

Optimizing Assets through Reliability- centered Maintenance



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Optimizing Assets through Reliability-centered Maintenance

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“In technical literature, reliability-centered maintenance (RCM) continues to show up as the prominent future strategic direction in machinery maintenance, and for good reason. RCM is the best method to use when optimizing the operational reliability of plant equipment. It is important for reliability professionals to understand RCM and how condition-monitoring tools fit into the RCM picture.

Optimizing Reliability

RCM is the systematic process to optimizing reliability and associated maintenance tactics with respect to operational requirements. Economic optimization of machine reliability relative to organizational goals is the primary objective of the RCM process. Simply stated, RCM helps to ensure that if a dollar is spent on improving reliability, the full dollar will come back, plus some acceptable return on the investment.

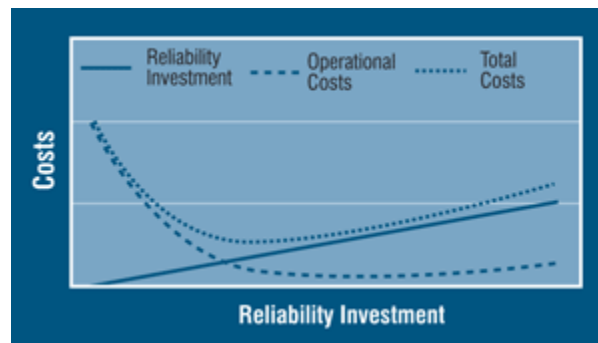


Figure 1. Economic Analysis of Reliability Investments

As shown in Figure 1, the law of diminishing marginal returns applies to the implementation of reliability improvement measures. Generally, the first dollar invested in reliability improvement tends to yield a higher return on investment than any dollar subsequently invested. The objective is to reach the point of optimization that the benefits of reliability, expressed as total operating costs, are maximized through cost reduction. RCM is a set of systematic engineering procedures for achieving and maintaining this objective.

The Origins of RCM

RCM's roots trace back to the 1960s when it was considered advanced to improve the safety and reliability of commercial aircraft. It has since begun to move into the industrial sector as a result of work conducted by several authors.^{1,2} Going further back, however, RCM owes its origins to the development of the reliability engineering discipline.

It was here that the fundamental analytical tools were created to estimate the reliability of electrical and mechanical components and systems. Simply stated, RCM is a component of the quality movement focused on improving the safety, reliability and productivity of the equipment that our society depends on for transportation, power and energy, and goods and services.

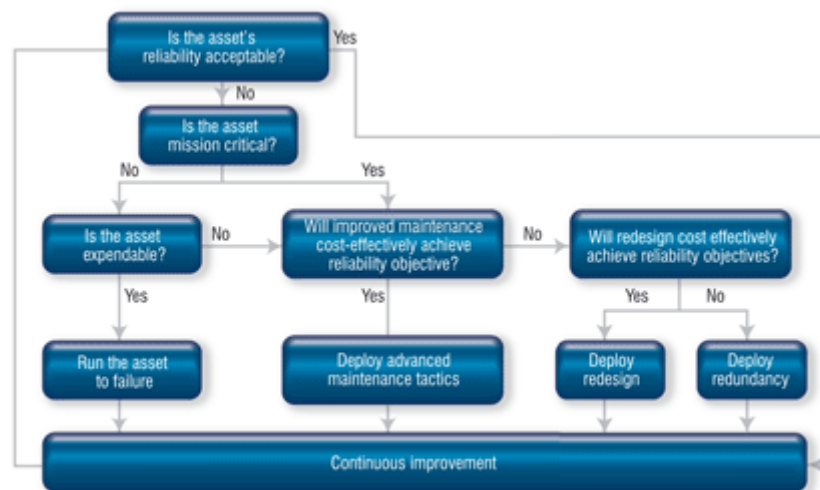


Figure 2. Selecting a Reliability Strategy

Why RCM and Why Now?

In an economy where prices are set globally, Americans must profitably produce products with aging equipment operated and maintained by a workforce that is among the most expensive in the world. This means that manufacturing assets must deliver big - as should the maintenance strategies, such as RCM, to maximize profitability.

For the economic optimization to be realized, RCM guides the reliability investment with improvement measures and techniques. NASA has identified specific guiding principles of RCM. However, the reliability engineer must answer the following questions:

- What is the system or equipment asked to do?
- What functional failures are likely to occur?
- What are likely consequences of these functional failures?

- What can be done to prevent these functional failures?

In the past, attempts to achieve reliability were made with frequent rebuilds. The strategy was founded on the assumption that the failure rate of machines increased as the asset aged. While some items fail in this manner, most complex systems, such as those found in process and manufacturing plants, do not. In one study, 30 identical deep-groove ball bearings were run to failure on a test stand under highly controlled conditions.

The variation in failure times was so great that if you statistically estimated the appropriate replacement time at the 95 percent confidence level, the machine would never be started! In the field, the variation in time-to-failure is even greater. Therefore, the time frame for complex equipment to be rebuilt cannot, in many cases, be effectively estimated.

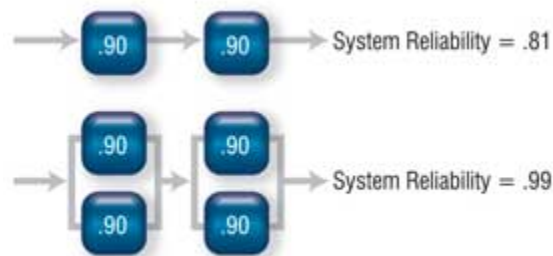


Figure 3. Serial, Parallel and Combination Systems

Selecting a Strategy

More recently, vibration analysis, lubrication analysis, thermography, and other condition-monitoring and predictive maintenance tools have been employed in an attempt to identify early stage failures so corrective action can be scheduled based on condition. Proactive measures have also been applied to monitor and control the root causes of degradation and failure.

