figure 9. A total annual workload reduction of approximately 10,000 hours was achieved using this approach.

Eighteen months after the implementation of the frequency changes, the site has experienced no adverse affect on reliability as a result of the alterations made to Preventive Maintenance frequencies.

Business Impact	Code	Change to Frequency
Safety / Environmental	S	No Change
	10	No Change
Total Loss of Production	9	No Change
	8	Very high frequency reduced by one week or 50%.
Partial Loss of Production	7	One month or more – no change. Less than one month reduce by one week or 50%.
	6	One month or more – no change. Less than one month reduce by one week or 50%.
Negligible Impact	5	Reduce frequency by 100% for current frequencies up to 6 months.
	4	Reduce frequency by 100% for current frequencies up to 6 months.
	3	Reduce frequency by 100% for current frequencies up to 6 months.
	2	Reduce frequency by 100% for current frequencies up to 6 months.
	1	Reduce frequency by 100% for current frequencies up to 6 months.

Table 2 – Approach to Frequency Reduction

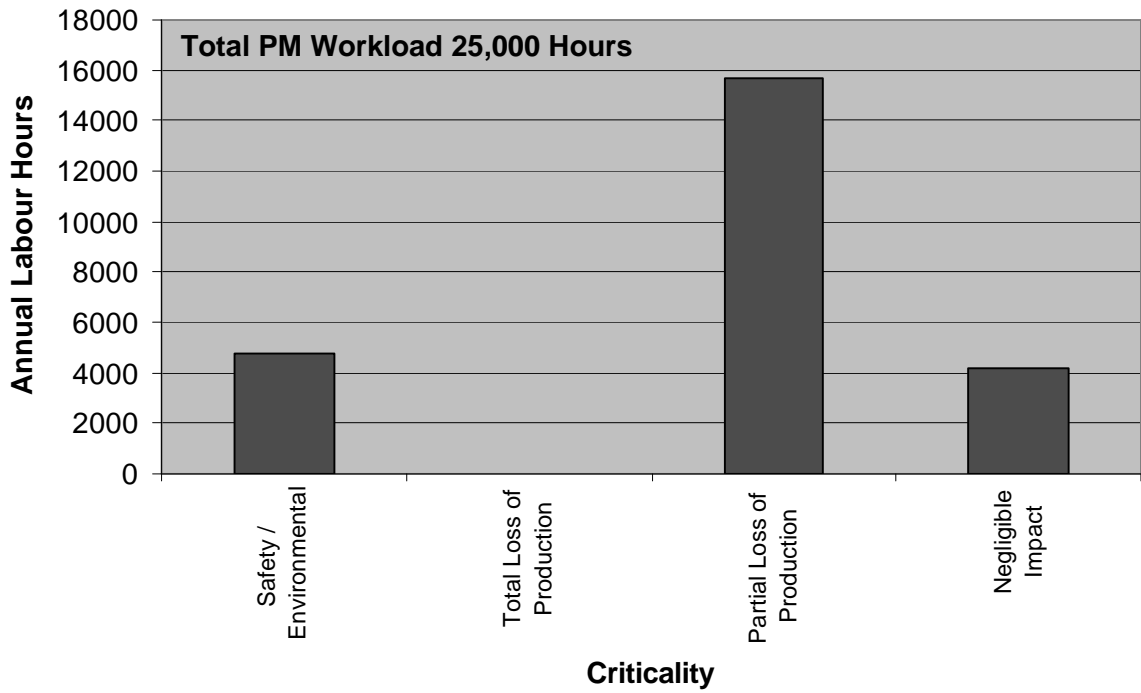


Figure 8 – Preventive Maintenance Workload – Before Frequency Modification

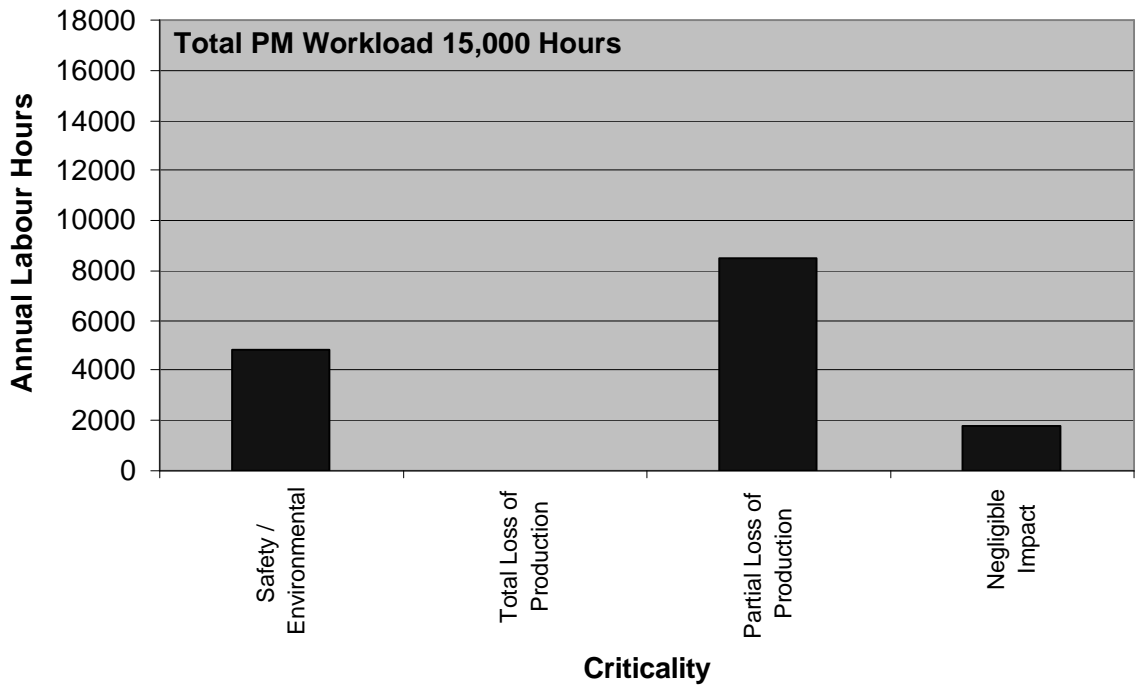


Figure 8 – Preventive Maintenance Workload – After Frequency Modification

CONCLUSION

Preventive Maintenance activities can have a significant impact on waste in maintenance and manufacturing as a result of both under-maintaining and over-maintaining. The problem of over-maintaining receives little attention by comparison with under-maintaining.

The choice of Preventive Maintenance frequency impacts the total cost of the Preventive Maintenance program. Conservative approaches to setting Preventive Maintenance frequencies increase maintenance waste while adding little or no value to the detection or prevention of asset failure.

