Development of a Condition Monitoring Framework for Water Corporation Assets.

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Abstract

This paper looks at the development of a condition monitoring framework for Water Corporation assets, using wastewater pump stations as a case study. Condition Monitoring is one of several maintenance strategies and has the potential to reduce maintenance costs and increase reliability when applied in a suitable environment. The project looks at the various areas requiring consideration in the framework development and applies them to the case study, assessing its suitability for condition monitoring. It is hoped that the approach presented can then be applied to other business areas within the Water Corporation, in an effort to ensure that the most suitable maintenance strategies are employed. The study shows that unplanned maintenance accounts for the majority of maintenance conducted on major site assets. The quality of the maintenance data was low, and the consensus and support towards applying the maintenance strategy is lacking. Further work to improve data quality and understanding of condition monitoring is needed.

1. Introduction

The Water Corporation of Western Australia is responsible for over $1 billion worth of assets spanning a range of business areas. The successful operation of these assets is of paramount importance to the corporation as collectively, they are responsible for the supply, distribution and collection of water and wastewater to communities across the state. Consequently, the maintenance of these assets must be recognised as an area requiring serious strategic and technical focus in order for this aim to be achieved.

This project aims to develop a condition monitoring framework which, after implementation of the required steps, can be applied to appropriate assets in combination with other maintenance strategies. It is hoped that this will lead to increased availability of assets and minimised costs. For the purpose of this project the framework developed was applied to wastewater pump stations across the state in order to assess the suitability of condition monitoring for this business area. It is expected that if the strategy is found to be applicable to waste water assets, it will result in a decrease in the amount of emergency failures occurring; with future potential for extended intervals between scheduled maintenance as the condition monitoring techniques are mastered.

2. Process

The process used to deliver this project required that an initial framework be hypothesised and then applied to a case study, in this case, wastewater pump stations. This framework can be seen below in Figure 2-1.

