Reliability Centered Maintenance

Project Manager's Guide

reliability centered maintenance | Reliability Engineering for Maintenance

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Reliability Centered Maintenance Project Manager's Guide

Executive Summary

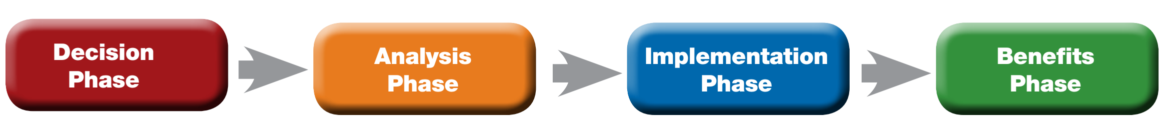
Hundreds of public and private sector organizations around the world have demonstrated that reliability centered maintenance (RCM) is consistently capable of significantly increasing asset performance by delivering value to owners, customers and stakeholders.

Despite the fact that successful approaches to RCM have been documented and refined over decades, not all organizations experience the level of success they desire. This RCM Project Manager's Guide was created to address that fact. It provides knowledge and success factors for anyone contemplating becoming a "champion" or project manager of a reliability centered maintenance initiative within their organization to:

1. Provide knowledge of capabilities and tools needed to be successful.
2. Guide the decision to do or not do an RCM project based on organizational readiness.
3. Measure progress toward positive results to minimize risk of failure and determine success during and after an RCM project to sustain RCM efforts.

The guide uses a clear, flexible process and set of criteria so an organization can assess what it takes to successfully conduct and implement an RCM project and avoid pitfalls along the way to experiencing measured results that add significantly to the bottom line.

This guide presents lessons learned and the ingredients essential for success in a simple framework based on four essential RCM project phases:



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In addition, the guide includes a primer on RCM fundamentals, a section dedicated to sustaining benefits while continuously improving, and a glossary of key terms. The appendices offer useful resources to gain commitment for success.

Dozens of experienced RCM practitioners contributed to this document through public workshops, written contributions and working groups from the time this guide was created to this current 2014 revision. It is aligned with published standards, Reliabilityweb.com's Body of Knowledge and Uptime Elements™. The authors and contributors sincerely wish your organization great success with RCM and hope your journey offers you a similar opportunity to contribute back to the community what you learn.

How to Use This Guide

The Reliability Centered Maintenance (RCM) Project Manager's Guide provides basic information about what an RCM project is, how it should be conducted and who should be involved. The material is presented as an assessment that an organization can use to determine if it is ready to undertake RCM and to identify areas it must improve upon to enhance the chance of success.

The guide is arranged in several sections:

Section	Title	What You Will Find
1	Introduction	Reasons and tips for using the guide
2	An RCM Primer	A foundation for applying the information in the guide
3	Deciding to Conduct an RCM Project	Basic, up-front requirements for success
4	Completing an RCM Study	Keys to finishing an RCM analysis successfully
5	Implementing the RCM Study	Ways to fully and quickly start to achieve the benefits of an RCM analysis
6	Measuring the Benefits	Keys to justifying the original decision to perform RCM, identifying areas to improve RCM capability and making the case for additional RCM projects
7	Sustaining an RCM Program	Values and capabilities required to continuously improve reliability centered maintenance results
8	Glossary and References	Definitions of important terms and concepts

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1.0 Introduction

Reliability Centered Maintenance – A Key Performance Tool

Reliability centered maintenance (RCM) originated in the airline industry in the 1960s and was implemented soon after in the military. Since that time, many organizations have been applying and improving the practice of RCM analysis. These organizations span hundreds of public and private sector organizations, including space agencies, manufacturing, utilities and countless other industries. With such a legacy, the benefits of RCM paint a picture of a tool that no asset-intensive organization should ignore. One practitioner, Anthony "Mac" Smith, has demonstrated through approximately 80 RCM studies conducted over 30-plus years that RCM is consistently capable of significantly reducing unplanned outages, increasing capacity and eliminating substantial levels of low value work.

For example, Three Mile Island Nuclear Station, Unit 1 implemented a classical RCM program involving 28 systems over a five-year period because suboptimal maintenance strategies were not managing risk, process availability, or cost. Over a three-year period, the plant measured a 37 percent reduction in corrective maintenance (CM) actions, increased throughput to set a free world capacity factor of over 100 percent, and measured a reduction of 7,669 preventive maintenance (PM) man-hours per year by increasing PM task intervals via the age exploration (AE) process.

Reliable Plant magazine published similar results in an article by Paul Arnold:

> Whirlpool, Findlay, Ohio: Completed 27 RCM analyses, identified 3,066 failure modes and 2,225 tasks. Of the tasks identified, 53 percent were operator care, 27 percent predictive maintenance (PdM), 11 percent redesign, 7 percent PM and 2 percent failure finding. Resulted in increased productivity of 27 percent, sustained overall equipment effectiveness (OEE) of 97 percent and a reduction in maintenance costs of 22.7 percent.
>
> Dunlop Sports Golf Ball Factory, Westminster, South Carolina: Performed 18 RCM analyses on critical assets, productivity increased 26 percent over two years, 1,937 tasks identified. Of the tasks identified, 49 percent were operator care, 21 percent PdM, 17 percent redesign, 10 percent PM and 3 percent failure finding. Resulted in a 200 percent reduction in emergency/demand maintenance and maintenance costs per dozen golf balls fell from a high of 77 cents to a sustained average of 24 cents.

Not all organizations experience these results with RCM. Most can, however, if they learn the lessons from others and follow the proven elements of success contained in this guide.

The Body of Knowledge

World-class organizations recognize that success is achieved through leadership, however, they also realize that results are only delivered through engagement and empowerment of everyone in the workforce. Leadership does not come from one person; it comes from everyone. This is especially true for reliability.

Creating a Reliability Culture

Regardless of how good your reliability strategy is, it is your organizational culture that will determine its performance. Culture is built from within and it is “cultivated” by leaders who aim to engage employees in delivering the performance of the organization.