These measures that employ advanced maintenance techniques and technologies have proven effective, but if over-applied, can be expensive and counterproductive. Moreover, in some cases, they simply don't provide the required improvement in reliability to get the job done. In these instances, system redesign or the employment of redundancy is required to achieve the goals of the organization.

The process to select a reliability strategy according to RCM is systematic and logical. As Figure 2 suggests, assets are audited with respect to their role in overall system reliability and productivity. If acceptable, no changes are required. If unacceptable, questions about the criticality of the asset define the need to identify the most efficient means of attaining the necessary reliability.

If the asset is deemed noncritical, for example, it is simply run to failure then rebuilt or replaced. For mission-critical systems, advanced maintenance techniques are typically the first choice because their use is relatively inexpensive compared to redesign and the employment of redundancy.

In some cases, redesign or employment of redundancies is required to meet the objectives of the organization. Redesign in the form of proactive measures to control (and monitor) lubricant contamination, alignment, balance, etc., is usually less expensive to deploy than failure detection strategies. Conversely, more involved system redesign is typically expensive and often produces unpredictable results.

The employment of redundant systems is the most expensive method to improve reliability, but does provide accurate results. Employment of RCM helps avoid the casual application of the latest panacea strategy, avoiding mistakes that waste resources and provide mediocre and unpredictable performance.

Maintenance Strategy	Action Required	RCM-based Application
Run to failure (reactive)	Repair or replace upon failure	Non-critical costs to control or detect failure exceeds benefits
Scheduled discard or restoration (preventive)	Repair or replace on time or cycles	Asset has a well-documented MTBF and a small standard deviation
On-condition maintenance (predictive)	Employ condition monitoring to detect early stage failures. Replacement or repair is scheduled based on condition.	Asset fails randomly. Critical nature justifies early detection techniques.
Redesign and condition-control (proactive)	Changes in hardware, loading or procedures. Condition monitoring detects the presence of root causes of failure	Objective is to reduce the failure rate for a given time period
Redundancy	Deploy active shared-load or standby redundant system	Mission-critical assets for which no other approach is acceptable

Table 1. Maintenance Strategy

Table 1 summarizes strategies for achieving reliability and the conditions in which they are selected in the RCM process. In today's competitive environment, organizations are looking for advanced maintenance strategies, especially condition-based maintenance, to provide the necessary reliability at minimum cost. The cost to rebuild or replace is quite high and yields dubious value.

Purchasing and maintaining redundant systems is reserved for the most critical systems where no other strategy provides satisfactory results. Advancing technology has brought condition-based maintenance to the forefront of the RCM movement. Lubrication management and oil analysis play an integral role as well.

Detection P-F Interval (what's going to happen)				Root Cause Failure Analysis (why did it happen?)		
	Lube Analysis	Vibe Analysis	Therm Analysis	Lube Analysis	Vibe Analysis	Therm Analysis
Root Causes Control						
Lubricant contamination	excellent	poor	poor	excellent	poor	fair
Misalignment	fair	excellent	fair	fair	excellent	fair
Imbalance	fair	excellent	fair	poor	excellent	fair
Wrong lubricant	excellent	poor	poor	excellent	poor	poor
Degraded lubricant	excellent	poor	poor	excellent	poor	poor
High operating	fair	fair	excellent	fair	fair	excellent
Failure Detection						
Wear	excellent	good	fair	excellent	fair	fair
Cavitation	good	poor	fair	fair	poor	fair
Gear tooth fracture	poor	excellent	poor	fair	fair	poor
Structural resonance	poor	excellent	poor	poor	excellent	poor
Fatigue	excellent	good	good	excellent	fair	fair

Table 2. P-F Interval vs. RCFA

Analytical Tools

The reliability engineer employs a number of analytical tools to optimize reliability relative to mission goals. Some of the more common tools include:

Reliability Statistics: Reliability statistics differ from conventional experimental statistics. They provide the means to estimate the likelihood that a system will achieve its mission, given a stated duration and operating conditions. It is important to become knowledgeable about the methods of reliability engineering in advance of undertaking an RCM project.

Reliability Block Diagrams: Once subsystem reliability is determined, the system can be effectively modeled from the reliability perspective. Once constructed, the weak links usually become evident and can be addressed with reliability growth measures to eliminate the deficiencies. Figure 3 illustrates block-diagrammed examples of simple serial, parallel and combination systems.

Failure Modes Effects and Criticality Analysis: FMECA is the inductive process of identifying primary functional failures, their related failure modes or states, the effect of the failure modes on the operation of the system, and the associated criticality of the failure mode as a function of impact and likelihood. This valuable analytical tool enables the removal or better management of failure modes through applying advanced maintenance techniques, redesign or redundancy.

Root Cause Failure Analysis (RCFA): RCFA assesses a failure after the fact with the intent to determine its root cause for occurrence. Once the root cause is

ascertained, the engineer can assess the risk of recurrence, the success with which the root cause might be controlled and the cost to control it. With this information, a decision can be made to deploy control measures or to let it go.

In conclusion, reliability-improving techniques must harmonize and align with the organizational objective of optimized asset utilization and maximized profit. RCM is the heart and soul of this process and maintenance and reliability personnel play an increasingly vital role in the RCM process.

References

1. John Moubray. RCM II - Reliability-Centered Maintenance, second edition. New York: Industrial Press, Inc, 1997.
2. National Aeronautics and Space Administration. RCM Guide for Facilities and Collateral Equipment. 1996.

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