The review of Preventive Maintenance activities has been shown in the past to effectively reduce waste caused by over-maintaining. A review of Preventive Maintenance frequencies offers further opportunities to reduce Preventive Maintenance effort. The reduction of Preventive Maintenance frequencies for high frequency activities on low criticality assets provides a method for quickly and effectively reducing Preventive Maintenance costs and eliminating maintenance waste.

REFERENCES

1 Buell J and Smedley P (March 2002), The War on Waste, Retrieved from http://www.optiant.com/news_articles_start.html

2 Author Unknown, Date Unknown, Waste in Maintenance: Seven Types – And What You Can Do About Them, Retrieved from http://www.bbpnews.com/safety/msb_35.shtml

3 Bever K, Enterprise Systems Integration: Opportunities & Obstacles Developing Plant Asset Management Systems March 13, 2000 (Presented at National Manufacturing Week, Chicago, Illinois)

4 Author Unknown, February 2002, Reliability Goes Nonfat With Lean Maintenance, Retrieved from http://www.mt-online.com/current/0202_leanmaint.html

5 Moubray J, *Reliability Centred Maintenance*, Butterworth-Heinemann, 2nd Edition

6 Hardwick J, Winsor G, RCM - Making the Process More Cost Effective One Year Later, ICOMS 2002

7 Turner S, PMO Optimisation Using PMO 2000 Reliability Software and Methodology, OMCS, 2002, Retrieved from http://www.pmoptimisation.com.au/downloads/pmo_for_assets_in_use.pdf

8 Jardine A K S, *Maintenance, Replacement and Reliability*, Pitman Publishing, 1973

9 Author Unknown, Facilities Engineering Electrical Exterior Facilities, Departments of The Army, The Navy and The Air Force, 1996, Retrieved from <http://www.usace.army.mil/inet/usace-docs/armymtm/tm5-684>

10 Author Unknown, TE 5.2-25 OFF POST PREVENTIVE MAINTENANCE TASK AND FREQUENCY CHART – APPENDIX, Retrieved from <http://www.mccoys.army.mil/A76/DSS/PWS/TE%205.2-25%20Off%20Post%20PM%20Task%20&%20Frequency%20-%20Appendix.doc>