Uptime Elements™, shown in *Figure 1*, provides a map of theory by which to understand reliability leadership and begin creating a culture of reliability. Two practices that are acknowledged as powerful culture-building tools are defect elimination (DE) and RCM. In addition to the obvious tangible asset performance benefits delivered, these practices get your team in “game shape” and “thinking right.” The proven approach to a successful RCM project provided in this guide is well represented by the Reliability Engineering for Maintenance (REM) elements on the left side of the Uptime Elements™ chart <u>and</u> just as well by the Leadership for Reliability (LER) elements on the right side. The <u>combination</u> of RCM technical excellence and empowered leadership at all levels is by far the most significant indicator of a successful RCM project or program <u>and</u> an organization that delivers significant results.

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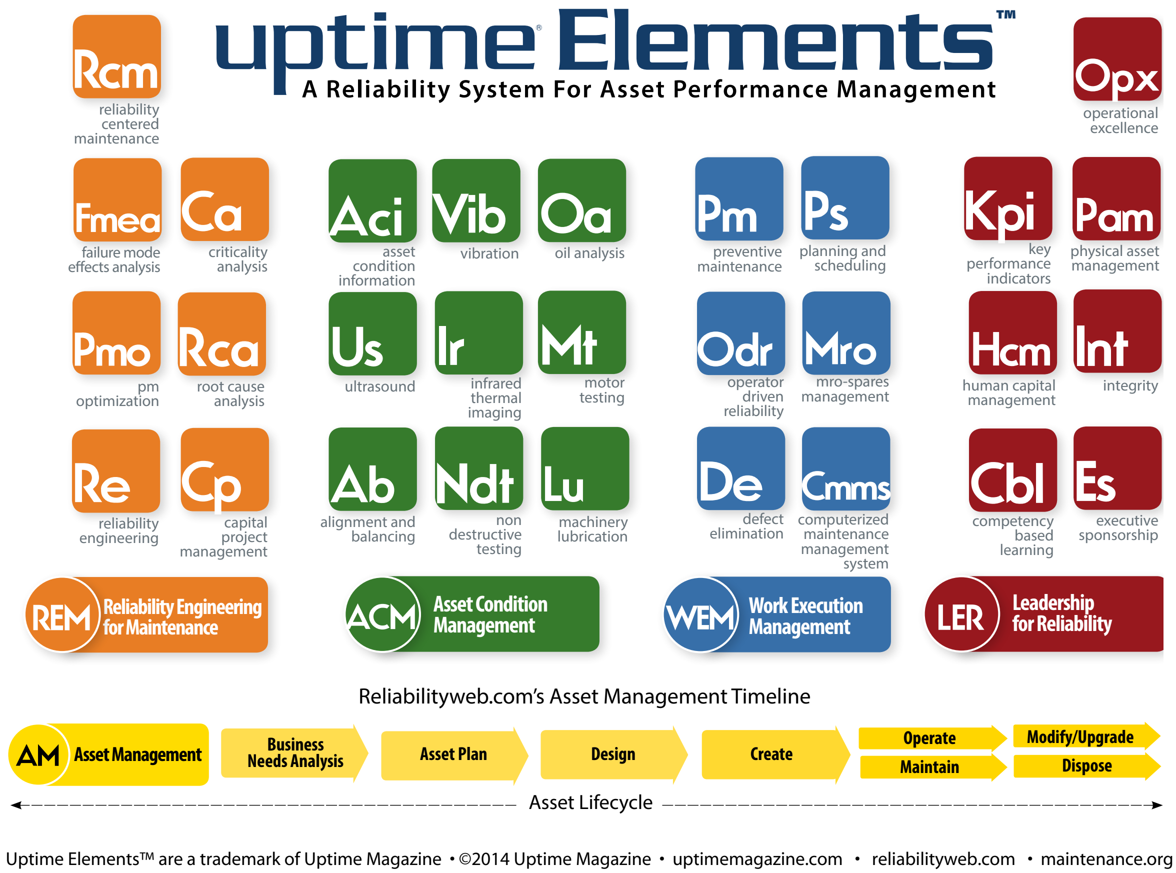
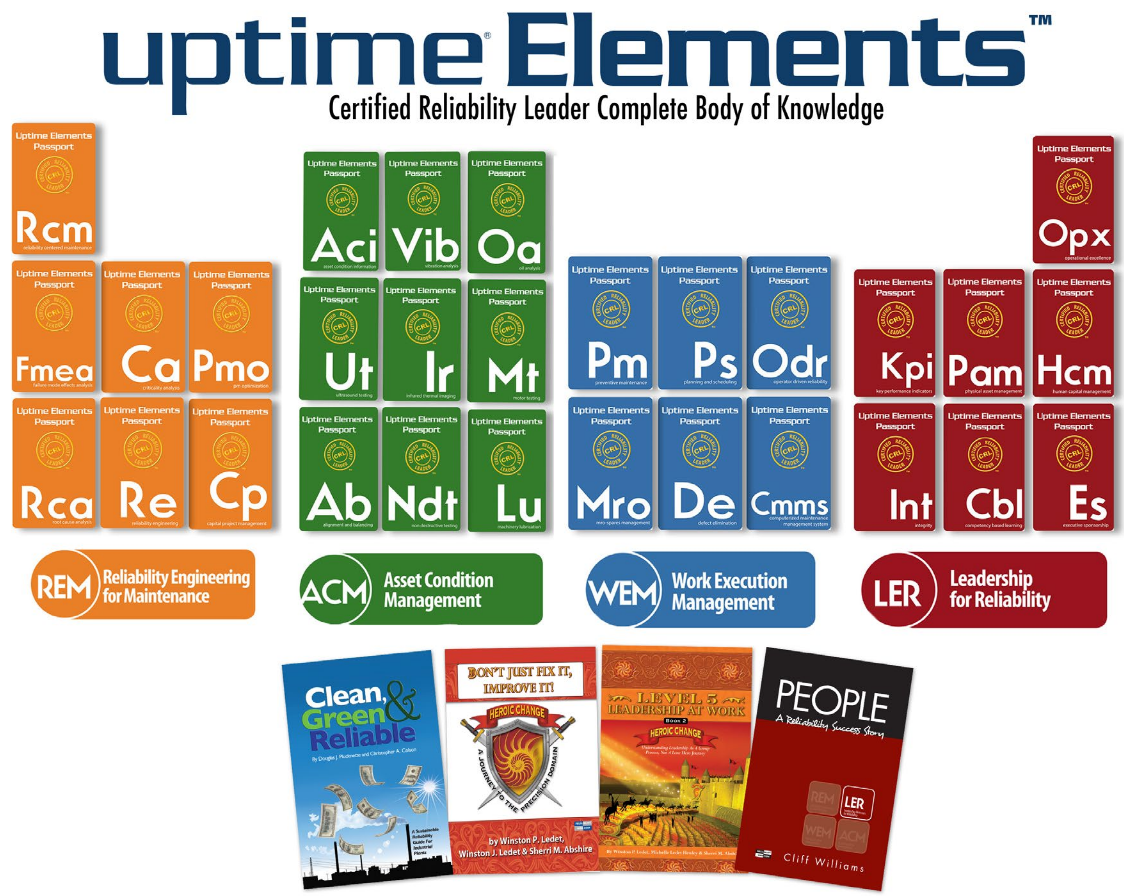


