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World Class Reliability Assurance*



Deciding when to use **RCM**
and when to use **PMO**
*Planned Maintenance
Optimisation*

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Table of Contents

Deciding when to use RCM and when to use PMO	1
Review of the RCM Approach	1
Functional Differences	1
Methodology Differences.....	2
1. Failure Mode Analysis	2
2. Rolling up of Failure Mode Analysis where Logical.....	3
3. Optional Functional Analysis	3
Flexibility comparisons	4
Filtering of failure modes by trade	4
PMO is self regulating in terms of investment and return.....	4
Benefits of speed	4
Weaknesses of Statistically Based Methods.....	5
Key Features of a PM Optimisation Program.....	6
PMO Quickly forms the Baseline for Effective Reliability Engineering and Defect Elimination	6
PM Optimisation is based on Sound Engineering Principles.....	6
PM Optimisation Recognises And resolves Problems with Data Accuracy.....	7
PM Optimisation Makes Effective Use of Scarce Labour Resources.....	7
PM Optimisation Improves the Productivity of Operators and Maintainers.....	8
PM Optimisation Is Adaptable to Suit Specific Client Situations and Objectives	9
PM Optimisation Motivates Personnel	9
Implementing PMO2000™	10

Deciding when to use RCM and when to use PMO

There is no doubt that conventional and statistical approaches to RCM have assisted industry gain better control of their assets and manage them more intelligently. However, it has long been considered that both methods have weaknesses and have not lived up to expectations.

Review of the RCM Approach

According to the standard SAEJA1011 Issued Aug 1999, any RCM program should ensure that all of the following seven questions are answered satisfactorily and are answered in the sequence shown:

- 1 What are the functions and associated desired standards of performance of the asset in its present operating context (functions)?
- 2 In what ways can it fail to fulfill its functions (functional failures)?
- 3 What causes each functional failure (failure modes)?
- 4 What happens when each failure occurs (failure effects)?
- 5 In what way dose each failure matter (failure consequences)?
- 6 What should be done to predict or prevent each failure (proactive tasks and task intervals)?
- 7 What should be done if a suitable proactive task cannot be found (default actions)?

Functional Differences

RCM and PMO2000™ are both methods used to define the complete maintenance requirements of physical assets.

Nolan and Heap (1978) coined the term Reliability Centred Maintenance (RCM) as a process to be used to draw up maintenance programs for new types of aircraft before they entered service (Moubray, 1997). Thus it was a zero-based tool developed for use in the design phase of an asset's life cycle.

In the absence of better methods, since Nowlan and Heap, RCM has been applied retrospectively to plants well into their life cycle. In over 20 years since its derivation, RCM has failed to become a day to day activity performed by most organisations. Few organisations have applied RCM to anything other than their most critical assets suggesting that there need to be alternate paths to the creation of maintenance policies rather than starting from scratch.

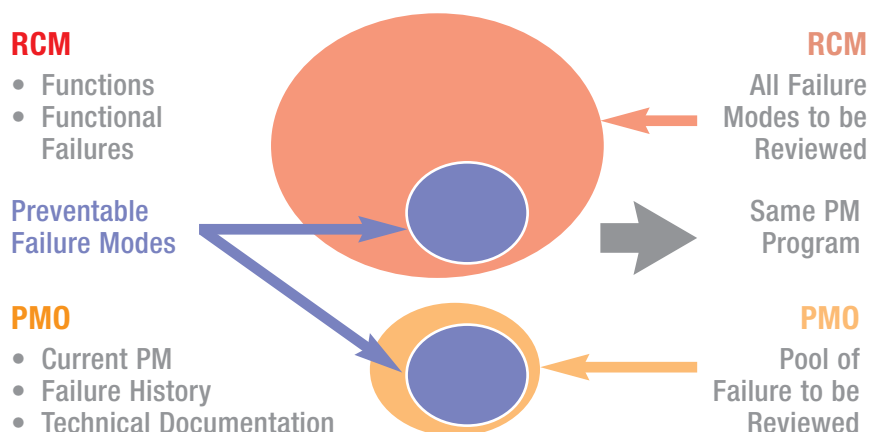
In response to this need, PMO2000™ was developed as a process of review for assets that have an established maintenance program (formal or informal) but where that maintenance program was inefficient or misaligned with business needs.