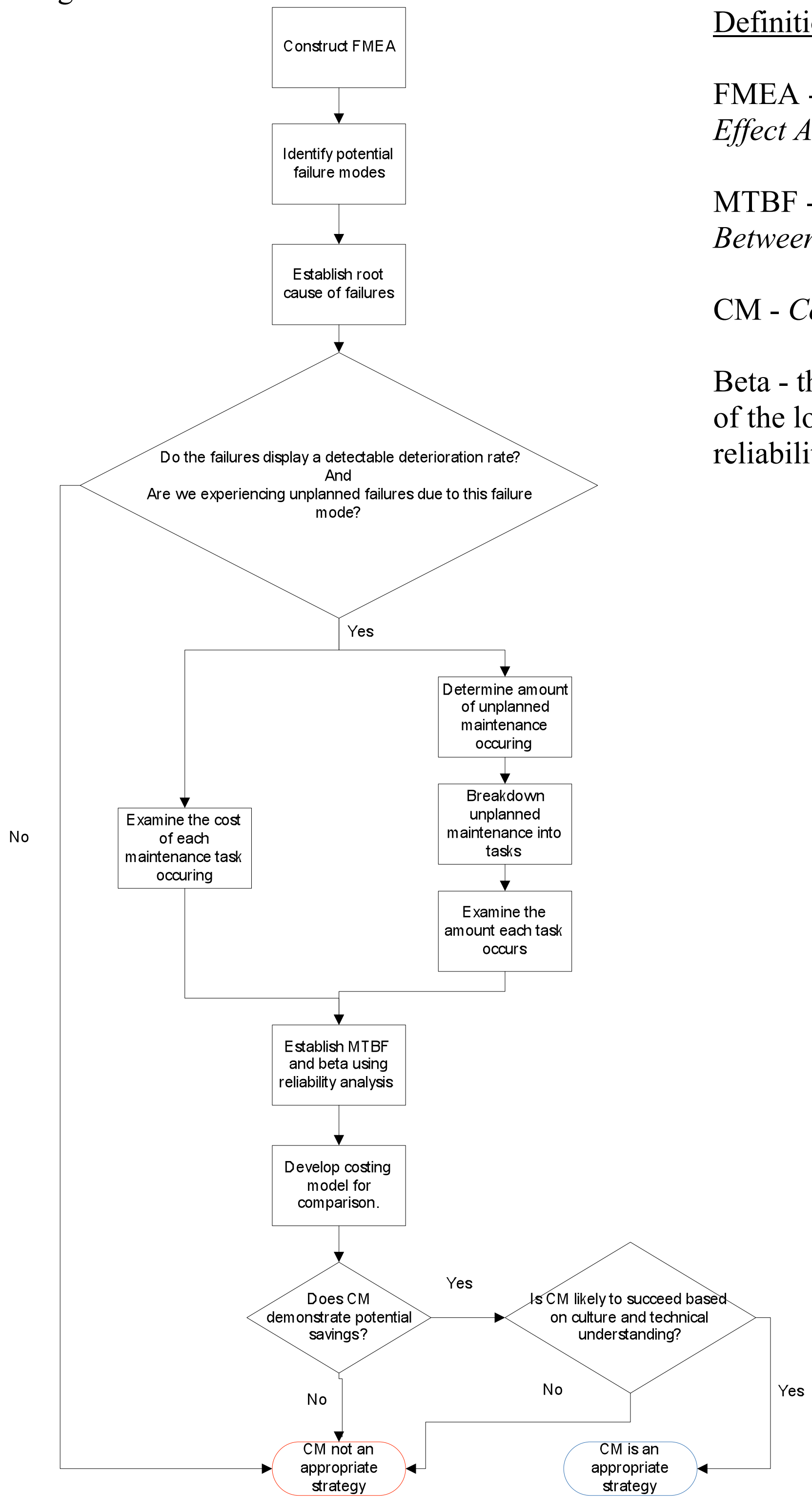

Figure 2-1: Proposed Framework

<u>Definitions</u>

FMEA - *Failure Modes Effect Analysis*

MTBF - *Mean Time Between Failure*

CM - *Condition Monitoring*

Beta - the shape parameter of the log-linear Weibull reliability plot.

The Framework brings together several different aspects crucial in the consideration of condition monitoring as a maintenance strategy. Essentially it examines the application of the strategy from two main perspectives:

1. Technical: will condition monitoring provide the required information?
2. Business: will the application of condition monitoring be worthwhile?

These two questions will be dependent on four main areas to be considered:

1. Historical data
2. Failure mode and root cause identification
3. Maintenance costing
4. Cultural attitudes and technical competency of staff involved.

In order to assess the current maintenance practised on wastewater pump stations, maintenance records for the past five years were extracted for analysis. This data was used to identify the cost of current maintenance, as well as the amount and different types of unplanned maintenance occurring.

Condition monitoring can only reduce failures which exhibit deterioration rates, as the strategy focuses on tracking this deterioration. If the failures identified are found to occur instantaneously (i.e ragging), then the application of condition monitoring will not contribute to reducing these failure occurrences.

A FMEA (failure modes effects analysis) of wastewater pump stations was conducted by breaking down a general station site into a set of functional subsystems and their associated components. The ways in which each subsystem could fail were identified using the historical data available as well as by consulting a variety of WC technicians and maintenance management personnel.

Using the established costs and reliability findings, a costing model was developed. It was constructed to enable the user to input the number of years required for the asset life, and then compare a base case of costs incurred without condition monitoring against those incurred with condition monitoring applied across this selected time period. The model also took into account the expected efficiency of the condition monitoring technique, and the expected reduction in failure frequency and cost as a result of the application of the selected technology.

In order to assess if a condition monitoring maintenance strategy would have the support of all personnel from management to technicians, an anonymous survey was carried out. The aim of this survey was to explore

1. Current condition monitoring practice, and
2. Views concerning when condition monitoring is appropriate.

The survey was conducted to find out at which organisational levels within the Water Corporation, condition monitoring was disregarded or embraced. Three separate distribution groups were established as seen in Figure 2-2.