Figure 1: Uptime Elements™

What's more, Uptime Elements™ works seamlessly with the international standards of our industry. According to the newly published ISO55000 asset management standard, an asset is a thing that has potential or actual value to an organization. Asset management is a coordinated set of activities to realize that value. The Uptime Elements™ take on reliability centered maintenance enables asset management by assuring capacity and function of the assets where value is demanded.

This guide aligns with these standard frameworks. The recipe for success found here is derived from industry best practices learned and communicated from dozens of practitioners involved in creating the body of knowledge behind them. Reliabilityweb.com has hosted several industry conference forums that contributed content to this guide and many authors have contributed examples and sections to this work.

Most recently, Reliabilityweb.com convened a working group to update the guide to reflect best practices common to all major RCM approaches and capture lessons learned from organizations deeply involved with RCM.



Body of Knowledge for Certified Reliability Leader (CRL) Certification can be found at www.mro-zone.com.

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2.0 An RCM Primer

Reliability Centered Maintenance Basics

Reliability centered maintenance has the power to help an organization focus its resources to maximize results while managing risks, but only when applied correctly and consistently. No other methodology has proven so effective while keeping the same essential format for decades. This is for good reason. RCM is a straightforward, stepwise methodology based on simple principles that are universally applicable to the systems organizations employ every day.

There are a variety of RCM approaches that adhere to core principles in varying degrees. This guide is neutral regarding RCM approaches and analysis techniques employed. Rather, its contents are usable regardless of which approach to RCM is used. A discussion of the various approaches is contained in *The Physical Asset Management Handbook*, 4th Edition, (ISBN 9780985361938) published by Reliabilityweb.com. It is recommended that prospective RCM project managers, at a minimum, read this guide before embarking on the decision to conduct an RCM project.

Four Basic Principles of Genuine RCM

While the methodology selected is beyond the scope of this guide, the one chosen must meet four basic principles to be considered a genuine application of reliability centered maintenance.

1. The analysis is scoped and structured to <u>preserve system function</u>.

2. The analysis identifies how functions are defeated (failure modes).

3. The analysis addresses failure modes by importance.

4. For important failure modes, the analysis defines applicable maintenance task candidates and selects the most effective one.

This guide pertains only to RCM methodologies that meet these four basic criteria because anything else will not offer the full benefit of RCM, as supported by SAE JA1011 and JA1012 standards available at www.sae.org.

Applying the Four Basic Principles

In an RCM-based program, the analysis process is focused first at the level of functional failures (how a system might fail to function as required by asset user), then at the level of failure modes (ways components cause functional failures) and the maintenance tasks that are chosen to mitigate or prevent the failure mode. Failure modes are identified at the level of causation that makes it possible to identify an appropriate failure management policy (SAE JA1011). This leads to a focus on the failure mode because maintenance tasks alone cannot do anything about underlying causes of human error, environmental effects, wear out, or other inherent design limitations.

While the focus is on maintenance tasks, the many things that can be done in other potential areas of improvement that may offer immediate and significant benefits should not be neglected. An RCM project must provide a clear way to identify and act on opportunities to improve training, policy, procedures, designs, control schemes and other enhancements that will (based on the experiences of many RCM experts) offer significant and immediate benefits, even to the point of paying for the RCM project.

For purposes of this guide, in order to give all task-related metrics a common base, it is paramount that **each task be related to a failure mode, not to a component**. This may be difficult to do for legacy, pre-RCM program tasks and, indeed, there may be tasks for which no related failure mode is evident, providing one basis (among several) for consideration of whether it should be retained in the RCM-based program. Furthermore, **each failure mode must be prioritized by the severity of its effects** on the component, the system and the plant.

All tasks for an RCM-based program must be **both** applicable and effective. An RCM analysis applies a rigorous methodology to ensure each selected maintenance task meets these criteria:

- An applicable task will prevent or mitigate the failure, detect onset of failure, or detect a hidden failure.
- An effective task balances the organization's safety, environmental and economic drivers to select the best fitting tasks from among the applicable candidate tasks.

Where no task can be effective and, depending on the effects of the associated failure mode, a redesign or a run to failure decision may be the default strategy that is applied.

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The Typical RCM Project Framework

Experienced RCM project managers typically structure an RCM project into four phases that must be accomplished to fully perform RCM. These phases, as shown in Figure 2, are:

1. **Decision** – Justification and planning based on need, readiness and desired outcomes.
2. **Analysis** – Conduct the RCM study in a way that provides a high quality output.
3. **Implementation** – Act on the study's recommendations to update asset and maintenance systems, procedures and design improvements.
4. **Benefits** – Measure the improvements and identify opportunities to further improve.

Successful RCM projects are based on a thorough understanding of these four phases, the requirements for each and an understanding on how they interrelate. This guide will help in understanding the phases and overall process for identifying the essential requirements, capabilities and values required for success in any organization. This is an important part of an organization's journey to a comprehensive, living reliability program.

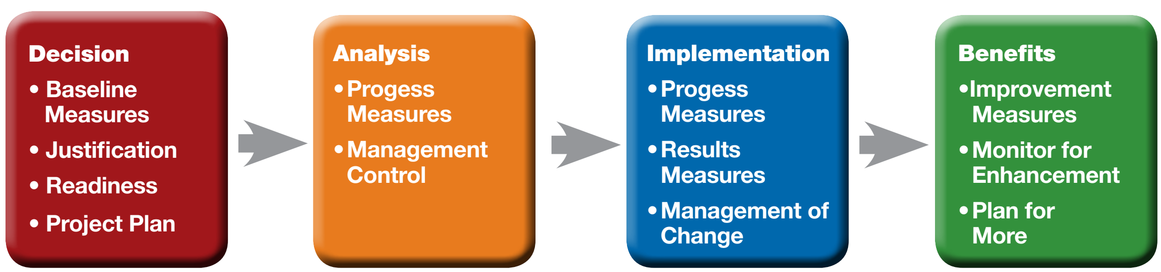

Figure 2: Four phases of an RCM project

Phases 2 through 4 should be conducted with some overlap, as illustrated in Figure 3, so the organization can start seeing and communicating the impact of the benefits as soon as possible. (Note: Figures 2 and 3 are Color-coded to align with best practice maintenance reliability principles from the Uptime Elements™ framework.)

