Using Business Common Sense to Improve Maintenance Practices

Summary

In recent years, we have seen the widespread proliferation of techniques which add little or no value to maintenance; instead they all too frequently represent the triumph of good marketing over good analysis. Further to this, we often see maintenance pundits struggling to define the output of maintenance as “reliability, availability and maintainability”. Instead, the output of maintenance should very simply be “to improve the value of the organization”. So how do we define value? The short answer is company share price. But in an operational sense we will use its proxy – ROI or Return On Investment. As part of this new evolution, we should be making a strong argument for the application of this business common sense to all common maintenance practices.

In short, if it does not add value, don’t do it.

In this paper, we will use this logic to resolve some common maintenance issues and dichotomies. We will use a combination of logic, statistics and the application of well-accepted techniques to improve maintenance decision making. To do this requires better data and better analysis of that data. The result is better selection of maintenance tactics, better equipment reliability and better company value.

Standard Techniques – the Drawbacks

RCM (Reliability Centred Maintenance), CMMS (Computerized Maintenance Management Systems and embracing EAM’s – Enterprise Asset Management systems) and CM (Condition Monitoring) have all existed for 30 or more years; their techniques and logic are widely used to select and implement maintenance tactics. But they have flaws that inhibit their effective use. We would like to first, identify some of these drawbacks, and second, to suggest how to rectify them.

1. RCM pays little attention to historical data; the root cause of this is that the main proponents of (and salesmen for) RCM saw themselves in competition with the main historical data source (the CMMS). An objective view would see them as necessarily complementary – how for example can one track the occurrence frequency of failure modes better than on a CMMS work order? And what better way to start an RCM implementation than by examining the Failure Modes that have actually occurred? The resolution of this lies in linking the RCM database to the CMMS database. (More of this later).

2. The reality of the RCM process is that Failure Modes are not comprehensive – dependent, as they are, on “what if” scenarios applied by maintenance and reliability engineering staff. Indeed one detailed study suggests that of the 610 RCM Failure Modes identified on turbofan aircraft engines, only 142 actually were observed over a 10 year period. Perhaps this a triumph of failure
avoidance; on the other hand, by mining the CMMS data, 585 additional, unexpected Failure Modes were discovered. The resolution of this lies in enhancing the RCM database by adding actual maintenance experience, as it happens, from the CMMS. (Again, more later).

3. A major deficiency in failure analysis is that it predicts the future by looking backwards (ie at the CMMS databases); but these databases typically omit information relating to (for example) the RCM concept of Potential Failures (PF’s). Two reasons for this – first the CMMS does not allow for this data to be collected, and secondly the technicians are not trained to recognize PF’s in the flesh. Solving this problem requires minor modifications to the CMMS Work Order process and a modicum of training at the coal face. Successful implementations of this combination at industrial site have been enthusiastically accepted both by the technicians and the supervisors.

4. The purpose of CM data is to provide the basis for more intelligent decision-making. Three steps are involved – first collect the right data (and stop collecting the wrong data); second, do the right analysis; and third use the data for making the right decision. In our experience, upwards of 70% of the data has no predictive ability; plus of course, key data is missing. The critical point is that CM data must relate to the failure mode – the question is how to demonstrate this. We will show this connection later.

**Failure Prediction**

No one questions the need to predict failures. But this simple statement begs so many questions….

a. Which failures? Here we revert to our earlier stated objective of maintenance adding value, and propose to use “cost of failure” as the primary determining factor….

\[
\text{Cost of Failure} = \\
\text{Cost of Emergency Repair} + \\
\text{Cost of Lost Revenue} + \\
\text{Penalty Costs, Reputation Costs, Fines and Reparations}
\]

In the military sphere, adjustments need to be made to recognise mission readiness and unnecessary backups as key costs of failure instead of loss of revenue or profit. The rush to solve an emergency inflates the repair cost – including overtime, expediting or scavenging parts, building work-arounds; and safety costs, environmental costs, political embarrassment, etc need to be factored in. In a Government environment, we may use customer satisfaction as the proxy for revenue loss or profit loss. This leads us to produce a simple failure cost report:
This draws our attention to the overall cost of the failures rather than the frequency and the duration. Bad Actors then become Bad Cost Actors. Every Maintenance Manager should have this report on his desk every month.

b. How do we measure resistance to failure? This has great theoretical prominence – but it is a complex and little understood issue; however if we substitute “performance” as a proxy for resistance to failure, then the concept becomes simpler and easily measured. Hence a pump required to pump 1000 litres per minute has “failed” if it pumps “only” 999 – the required amount being necessary for feedstock supply, cooling purposes etc. Thus an instance of Functional Failure can be readily recorded on the work order.