The central difference between RCM and PMO2000™ is the way in which failure modes are generated.

- RCM seeks to analyse every failure mode on every piece of equipment within the system being analysed.
- PMO generates a list of failure modes from the current maintenance program, an assessment of known failures and by hazard analysis of technical documentation - primarily Piping and Instrumentation Diagrams (P&IDs).

Figure 1:

Illustration of how RCM and PMO produce the same result.



The differences in the two approaches mean that PMO2000™ deals with significantly less failure modes than RCM and arrives at the failure modes in a far quicker time frame. PMO2000™ selective coverage means that the maintenance program that results will be the same regardless of whether PMO2000™ or RCM is used (figure 1).

Other differences are discussed in the following paragraphs.

1. Failure Mode Analysis

The focus of good equipment design is to ensure high levels of reliability, maintainability and operability over the equipment life cycle. At the design stage, this means attempting to eliminate all high likelihood and high consequence failures

It is therefore, not surprising that when reviewing the complete set of likely failure modes using RCM analysis, that by far the greatest number of outcomes, or recommendations, are "No Scheduled Maintenance". This is to say that for the failure modes left in the design, either:

- Their likelihood is very low therefore the cost of a preventive or predictive task is likely to be more than the cost of failure, or
- There is no technically feasible predictive or preventive maintenance task known to manage them.

In the author's experience, rigorous RCM analysis of equipment in accordance with the standard shows that, on average, about 80% of failure modes result with the policy of No Scheduled Maintenance.

3

This number rises with electronic equipment such as a PLC and falls with equipment that has a high number of moving parts such as a conveyor.

Table 1:
Illustration of Failure Mode Analysis using PMO

Task	Failure Mode Analysed (rolled up)
Perform Vibration Analysis on the Gear box	Gear wears, or cracks. Gear bearing fails due to wear. Gearbox mounting bolts come loose due to vibration. Gearbox coupling fails due to wear.

Table 2:
Illustration of Failure Mode Analysis using RCM

Function	Function Failure	Failure Modes
To provide 20 hp of power to the fan such that the fan spins at 200 rpm	No power whatsoever	Gear wears
	No power whatsoever	Gear cracks due to fatigue
	No power whatsoever	Gearbox fails due to wear
	No power whatsoever	Gearbox bearings fails due to wear

2. Rolling up of Failure Mode Analysis where Logical

RCM treats each failure mode independently. This results in the same analysis being documented many times but resulting in only one task being recommended for all the failure modes listed. Using RCM this is unavoidable no matter how experienced the analysis team may be.

PMO2000™ starts from the maintenance task and therefore many failure modes can be listed against the one task. This significantly reduces the analysis time by reducing the records that need to be dealt with. The concept can be best described by reference to Tables 1 and 2. It can be seen from Table 1 that providing vibration analysis was a technically feasible and cost effective task to prevent all these failure modes from occurring unexpectedly, PMO2000™ would consider the failure modes as a group.

Conversely at Table 2, RCM can be seen to have created a lengthy analysis process compared with PMO2000™. Accepting that the resulting maintenance program will be the same the route to this result covered four times the administration and probably double the analysis time. Furthermore, with decomposed failure modes, there is additional administrative effort required to roll them back up and link the four failure modes to the one task.

3. Optional Functional Analysis

RCM begins with a complete functional analysis of the equipment whereas with PMO the effort expended on functional analysis is discretionary. This is primarily because consequence evaluation is performed at Question 5 of PMO2000™. As consequence evaluation implicitly involves understanding what loss of function is incurred, additional functional assessment is a duplication¹ of effort.

Done properly, functional analysis consumes 30% of the total RCM analysis time and is the lowest value adding activity of the process.

¹ This point is also relevant where functions are hidden, as the loss of hidden functions will result in consequences that are conditional on some other failure occurring.

Filtering of failure modes by trade

RCM analysis cannot regulate or filter which failure modes are analysed at which time. Therefore, RCM analysis requires the presence of all trades simultaneously.