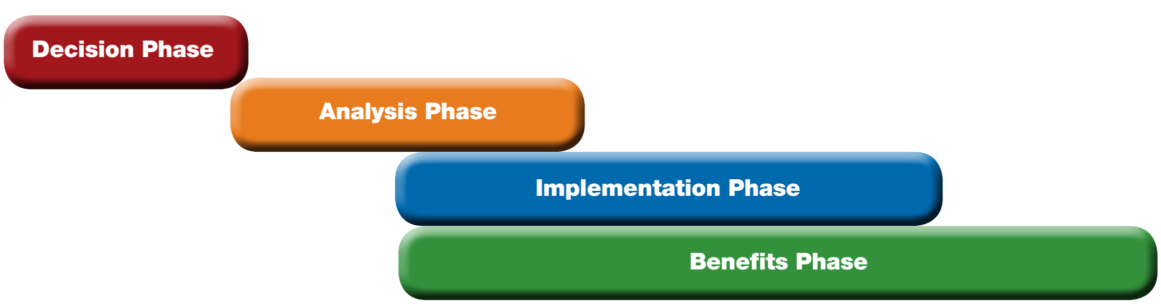

Figure 3: Phased timeline of an RCM project for early impact

Sections 3 through 6 in this guide will help project managers understand and successfully perform the four steps of an RCM project in their organizations. Section 7, Sustaining an RCM Program, will help in

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applying the knowledge and experience gained from the project to a living reliability program.

The rest of this guide describes the nature of an RCM project in detail. Besides meeting the four basic principles, the work being planned must also include all the essential elements of an RCM project if this guide is to be applicable to the organization and prove effective in helping to achieve success. These essential elements are:

1. The RCM study is performed on a system that is composed of components that together provide an important, and even essential, function to the organization.

2. The primary purpose of the project identifies and implements applicable and effective maintenance and operational tasks.

3. The analysis work is performed by a cross-functional team composed of field personnel highly experienced in all the technical and operational aspects of the system, including full time representation from all maintenance trades (e.g., instrumentation, electrical, mechanical, etc.) and an operator. Other resources (e.g., engineering and outside expertise) may be necessary and are available on short notice to respond to questions from the team, or are assigned to participate full time with the team.

4. The organization's A-team, or its most experienced technicians and operator(s), are fully dedicated to the analysis portion of the project.

5. Knowledge of non-intrusive asset condition monitoring (ACM) methods and applications (e.g., predictive maintenance or condition monitoring technologies) exists so RCM recommendations can be as efficient and non-intrusive as possible.

6. A highly experienced RCM facilitator is dedicated to guiding and facilitating the analysis phase. Experience is with RCM and maintenance of systems, including condition monitoring technologies. Knowledge of the candidate system itself is not necessary for the facilitator.

7. The organization has a strong, informed executive sponsor (Es); an empowered and energetic RCM champion; buy-in to provide sufficient resources; and a willingness and ability to adopt new maintenance tasks, ensure their implementation and sustain them.

8. Implementations are carefully planned, expected and communicated to the appropriate stakeholders. With approximately 50 percent of implementations failing due to a variety of follow though causes*, a fundamental best practices foundation should exist within the organization to support the outcome of the RCM analysis (e.g., effective work management practices to include planning and scheduling (Ps), and continuous improvement efforts, such as defect elimination (De)).

* *RCM Best Practices Study*, Reliabilityweb.com 2005

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3.0 Deciding to Conduct an RCM Project

Readiness of the Organization

Table 1 – RCM Readiness Factors

Readiness Factors	Yes or No	What To Do Next
Do I have a champion to conduct and implement the work?	Yes	Engage. Designate him/her to champion.
	No	Without one, the chances of success are dramatically reduced. This guide recommends a no-go decision. First, educate staff and stakeholders on the benefits of RCM.
Is my organization (leadership and staff) aligned with the desired outcomes?	Yes	Communicate the desired outcomes and expectations frequently to all stakeholders.
	No	Work to create legitimate expectations that are in line with the organization's goals. This guide recommends a no-go if they are at odds.

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Readiness Factors	Yes or No	What To Do Next
Do I have the data to select a "bad actor" system for analysis? (An experienced RCM practitioner can help draw out this data through a guided discussion process.)	Yes	Engage a team to pick a selection method, review top candidate systems and select the system with the highest potential benefit.
	No	Picking the right system is essential. This guide recommends a no-go decision. First gain insight on the systems and their performance in delivering value.
Do I have access to a trained, experienced facilitator?	Yes	Engage him/her for full commitment during the time required and align expectations for deliverables, methods and outcomes.
	No	RCM facilitation is a skill, an art and a calling. It is essential to an effective, efficient study. This guide recommends a no-go decision until a facilitator can be trained, hired, or contracted.
Do I have access to the operations and maintenance (O&M) A-team for the duration of the study?	Yes	Get firm commitment from management to staff the RCM study full time with a dedicated team of knowledgeable A-team operations and maintenance staff, plus others as needed.
	No	RCM success is determined by the level of knowledge and sharing by the team. Recommend no-go if only inexperienced or low-energy team members are made available.
Can my organization provide continuity of assignments and consistency of management support over the RCM project lifespan?	Yes	Request clear and "protected" assignments through the duration of the work and have an approved contingency plan to replace key roles. Document the project's purpose and benefits and reinforce with management, especially new management.
	No	RCM success is highly dependent on management support and focused follow through. Recommend no-go if support cannot be sustained or if key roles cannot be protected.

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Readiness Factors	Yes or No	What To Do Next
Can I demonstrate how the benefits will outweigh the costs?	Yes	Use the cost/benefit information to build support for the project and provide a basis for expected results.
	No	Work with experienced practitioners, production managers and financial staff to clarify opportunities for cost reduction and production increase. With a reasonable estimate of project costs, gain the support of executive management to invest in RCM.