c. Similarly, as the performance starts to slide down the slippery scope of the P-F curve, the point of acceleration in the rate of performance degradation is often readily apparent.
in practice – thus suggesting the Potential Failure point. Just as we have defined a measurement for the FF point, so we need to define a specific condition value for the PF point – 1100 litres per minute in the above example. Implementing the “Pass/Fail” score in each case, greatly facilitates the ease of data collection and analysis. More importantly – as we shall see later – the PF acts as a warning signal needing a response.

d. How do we deal with equipment where the PF and FF points are not foreseeable? The obvious examples are electronic and electrical equipment. Clearly the FF and PF points exist – but they are typically simultaneous. Hence condition monitoring will not help except to advise us of complete failure. In these cases, we respond with stand-by units, parallel processors, plug-out plug-in replacements and other well established techniques. (We may well argue that measurable conditions do in fact exist, but that we have not yet figured out how to measure them – but that is beyond the scope of this paper).

e. How does age fit into the equation? As Nowlan and Heap – and others – have pointed out, age has a direct impact on failure in only a relatively small number of cases. Yet intuitively we feel that age is an important factor. A partial explanation of this dichotomy lies in how we define age; rather let’s define it as “working age”. This has several implications – involving for example (on the negative side of probability of failure) load and (on the positive side) an out-of-service state. Load or stress on the equipment is difficult to track accurately, so most frequently we default to operating hours (equals total time minus out of service time). Which in turn requires us to record “suspensions” on the work order (as an alternative to a PF or an FF).

f. Next, how do we relate the multiple streams of data that are now so frequently readily available from the CM systems, to the Failure Mode? The answer lies in the use of Proportional Hazards Modelling – an advanced statistical technique which shows which of the variables (or co-variates) have the most significant impact on the failure mode. And which have little or none. This technique is built into EXAKT – a product developed
by Dr Andrew Jardine at the University of Toronto. Repeated use of this tool suggests that most CM data has almost zero relationship to the incidence of failure and therefore can be ignored as a predictor. Such data does not need collecting. Equally, key data such as working age and other condition variables are frequently missing.

g. In predicting failure, we require the predictive ability of CM data to be accurate and consistent. EXAKT achieves this by providing a probability of failure in a given period (completion of a mission, prior to a maintenance shutdown etc), and at the same time applying a statistical test showing confidence levels. Relating the three elements of failure probability, confidence levels and cost of failure provides a strong insight into the “best” maintenance tactic to follow. Low confidence levels prompt both conservative action (to pre-empt the FF point) and the collection of more data, more accurate data or more consistent data. Especially when the cost of failure is high.

h. Recognizing the shortcomings of CM as the best or only basis for the prediction of failure, pushes us to develop a better approach. Given that the output needs to be an improved reliability analysis, and given that there are already some effective reliability analysis tools on the market, what is the missing link? Let’s call it a Reliability Database.

**Reliability Database**

We have previously hinted at the key elements of the reliability database – ie the sources of data. Let’s now put a structure around these sources of data:

1. Historical data – primarily from the CMMS – but with simple modifications to the work order to accommodate the missing FF, PF and Suspension data. Also, for reasons explained later, to add a cross reference to the appropriate record in the RCM database.

2. Current status data – primarily from the CM sensors. These will give us (along with PLC’s, SCADA and others) the best insight into the current equipment conditions.

3. Expected data – or what failures we should realistically expect based on our assessment of the equipment and its operating context as recorded in the RCM database.

In order to accommodate these data sources, Living RCM (LRCM) software has been developed. This sits among the three data sources and acts as the data traffic cop – collecting, rejecting and storing the various data elements to create a Reliability Database. This in turn acts as the feedstock for the commercial reliability tools (such as EXAKT mentioned above, but also Pareto, Weibull, OREST, Perdec, Age/con and others).
Earlier in this paper, we touched on the linking of the RCM and CMMS databases. Clearly these are complementary in prompting a better understanding of failure and reliability. Contrary to common practice, the best output of an RCM analysis is not a row of dusty tomes on the top shelf of the engineering office; the best output of an RCM analysis should be an improved Work Order. And equally well, a very satisfactory output of a Work Order is an improved RCM record – especially if it adds new knowledge or a new failure mode to the RCM analysis. By looking at the logical flow of activities, we can quickly see the advantages of integrating CMMS and RCM:

1. The Inspection prompts identification of measurable Potential Failures.
2. This leads to the preparation of a PM Work Order (or often, an immediate on the spot remedial or preventive action).
3. The PM tasks are specifically designed to prevent a Functional Failure. If we cannot tie the PM tasks to the prevention of a Functional Failure, then we must challenge the value of the PM.

4. LRCM prompts the technician completing the work order, not to fill in the typical Fault Code (the value of which is highly questionable, and in our experience rarely used), but instead to access the Failure Mode in the RCM database and insert it in the Work Order.

5. In the event of a “significant” task – ie one that adds to our knowledge of the equipment, such as a new Failure Mode, or one that exhibits new characteristics compared to the RCM record – then a temporary record is created from the work order by LRCM to await validation by the RCM analysis team.