With PMO2000™ it is possible to review the activities of a particular trade on a particular piece of equipment or site. This is because PMO2000™ begins with maintenance tasks that can be filtered by trade. This is particularly useful when the activities of one trade are ineffective or inefficient and need to be reviewed in isolation from other trades.

There have been highly successful PMO2000™ analyses performed exclusively on either operator rounds, on instrumentation rounds, on lubrication rounds, on vibration analysis rounds etc. This type of focus is not possible using RCM.

PMO is self regulating in terms of investment and return

PMO2000™ is highly effective where equipment has numerous failure modes but where the vast majority of these are either random, instantaneous or not of high consequence. A simple example would be a mobile telephone. Mobile phones have hundreds of functions. To define the functions of a mobile phone would take many hours depending on how rigorous the group was in defining performance standards.

The other point here is that RCM if done diligently would require the input of specialist electronics engineers to define the failure modes properly². Conversely, PMO2000™ would require only the operators as electronic failure modes would not form part of the pool of failure modes that are currently addressed by PM or part of the failure history to any great extent.

PMO2000™ would take no more than 20 minutes to complete the analysis in total and realise that the only maintenance that is required is to do with managing the consequences of battery deterioration.

Benefits of speed

Experience in the US Nuclear Power Industry was that over a large number of analyses, PMO2000™ was on average six times faster than RCM (Johnson, 1995). PMO2000™ is considered to be a much faster approach than the approach taken by Johnson.

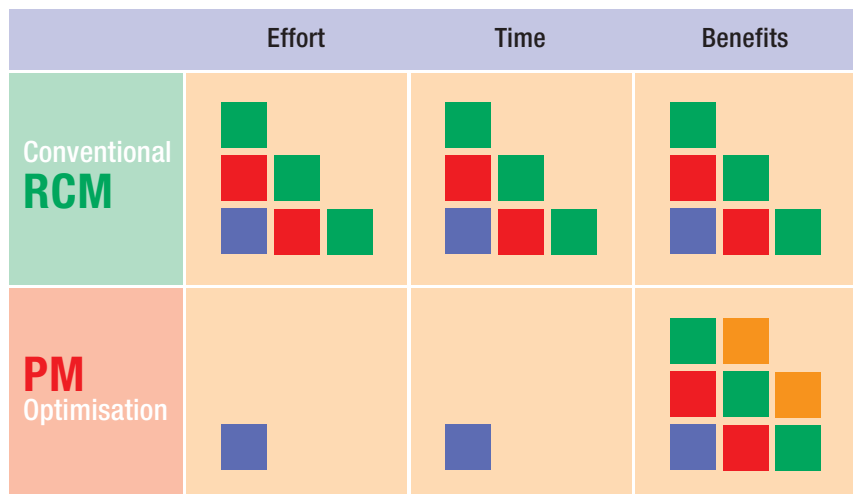
The positive effect of deploying a process of maintenance analysis that is six times faster than RCM for the same given outcome cannot be overstated. The benefits are listed below:

- Resources to perform analysis are generally the most valuable and scarce on site. The less resource intensive the program (for the same results) the less the organisation will suffer from the loss of its most valuable people.
- Efficient analysis allows the organisation to be implementation intensive rather than analysis intensive.
- Maintenance analysis is subject to diminishing returns. PMO2000™ is cost effective on all items of the plant whereas it is difficult to justify RCM on any other than critical assets because of the high fixed cost and the inflexibility of the process.

² In fact what happens in reality is that RCM facilitators "Black Box" the item which is to say that RCM in its strict use can not cope efficiently with analysis of such assets.

- Where the maintenance of failure modes that have safety or environmental consequences is considered suspect, the use of PMO2000™ will allow these issues to be dealt with much faster than by using RCM as they will be eradicated plant wide six times faster.
- First line supervisors who invest in the program get rewarded with labour productivity improvements six times greater. PMO2000™ targets a return on analysis time of 5 to 1. That is for every man-hour invested in analysis, five man-hours will be returned to the department every year. At this rate, line supervision is prepared to invest their resources. At a rate six times less, they often become uncooperative.

Figure 2:
PM Optimisation is six times faster than Conventional RCM for existing plant.