Initiating an RCM Project

The decision to initiate an RCM project goes beyond the RCM readiness factors (Table 1). The decision process itself must be designed to initiate the RCM project with enough support to guarantee the resources, focus the effort on an achievable level of benefit and follow through to complete the work and experience the benefits.

Identifying the Desired Outcomes

Getting support and buy-in for an RCM project requires a clearly articulated outcome that is in line with the organization's goals and expectations, and engages all the roles listed in the RCM readiness table. Organizations usually identify one or two key outcomes and several desired secondary outcomes. Examples include:

- Production – Increased reliability, decreased downtime and increased availability in an important system (increased production capacity).
- Cost – Reduced costs of downtime with optimized maintenance costs.
- Risk – Reduced probability of failures with environmental, safety, or regulatory consequences.
- People – Increased culture of reliability and proactive thinking, cooperation, or working knowledge of the system. Involved field personnel have buy-in as to why they are doing the maintenance tasks, thus they are more thorough with the execution of those tasks.
- Documentation – Maintenance decisions are justified and recorded, enabling future review of why tasks are being performed and providing an understanding

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of the consequences of not performing the tasks, thereby preserving valuable corporate knowledge.

- Optimized List of Critical Spare Parts – Allows improved inventory management while meeting production and cost outcomes.

Note that RCM cannot increase the inherent reliability of an existing system. Inherent reliability is determined by the initial design or subsequent design modifications.

Some practitioners rightfully observe that the need for RCM is driven by the necessity to protect or preserve critical system functions. An organization may find it valuable to identify critical systems and assess risks in those areas. Doing so can help make a case for performing RCM and clarify potential benefits. (An organization *might* find that a portion of its systems are configured in such a way as to not warrant RCM analysis.) The upcoming subsection on selecting a target system for RCM analysis builds on this concept by outlining how to select the right system for RCM by setting expectations for meaningful, measurable results and a positive return on investment. For more on this topic, please see the "Criticality Analysis Passport" in the Uptime Elements™ Body of Knowledge at www.mro-zone.com.

As the project proceeds, be sure to get and communicate feedback on how the RCM project is achieving the desired outcomes at all its appropriate phases.

Getting Support and Buy-In

One effective RCM initiation methodology involves forming teams to sponsor and commit to the project using a formal chartering process. Appendix 2 offers an example of a simple charter template that can adapt to any organization; the example is focused on the implementation phase. The chartering process can be simple and fast, or can be expanded to increase the level of involvement necessary for success. An organization may benefit from an expanded, involvement-driven process if the culture is not accustomed to change, or struggles with discipline or structure. To maximize involvement, the organization may want to engage a chartering facilitator who specializes in the area of organizational development or leadership. A facilitator's methodologies can dramatically increase cultural acceptance.

The charter/contract should include baseline reliability measures so the organization can compare past performance to present levels once the RCM recommendations are implemented and performed. At a minimum, the organization should provide a comprehensive training program for team participants on the principles and methodology of RCM, including history and case studies. Top management should receive an executive overview of RCM principles and the business benefits of reliability.

An RCM project requires several essential, well-coordinated roles to prepare, conduct and implement the results. During the chartering process, consider the following RCM-specific roles in Table 2 and how they will be supported through internal or external resources. The roles can be assigned to one or more individuals or teams depending on the structure of the organization.

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For example, an organization may have a reliability engineer who performs many roles, or it may contract some roles out while building internal capability. While some roles do not need to be identified in advance, they should at least be discussed, including expectations for who needs to provide input, who makes decisions and who is accountable to make sure commitments are made and carried out. Table 2 is a reference to help organizations assign the right roles and expectations at the right time.

Table 2 – Defining RCM Project Roles and Responsibilities

Role	What They Do	When to Get Firm Commitment	Who Provides Input on Expectations
Sponsor	Justification (desired outcome), Sets level of effort, Approves study recommendations for implementation	Decision Phase	Operations & Maintenance (O&M) Management
RCM Director	Selects RCM methodology, Establishes project plan, Designs analysis process, Selects facilitator, Quality control	Decision Phase or early in Analysis Phase before selecting a facilitator	Senior sponsor, Maintenance management, Reliability engineer
RCM Champion	Communicates, Owns management of change (implementation), Measures baseline and results, Monitors for enhancement	Decision Phase	Sponsor, RCM director, O&M managers
RCM Facilitator	Facilitates RCM analysis process with the team full time, Finalizes study	Beginning of Analysis Phase	RCM director
Maintenance Manager	Commits technician resource to the analysis and implementation	Decision Phase	Sponsor
Operations Manager	Commits operator resource(s) to the analysis and implementation	Decision Phase	Sponsor

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Role	What They Do	When to Get Firm Commitment	Who Provides Input on Expectations
Scribe/Recorder	Captures the analysis	Beginning of Analysis Phase	Facilitator
RCM Analysis Team	Participates full time in the analysis	Beginning of Analysis Phase	Facilitator
Senior Management Audit/Review Team (Optional, provides top-down buy-in. See Note 2.)	Reviews and approves the analysis and recommended changes/outputs	Beginning of Implementation Phase	RCM director, RCM champion, O&M managers
RCM Implementation Team	Updates maintenance strategies based on analysis team's recommendations	Implementation Phase	RCM champion, O&M managers, Planners, Often times members of analysis team

Note 1: An individual may play multiple roles in an organization. The Table 2 list does not imply that a separate individual is needed for each role.

Note 2: Use of this step depends on the organization's culture. Some organizations simply accept that all the recommended tasks are going forward. Exceptions are handled on a case-by-case basis. The concern is that those who have not participated on the team may not fully understand the context of the recommendation because they did not participate in the discussions. Overemphasizing this step could slow down implementation.

Some organizations require thorough financial analysis to justify RCM recommendations. If objective financial benefits are integral to the desired outcomes, the organization may need to involve a financial manager to provide financial information (e.g., maintenance costs, etc.), contract analysis and potentially additional resources for cost/benefit analysis. This step could apply to the beginning of the RCM analysis phase and would require input from the plant manager.

An involvement-driven process can help engage managers and staff at all levels to develop an outcome that is supported and promoted by the people in the organization. If a champion has not yet been identified, the involvement process is an ideal way to do so.

Once the decision to perform an RCM project is made, the commitments made by others must be called out consistently and continuously.