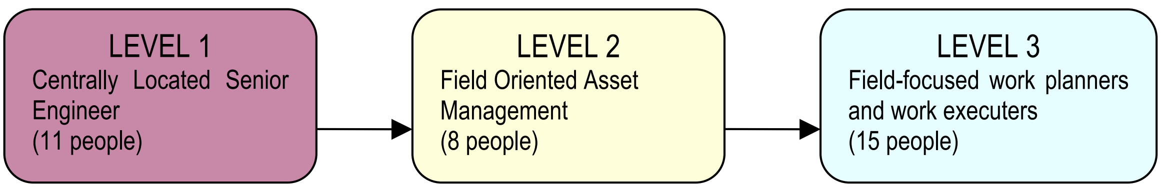

Figure 2-2: Survey Personnel Levels.

3. Results and Discussion

General industry practice for asset management aims for a higher rate of planned maintenance than unplanned maintenance. This not only has benefits in increasing the health and therefore the life of the assets, it also enables for better long term financial planning as unforeseen costs are minimised. Unplanned maintenance is commonly three to four times more expensive than planned maintenance (Chitra 2003). Wireman suggests that in a successful maintenance program, planned maintenance should account for approximately 80% of actions, with the remaining 20% being emergency maintenance activities (Wireman 1998).

The results indicated that for the assets in question, the WC planned maintenance falls well short of the 80% target set by Wireman. In fact planned maintenance accounted for only 35% of the maintenance occurring, whilst unplanned accounts for the remaining 65%. The cost of the unplanned maintenance occurring can be ranked according to the costs incurred for each task across the selected time period as seen in Figure 3-1.

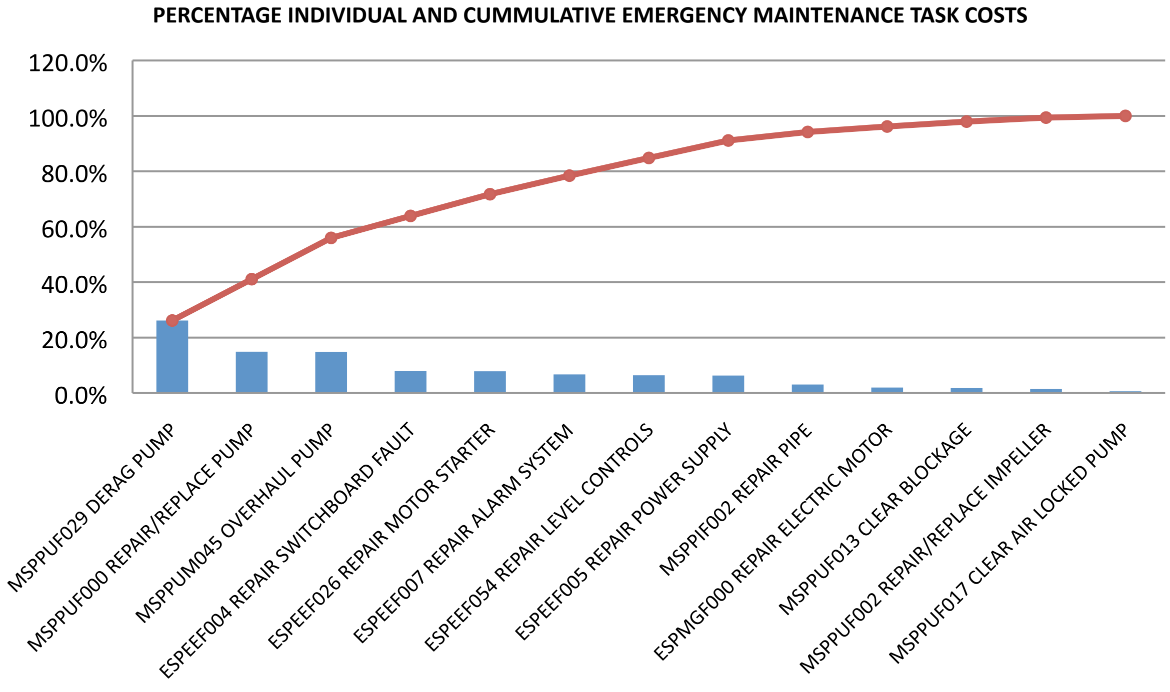

Figure 3-1: Wastewater Pump Stations Unplanned Maintenance Cost Breakdown (Years 2005 – 2010)