Weaknesses of Statistically Based Methods

Many organisations that have tried statistical methods have found that the outputs are frequently poor and misdirected due to the guesswork needed to compensate for a lack of data and other subjective production and accounting inputs. They also tend to ignore the valuable contribution to condition monitoring made by the operators.

Another drawback found in the use of statistical packages is the low involvement of shop floor personnel. This leads to omissions in the analysis.

The overall results of an incomplete or misdirected program are problems with implementation with the shop floor personnel failing to embrace the schedules.

By contrast, PMO2000™ decision diagram conforms to SAE JA1011, Issue Aug1999. This means that analysis is more experiential and empirical than purely statistical methods. PMO2000™ therefore relies heavily on the knowledge of the shop floor personnel and their understanding of the data. This creates a high degree of ownership and a direct responsibility to make maintenance work.

In final contrast, many statistical methods use algorithms that are based on flawed assumptions and do not conform to SAE JA1011 even though their name suggests they do³. This amplifies the errors caused by poor data and can result in serious levels of reactive maintenance of over expenditure.

³ Readers interested in learning more about where these algorithms are flawed can contact the author.



Key Features of a PM Optimisation Program

PMO Quickly forms the Baseline for Effective Reliability Engineering and Defect Elimination

There are two important points that allow effective reliability engineering and defect elimination. These are discussed below:

The first is bringing the plant failures from unexpected events to controlled corrective action.

In many organisations, reliability problems are seen mostly as problems with design or production methods. Experience tells us that the majority of reliability problems experienced by plants that are overly reactive are a result of lack of maintenance or care rather than the design.

Before expensive redesign is considered, organisations need to ensure that appropriate maintenance is being performed and then decide if the equipment is fit for purpose rather than assuming that the maintenance is adequate and the problem must be a design issue. The fundamental strength of a PMO2000™ program is that all maintenance tasks add value so there it makes good business sense to complete 100% of the program. Through the program a move reducing breakdown maintenance creates productivity improvements that clear the path to allow this to occur. After a short while, failures caused by lack of maintenance are rare.

The second is having a system where all the maintenance strategies (including operator rounds, condition monitoring rounds lube rounds, contractor PM etc) are stored in the one place and stored in such a way that each strategy or task is linked to a specific or set of failure modes.

In most, if not all Computerised Maintenance Management Systems (CMMS), there is no link between the equipment, its failure modes and the maintenance strategy. As much of the maintenance strategy is stored outside of the CMMS, the effort required to first assess if an unexpected failure was a result of lack of maintenance is a very time consuming and often a "hit and miss" affair. PMO allows for quick and efficient reference to the equipment failure modes and the current strategy. Moreover, in the living program, PMO2000™ software allows for an efficient and controlled means of changing the strategy.

PM Optimisation is based on Sound Engineering Principles

PM Optimisation utilises the RCM principles and concepts that have been successfully applied in the airline industry for over 30 years and in other industries for nearly 20 years. These principles have successfully improved operational reliability of civil aviation aircraft by over 10,000% during this time. Whilst PMO2000™ utilises the RCM principles, the implementation approach that is utilised by the airlines and other providers of "classic" RCM consultants has serious practical weaknesses in an industrial environment, as discussed earlier. PMO2000™ applies the RCM principles and concepts in a manner that is more highly focused on benefits realisation in an industrial environment than traditional RCM approaches.

PM Optimisation Recognises and Resolves Problems and Data Accuracy

While PMO2000™ utilises existing failure history as one input to the PM review, it also recognises that in most organisations today, the data that is contained in CMMS systems is likely to be inaccurate and incomplete. Frequently, one benefit that arises from using in-house personnel in this way is a significantly increased recognition, amongst shopfloor people, of the need for accurate data recording on Maintenance work orders. When successfully harnessed, this can drive significant cultural change towards increased data accuracy and a focus on “management by the facts”.

PM Optimisation makes Effective use of Scarce Labour Resources

In these days of “lean” organisations, any improvement effort that requires the involvement of in-house labour, whether from the shopfloor, or support staff, must be sure to use these labour resources in a highly productive and effective manner.