RCM project roles and responsibilities should fit into a team structure that is flexible to meet the

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needs of the organization. The structure should identify when the teams are in action, who is on each team and how the teams function together. One possible simple approach is shown at a very high level without much detail in Table 3.

Table 3 - Team Structure and Membership

Phase Team	Executive	RCM Director	RCM Champion	RCM Facilitator	Managers	Staff
Sponsor	X					
Steering Team		X	X		X	
RCM Analysis Team				X		X
Audit/Review Team		X	X		X	
Implementation Team			X			X

Scoping the RCM Project

An RCM project can take a variety of forms. An organization may desire a pilot RCM project to test the concept, or a more extensive effort. It may also require outside support for the duration of the project, or just enough support to train its own staff to sustain the work if the organization wishes to internalize RCM capability.

The structure of the RCM project must provide the appropriate level of capability and resources for the organization's needs. Tables 4 and 5 identify requirements for two common RCM project scenarios:

1. A pilot project on a complex system requiring two to three weeks of analysis.
2. An extensive project with limited/novice internal resources.

A representative level of effort is listed for the pilot study. Note that if one person holds multiple roles, the overall level of effort will be less. The level of effort for more extensive projects can be scaled from the pilot effort depending on the size and duration.

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Table 4 – Resource and Capability Requirements for a Pilot Project on a Complex System

RCM Project Role	Pilot Project Resource and Capability Requirements	Effort (varies based on circumstances)
Sponsor	Internal; Supportive executive interested in learning more about RCM	4 to 8 hours
RCM Director	External; Expert who provides training and pilot feedback report	40 to 80 hours
RCM Champion	Internal; Energetic, responsible person, typically from maintenance reliability, who can communicate upward/downward effectively and firmly believes RCM is important to the organization; Will require training and mentoring	240 hours
RCM Facilitator	External; Expert	120-160 hours
Maintenance Manager	Internal; Maintenance leader willing to support a proactive approach, partner with operations, provide resources and enforce change	8 hours
Operations Manager	Internal; Operations leader willing to partner with maintenance to improve performance and provide resources	8 hours
RCM Scribe or Recorder	External; Performed by facilitator or Internal; Will require software training	80-120 hours
RCM Analysis Team	Internal; The best subject matter expert technicians with hands-on experience in all crafts, plus the most experienced operator	50-120 hours each for 4 to 6 staff persons
Audit/Review Team	Internal; Senior managers with operations and maintenance feedback	8 hours each for 4 to 6 staff persons, plus 4 hour meeting with RCM facilitator and select RCM analysis team members
RCM Implementation Team	Internal; Analysis team members plus planning and scheduling staff with time to dedicate External; Support staff to package tasks and enter data (must use internal staff as well)	100-200 hours total (may be higher if changes are significant)

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For Table 5, which lists extensive project efforts with limited or novice internal resources, the level of effort column has been left out because the need, amount and capability of resources will vary from organization to organization. The roles are similar to Table 4, but significant differences are added to accommodate any potential limitations the organization may need to address.

Table 5 – Resource and Capability Requirements for an Extensive Project Effort

RCM Project Role	Extensive Project Effort with Limited or Novice Internal Resources
Sponsor	Internal; Supportive executive committed to maximizing the benefits of RCM and embedding the necessary skillsets to do so
RCM Director	External; Expert provides training and periodic structured feedback and mentoring to embed internal expertise; Selects an RCM methodology with a strong training program and efficient software tools
RCM Champion	Internal; Energetic, responsible person(s), typically from maintenance reliability, who can communicate upward/downward effectively, firmly believes RCM is important to the organization, wants to pursue reliability experience and can manage complex projects; Will require training and mentoring
RCM Facilitator	External; Expert, possibly multiple; Be sure the selected RCM methodology has sufficient external facilitators available Internal; Facilitators can be trained and mentored in live-round analysis sessions with external experts
Maintenance Manager	Internal; Maintenance leader willing to support a proactive approach, partner with operations, provide resources and enforce change
Operations Manager	Internal; Operations leader willing to partner with maintenance to improve performance and provide resources
RCM Scribe or Recorder	External; Performed by facilitator or Internal; Will require software training
RCM Analysis Team	Internal; The best subject matter expert technicians with hands-on experience in all crafts, plus the most experienced operator; Ensures the project avoids high staff utilization times, does not conflict with other priorities and works around vacation times
Audit/Review Team	Internal; Senior managers who must buy-in to the recommendations External; RCM facilitator to defend the analysis decisions (with the team, if possible) and RCM director to encourage proactive approach

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RCM Project Role	Extensive Project Effort with Limited or Novice Internal Resources
RCM Implementation Team	Internal; Analysis team members plus planning and scheduling staff with time to dedicate External; Support staff to package tasks and enter data (must use internal staff as well)

For all scenarios, be sure to determine and acquire:

1. Annual/ongoing budget allocation to keep the overall program moving along over a multi-year period.

2. Funding for this project's analysis, implementation and benefits phases.

3. Time commitment of top subject matter expert technicians (this key requirement cannot be overemphasized).

4. Facilities and equipment for the RCM team's work space, computer, projector, etc.

5. RCM methodology.

6. External qualified expert director/facilitator resources with adequate availability (ensure during contractor selection/procurement phase that support selected has adequate experience, a good track record and credibility with prospective analysis and implementation of team members).

7. RCM software that specifically supports the selected methodology.

8. RCM training for all involved and software training for facilitators/recorders. Conduct the RCM training immediately, or no more than one week, prior to the beginning of the first RCM analysis.

9. Commitment to implement results over an extended period.

Before moving on to selecting a system for RCM analysis, be sure to document the organization's desired outcomes, individual role assignments and expectations, and other details in a project plan document. Update the project plan with the decisions made while working through the rest of this guide.

Selecting a Target System for Reliability Centered Maintenance Analysis

When selecting the target system for RCM analysis, it should be based on measurable system performance and business drivers that are best addressed through RCM (refer back to the subsection on identifying the desired outcomes). RCM is resource-intensive and is necessary

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for the most significant improvement opportunities. Those opportunities may or may not align precisely with an organization's most critical systems. However, the most critical systems may have drawn so much attention already that opportunities to improve using RCM are greater in other systems.