It can be seen from Figure 3-1 that six maintenance tasks are responsible for 80% of the costs. Of these six, only a maximum of four have the potential to use condition monitoring to decrease their frequency and costs incurred. The remaining two; ‘Derag pump’ and ‘Repair Alarm system’ are failures which do not exhibit a rate of deterioration, rather they are random failures and therefore condition monitoring techniques cannot be used to predict the likelihood of potential failures occurring. Overall, potentially detectable failures account for approximately 51% of the maintenance failure tasks seen to occur.

The FMEA also highlighted the low amount of detectable failures known to occur. Only 43% of the failure modes identified occurred in a manner that was detectable at some deterioration rate. Combined with the unplanned maintenance tasks identified in Figure 3-1, it can be seen that only 47% of the total number detectable failure modes identified were seen to occur at sites.

Table 3-2: Detectable Failures based on FMEA

SUBSYSTEM NAME	NUMBER OF COMPONENTS	NUMBER OF FAILURES MODES	NUMBER OF FAILURE CAUSES	FAILURES WITH DETECTABLE RATE BEFORE OCCURANCE (%)	FAILURES WITH DETECTABLE RATE AFTER OCCURANCE (%)	UNDETECTABLE FAILURES
Pump	10	27	45	53%	32%	33%
Motor	3	6	11	72%	33%	27%
Switchboard	1	1	1	~100%	~0%	0%
Power	1	1	2	0%	0%	~100%
Level Sensor	1	1	1	~0%	~0%	~100%
Alarm System	1	4	6	14%	0%	86%

A cost prediction model was then constructed for each main asset (pump, motor and switchboard). For the construction of this model it was assumed that for every 10% decrease achieved in emergency maintenance, a 5% reduction in scheduled maintenance could also be achieved. Both the internal and external application of each condition monitoring technique (thermography, efficiency testing, P.I testing and vibration) was then compared to the Base Case, and the reduction factors examined. Figure 3-3 shows an example of this model, portraying the cumulative maintenance cost after ten years for Pumps based on the execution of condition monitoring using external services. The model includes the initial start up costs of condition monitoring maintenance, as seen by the differing initial costs for each technique.