6. Adding the RCM record reference number (which is automatically ported over to the work order with the Failure Mode), we now have a record of the occurrence frequency of the RCM Failure Mode – surely a valuable tool in evaluating reliability.

7. In addition, a CMMS record of an unexpected occurrence of a Failure Mode in a critical equipment demands several responses – not only the repair of the equipment, but also the repair of the RCM record, AND the repair of the RCM logic AND all the other records which used the same logic. Ease of access of the RCM database from the CMMS thus becomes critical to creating a regime of Living Reliability.

**Maintenance Improvements – do they happen?**

Coming to the bottom line – does the application of these techniques reduce costs and improve the quality of maintenance; does it improve decision making?

Here we can offer a number of indicators:

a. does the proposed new maintenance regime or individual tactic reduce costs? The cost function built into EXAKT incorporates the cost of failure and the cost of preventive repair. Its cost optimization model shows the lowest cost combination of preventive work and run to failure, and compares it with the current actual mix of maintenance tactics. A second modelling option provides the optimum balance of PM and Run to Failure (RTF) to achieve the minimum downtime, or (a third model) to achieve a given minimum level of reliability. Industrial experience shows cost reductions in the order of 20 to 40% of current maintenance costs – using the customers’ cost data as the baseline.

b. As to whether the quality of maintenance is improved, we should go back to one of the fundamentals of RCM. One of the key insights is the use of PF’s to prevent FF’s; so what better way to test the validity of the process by graphing the two; built into the analysis program must be a self-checking mechanism (as well as many other standard KPI’s). Would it not be a remarkable improvement if our vibration analysis or oil analysis programs could tell us whether they are doing their job properly? Or not?

c. Is business decision-making improved? For this we look at the basic logic:
1. If we can apply the cost of failure (as defined above) to the probability of failure (as defined by EXAKT above), then we can conclude with a practical definition of “Risk”. The do-nothing scenario can be called the “Run Risk”.

\[
\text{Run Risk} = \text{Cost of Failure} \times \text{Probability of Failure}
\]

2. If we now calculate the cost of a PM (using directly parallel logic, but different numbers for the cost components) to the probability of doing the PM (which if we decide to do it is clearly 100%), then we can define the “PM Risk”.

\[
\text{PM risk} = (\text{PM cost} + (\text{Outage cost per hour} \times \text{PM time})) \times 100\%
\]

3. By comparing the Run Risk to the PM Risk, we can develop a Risk Ratio.

\[
\text{Risk Ratio} = \text{Ratio of Run Risk to PM Risk}
\]

Operations managers (and politicians) can now decide whether the investment of say $40,000 in a PM to avoid the Run Risk of $200,000 (comprising a 25% probability of a $800,000 failure) is a good decision – ie a Risk Ratio of 5:1. Or should we spend $360,000 to eliminate the 15% probability of a risk of a $3million failure – a Risk Ratio of 1.3:1 (see table below). Clearly the higher the Risk Ratio, the greater the PM’s leverage in reducing risk; and consequently the higher the PM’s ROI, and the more value is added to the company.

<table>
<thead>
<tr>
<th>Unit</th>
<th>PM Cost</th>
<th>PM Time</th>
<th>Outage cost per Hour</th>
<th>PM Risk</th>
<th>Failure Repair Cost</th>
<th>Failure Repair Time</th>
<th>Failure Probab 30 days</th>
<th>Run Risk</th>
<th>Risk Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Niigata Diesel</td>
<td>25,000</td>
<td>15 hours</td>
<td>1,000</td>
<td>40,000</td>
<td>100,000</td>
<td>29 days</td>
<td>25%</td>
<td>200,000</td>
<td>200:40 = 5:1</td>
</tr>
<tr>
<td>Yugo Turbine</td>
<td>25,000</td>
<td>1 week</td>
<td>2,000</td>
<td>361,000</td>
<td>250,000</td>
<td>60 days</td>
<td>15%</td>
<td>470,000</td>
<td>470:361 = 1.3:1</td>
</tr>
</tbody>
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As a logical next step, senior managers can then establish whether the Risk Ratio (in this case 5:1) violates the organization’s risk limits policy. Plus by tracking the change in the Risk Ratio through time, they can see whether the current Risk Ratio trend exceeds the operating policy before the next scheduled maintenance shutdown or before the end of the mission.

Despite it being the fallible human that pushes the button, business logic such as this must surely improve decision making. Providing a (relatively) objective assessment of alternative business risks surely provides a stronger foundation for improved decisions.

In this paper, we have attempted to show how the use of solid business logic to maintenance can lead to better decision-making, maintenance improvements and reduced maintenance costs. The distinct advantage of this approach is that while the whole program may look intimidating, each step is relatively straightforward and can be implemented with minimal change to the current status. And each step brings us closer to making Maintenance a Business Value provider.