If pilot testing RCM, do not pick an easy system. RCM is a powerful tool meant for complex, difficult performance gaps. When conducted by a qualified facilitator, the results will be significant to the extent that performance of the selected system can be improved. Picking a system with little potential will not justify the use of the organization's resources or promote the value of RCM.

Use the metrics listed in Table 6 and defined in the Glossary at the end of this guide to identify the system with the highest potential for improvement. Most of the same metrics selected may be used as a baseline set for comparison with RCM-based program results.

The decision of whether or not to conduct RCM analysis on a system requires the consideration of either profit/cost factors or showstopper risk factors. Profit/cost factors include:

- A high level of importance of the system to the activity in which it is engaged and the importance of that activity to the mission of the organization.
- The system is among the organization's 80/20 or bad actor systems.
- If there are plans for engineering modifications or capital improvements, consider waiting for those plans to be completed and then reevaluate.

Selecting a system based on showstopper risk factors acknowledges that there may be no immediate financial benefit for conducting RCM on the risky system. Furthermore, the nature of the hazards involved in operating and maintaining the asset, both to employees and people in surrounding areas and communities, justify the expense.

A bad actor system can be identified by measuring performance attributes that quantify problems encountered in operating the system, such as:

- Forced outages over two to three years.
- Availability, uptime and downtime relative to demand for the most economical operation of a system, such as a production line, unit process, or transport vehicle.
- Quality of the product or service produced (e.g., scrap rate).
- Cost of operation of a system as expressed in efficiency (e.g., heat rate for an electricity generating plant or cost of energy for a production plant, vehicle, or service facility).
- Throughput and yield or capacity factor relative to that needed to meet demand.

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- Total cost of maintenance or total cost of operations, cost of quality, or other economic factor of production when it is affected by the maintenance reliability program. This is commonly referred to as the cost of unreliability.

- Overall profit margin for the product or service provided with the asset.

Select a system for RCM analysis by choosing one or a few of the attributes that are meaningful to the organization from the above list. Measure the performance of all important systems for those chosen attributes. The most worthy candidate system will have the highest opportunity to improve (by definition a bad actor). Typically, 20 percent of an organization's systems will cause 80 percent of the problems. Selecting an RCM system from the top 20 percent is a best practice proven by many organizations.

Measuring all performance attributes is not a requirement. Easily measured performance attributes, like maintenance cost, production loss and number of force outages, correlate to the measures, such as overall equipment effectiveness and total effective equipment performance.

Organizations that get the most benefit from RCM focus its application on systems with significant potential to improve financial performance or to manage risks. Organizations that have other business drivers, such as rightsizing the maintenance force, optimizing outage plans, or introducing a strategic improvement initiative, should use RCM as a significant component of an overall maintenance reliability program that includes other methodologies suitable for a less rigorous and broader application.

Measuring Baseline Performance

Prior to the RCM analysis phase, calculate baseline system or plant performance measures according to the desired RCM project outcomes. Potential measures are listed in Table 6. During the implementation and benefits phases of the project, repeated measurement will allow organizations to compare baseline performance with post-RCM results so they can gather helpful feedback on the RCM process. RCM is all about results; baseline measures compared with ongoing measurements are the surest way to demonstrate benefits clearly to management and staff. Doing so maintains buy-in and support. These key performance measures of results are known as key performance indicators (KPIs).

The time period for the collection of KPIs will vary from organization to organization and differ between industries and various types of facilities, activities, services, or missions. Select a timeline to provide a representative baseline for later comparison. Trending a KPI over time is a powerful way to communicate performance. It is important, however, to ensure that the metrics collected are for the same asset or combination of assets before and after implementation. Limit the number of KPIs to seven or less.

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Table 6 – Common Baseline System Performance Metrics

Metric	**Desired Trend Direction and Target** (if applicable)
Safety Incidents for Staff Involved with the RCM System	Down, Target Zero
Throughput or Output	Up
Yield or Capacity Factor	Up
Scrap Rate, Heat Rate, etc.	Down
Quality Rate	Up
Rework Rate	Down
Overall Equipment Effectiveness (OEE, see Note 2)	Up, 10% Increase
Total Effective Equipment Performance (TEEP)	Up
Failure (forced outage) Rate	Down, 10% Decrease
Corrective Maintenance (CM) Events (see Note 2)	Down, 50%-70% Decrease
System Availability or Overall Equipment Availability	Up
System Reliability or Overall Equipment Reliability	Up
System Mean Time to Restore (MTTR) or Overall Equipment MTTR	Down
Emergency/Demand Maintenance Labor Hours as a Percentage of Total Maintenance Labor Hours (see Note 1 and 3)	Down
Overtime Labor Hours by Maintenance Personnel as a Percentage of Total Maintenance Labor Hours (see Note 1)	Down
Lost Profit Opportunities	Down
Corrective Maintenance Labor Hours as a Percentage of Total Maintenance Labor Hours (see Note 1)	Down
Hours of Unscheduled Downtime (see Note 2)	Down, 25%-50% Reduction
Hours of Scheduled Downtime	Down
Total Cost to Perform Maintenance and for the Whole Facility (see Note 2)	Down
Total Cost of Replacement Parts for a Representative Period	Down
Total Cost of Consumables	Down

Note 1: Where a metric involves labor hours, it may be useful to break out subsets by trade category (e.g., Electrical, Mechanical, etc.)
Note 2: Specifically those events that occurred after functional failure. Refer to the examples shown in the introduction on the measurable benefits of RCM.
Note 3: It has been useful in some instances to distinguish between labor hours and replacement parts cost for repair of the primary system separately from collateral damage costs in secondary systems.

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Preparing to Conduct the RCM Study

Once the RCM project scope has been defined and the system is selected and baseline measures are captured, the project manager must plan for the RCM study analysis phase and communicate with those involved. A visual communication tool can help communicate the RCM analysis process and set expectations for involvement by participating teams. Figure 4 shows one example used by a large North American public sector organization.