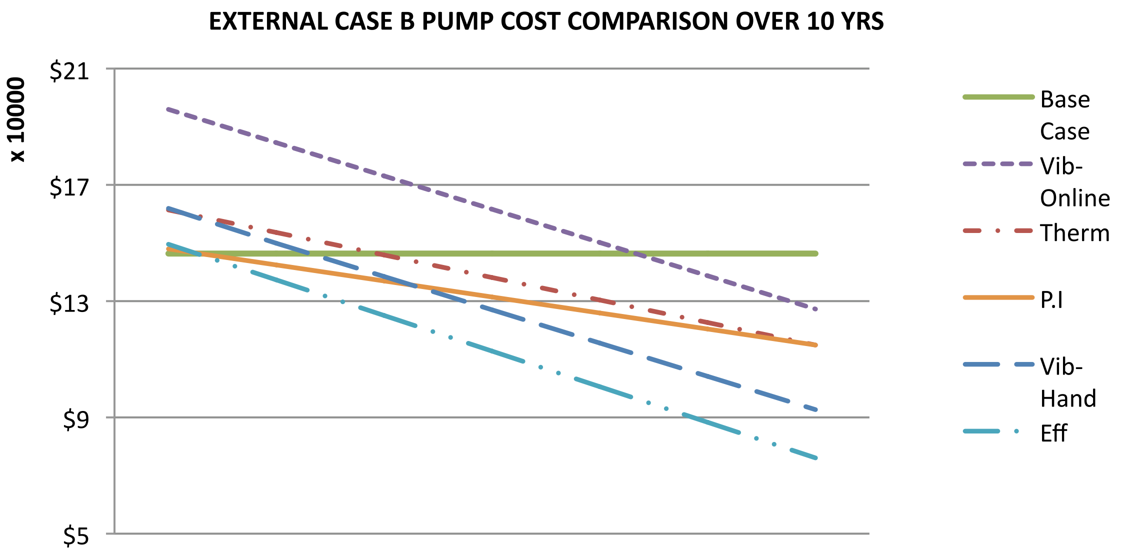

Figure 3-3: External Pump Cost Comparison for fixed reduction period.

This enables prioritising of condition monitoring techniques by considering the maximum reduction factors required for a particular saving to be achieved. For this plot it can be seen that efficiency testing demonstrates the greatest potential savings. Based on the data available, it was found to be cheaper than many other techniques, but also required the smallest reduction factors in order for the same amount of saving to be achieved.

The survey conducted found that there was a large divergence of opinion across almost every aspect regarding how and when to apply condition monitoring. The following table displays the overall responses to each question for all persons surveyed. The overall response amount was 71%.

Table 3-1: Survey Response Percentages, majorities highlighted. (Num persons = 24).

	STRONGLY DISAGREE	DISAGREE	UNSURE	AGREE	STRONGLY AGREE
1. I know situations when failures were avoided due to condition monitoring.	9.1	9.1	13.6	50	18.2
2. I know situations when failures occurred, which could have been prevented by condition monitoring	0	4.5	4.5	63.6	27.3
3. The appropriate assets have condition monitoring data collected	4.5	54.5	27.3	13.6	0
4. There are assets that should be included in the condition monitoring program which are not currently monitored.	0	0	22.7	54.5	22.7
5. We collect too much condition monitoring data	22.7	40.9	27.3	9.1	0
6. It is clear what decisions the condition monitoring data is used for	4.5	54.5	9.1	31.8	0
7. It is clear who analyses the condition monitoring data and makes recommendations	18.2	45.5	13.6	22.7	0
8. Condition monitoring is one of a number of maintenance strategies for an asset	0	9.1	0	63.6	27.3
9. The appropriate asset maintenance strategy is determined by the failure behaviour and consequence of the failure	4.5	36.4	9.1	36.4	13.6
10. Condition monitoring is the best maintenance strategy for pumps	9.1	36.4	27.3	22.7	4.5

When these trends are examined and compared between the personnel levels, it appeared that overall although people are aware of condition monitoring benefits and have seen them in the past, there is little support for current condition monitoring programs within the Water Corporation due to a belief that it simply 'isn't right' for the organisation. The division between those who agree, and those who disagree, is quite large in upper level management, resulting in the propagation of this split in attitudes down through lower work levels. This in turn impacts the quality of data collected, and the storage and analyses of data.

4. Conclusions and Future Work

In summary it is found that whilst there is certainly a lot of room for improvement in the maintenance currently practised, condition monitoring may not be the best strategy in this instance. This is due to the low quality of data available for the framework construction, and the current attitudes towards using condition monitoring. It would indicate that these areas require a lot more focus before a more reliable framework, which has the support of those involved in its execution, can be constructed. Future work could be conducted in examining the motivating factors behind quality data collection and investigating how to further improve understanding and communications regarding condition monitoring strategies in relation to current practises.

5. References

1. Chitra, T. 2003, 'Life Based Maintenance Policy for Minimum Cost', in *Reliability and Maintenance Symposium 2003*, RAMS, Florida, pp. 470-474.

2. Wireman, T. (1998). *Developing performance indicators for managing maintenance.* First edition. Industrial Press, Inc. NY