Unlike other approaches, PMO2000™ is strongly productivity focussed. PMO2000™ makes best use of the involvement of shopfloor personnel by:

- Having an analyst collect and consolidate existing failure data prior to review by shopfloor work teams,
- Focusing effort on those failure modes which are currently causing problems, or which are currently subject to some form of PM. In classic RCM analysis, more than 50% of failure modes that are analysed result in No Scheduled Maintenance. PMO2000™ reduces the time and effort wasted on these failure modes.
- Taking a more targeted approach to the development of equipment function statements than classical RCM (and in many cases, eliminating the need for function statement definition at all).

In effect, PM Optimisation rationalises what is being done, and adds to that what needs be done that wasn't in place previously. In doing this, PMO2000™ can be six times faster at analysis than conventional RCM, thus shifting the resource intensity from analysis to implementation.

PM Optimisation Improves the Productivity of Operators and Maintainers

Not only does PMO2000™ make most effective use of operators and maintainers time during the course of the PMO analysis, it also significantly improves the productivity of operators and maintainers during the course of their daily duties. It achieves this in two ways.

First, PMO2000™ successfully identifies areas where there is overlap between operators', maintainers' and contractors' duties, and effectively resolves any duplication or communication issues involved. For example,

- Vibration Analysis contractors may be being used to monitor bearing vibration on certain pumps on site.
- Operators may be being required to monitor these same bearings for audible noise during the course of their daily rounds, and
- Tradesmen may be expected to replace these bearings on a routine basis during scheduled pump overhauls.

In this case, PMO2000™ would rationalise this situation by resolving the conflicting maintenance strategies in place for the bearings (condition-based vs. scheduled replacement), and by resolving the duplicate inspections being performed by both contractors and operators. In most organisations, where PM programs have grown in an informal manner in response to specific situations and events, our experience has been that there is significant duplication of this type.

Second, PMO2000™ ensures that the person with the appropriate skills to perform a specific task is the one that is allocated that task. In most organisations, skilled tradespeople are being utilised to perform routine visual inspections that require no specialist trade skills. On the other hand, operators are already working in the area, and have the necessary skills, and time, to perform these inspections. In the team-oriented forum of the PMO review meetings, we frequently find that operators volunteer to take on these additional duties, and tradespeople are happy for the operators to perform them. This releases trades people's time to perform work that better utilises their specialist skills, and which they find more interesting.

The result is a general up-skilling of the trade's workforce, with a focus on performing higher quality, precision maintenance.

PM Optimisation is Adaptable to Suit Specific Client Situations and Objectives

A major feature of the PMO2000™ process is the ability of the technique to be applied with various levels of rigour whether the system depending on the criticality assessment. This contrasts with other approaches, which apply the same level of rigour (and time, effort and expense) to the analysis of all systems, regardless of their criticality and regardless of the size of the benefits to be obtained from the analysis. For highly critical equipment items, where a more “classic” RCM approach is required, including identification of all equipment functions, consideration and analysis of all possible failure modes, and where compliance with International Standards for RCM Analyses are required, PMO2000™ will apply this level of rigour. Even in these situations, however, the nature of the PMO2000™ process means that these rigorous analyses are still completed more quickly than “classic” RCM processes. For less critical items, where the time and effort involved in a high level of rigour cannot be justified, PMO2000™ takes a more streamlined and focused approach. In this way, PMO2000™ is highly focused on maximising the return for effort involved in reviewing routine operations and maintenance tasks.

PM Optimisation Motivates Personnel

PMO2000™ quickly revitalises the motivation of the people working within the process of maintenance. In doing so, performing the analysis can result in step improvements in both human resource and plant productivity. The PMO2000™ approach also motivates improvements in many other aspects of asset management apart from the maintenance analysis. Some of these areas are:

- Production / Maintenance Strategy,
- Performance measurement,
- Failure history recording,
- Defect elimination,
- Work order management, and
- Spares management.



A full scale PMO2000™ implementation program generally starts with some workshops or briefings introducing key decision-makers to the process. The objective of these sessions is to lay the groundwork for ensuring successful implementation.

Prior to this however, most organisations choose to trial the PMO2000™ process on one or more equipment items or systems. In this environment, the workshop is strongly facilitator lead. Following the trial, the benefits, costs and implementation issues are assessed, and a decision reached on whether, and how, to roll out PMO2000™ on a wider scale within the organisation. Following a trial, the take up rate has been 100%.