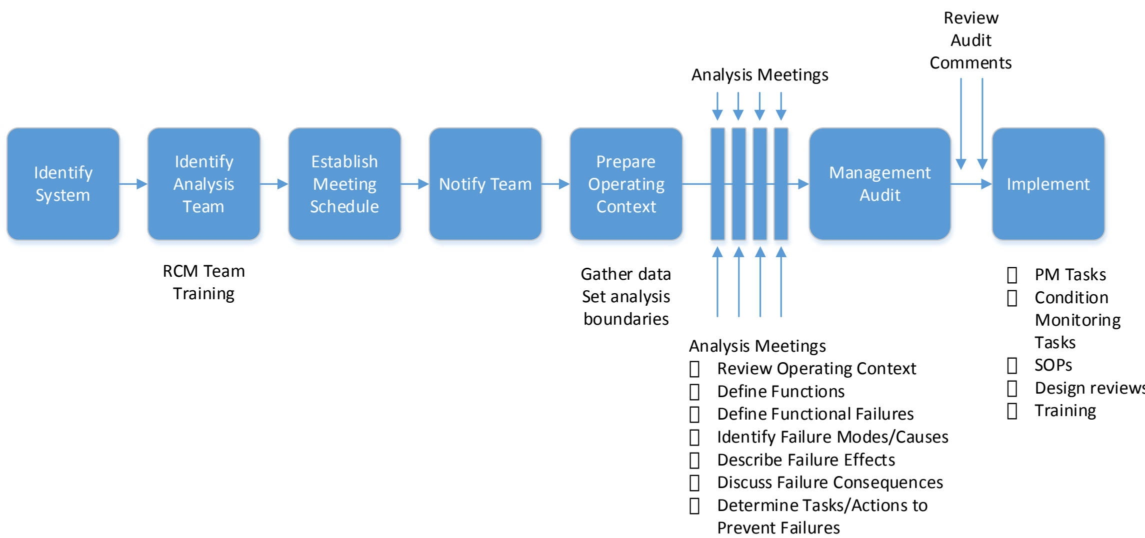

Figure 4: RCM project process diagram

The project manager must determine, coordinate and schedule:

- Training of analysis and implementation team(s) and support personnel;
- Orientation of cognizant managers and supervisors;
- Start date(s) for analysis (schedule so the most qualified and credible subject matter experts can participate with no conflicts with major events, peak vacation periods, or availability of key internal support personnel);
- Dedicated work space conducive to the duration of the analysis and implementation phases of the project;
- Support equipment (e.g., computer and peripherals, RCM software);
- Meeting times so they are limited to a maximum of four to six hours per day and avoid back-to-back weeks of analysis;
- Refreshments or lunch (this can be a major success factor!).

The project manager or champion also must notify all prospective participants well in advance so no one is surprised. Everyone should be reminded of the seriousness of their commitment and the expectations for their constant participation over the long term.

Support personnel should assemble documentation needed by the project team, including:

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- Maintenance history;
- Copies of PM and condition monitoring procedures/schedules (note that some RCM methods prohibit using the existing PM/condition monitoring program during the analysis phase);
- System and equipment technical manuals;
- Performance standards;
- Process and instrumentation diagrams and electrical drawings;
- Stockroom or in place spares inventory lists;
- Training manuals on systems and equipment;
- Operating procedures and checklists;
- RCM reference materials covering the analysis approach(es) to be applied, etc.;
- Design or safety failure mode and effects analysis (FMEA), if available.

The project manager also must decide on:

- Progress reports to be made and to whom,
- How to communicate analysis phase results (relative to the desired outcomes),
- Backup plan/schedule in case of plant emergency (include contingency for outside support).

Valuable Lessons Learned by Other Organizations

Many organizations that have successfully or unsuccessfully completed an RCM project have contributed valuable lessons learned from their experience. Given that a large percentage (estimated at 50 percent or more) of RCM projects fail due to a lack of one or more essential elements, a review of some of the reasons for failure will help organizations avoid problems encountered by others. Some of the many pitfalls that cause failure and, therefore, must be avoided are:

1. Failure to train those participating in the analysis on the concepts of RCM prior to sitting for the analysis. Training gets all participants to a "common language" and speeds up the analysis.

2. Too much analysis and time off from the "real" job required by subject matter experts (SMEs), either because proper preparation was not made in advance or the tools available to support the analysis didn't support high productivity.

3. Failure to provide for prompt, if not simultaneous, recording of the results of the analysis so they are immediately available to the team for each new day's effort. These recordings are usually performed by a competent recorder, ideally from inside the organization, who can control and provide access to them later.

4. Failure to plan prior to analysis for the implementation of results at the earliest possible time, resulting in delay in realizing return on investment of time and resources in the project.

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5. Failure to pick a field-proven RCM project software program for use during and after the analysis phase. The constant recording required during analysis is nearly impossible without good efficient and user-friendly software. Poor software slows the analysis, does not focus efforts on the RCM process and causes long delays between team sessions.

6. Failure to have approved and accepted cost benefit values in terms of manpower requirements and costs for training, orientation, analysis and implementation are underestimated or ignored, resulting in a lack of buy-in from stakeholders in the outcome of the project.

7. No buy-in, especially when desired outcomes are driven by outsiders and lack meaning due to insufficient, substantive input from stakeholders inside the organization.

8. Failure to assign the most experienced SMEs to the RCM analysis, because they simply aren't available (the O&M A-team is usually the only knowledge source for potential failure modes and their effects).

9. Lack of top technical experts, failure data, or the will to conduct thorough root cause failure analysis, failure mode and effects analysis and follow up, or difficulty or impossible collection of data on maintenance history or equipment failures.

10. Lack of commitment by those who control assignment of SMEs' time and expenses when the RCM project manager or champion does not control personnel assets assigned to the project, or the travel and living budgets for those who come from outside a facility to support the project.

11. Failure to develop a system "operating context" to focus the RCM analysis and avoid overprescribing maintenance just on the basis of technically applicable failure modes.

12. Failure to have those engaged in the analysis phase lead the implementation of results.

13. Too little knowledge of or aversion to condition monitoring technologies, clinging instead to time-based, intrusive tasks.

14. Failure to involve parties skilled in condition monitoring, at least during the task selection step of the analysis phase.

15. Getting bogged down with having to "slog" through analysis results to identify new tasks to be scheduled and old tasks to be deleted because the analysis reporting mechanism isn't definitive enough.

16. A review and approval chain that is too long and over-controlling, causing unnecessary delays in implementation and subsequent realization of benefits from the project.

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17. An organizational culture that does not embrace change or lacks a support mechanism for incorporating change on a permanent basis.

18. Lack of appreciation that the analysis phase is easy compared to the implementation phase of an RCM project and that the longer the time between analysis and implementation, the lower the probability of ever getting tangible results.

19. Lack of assurance that management will provide the resources to support the whole effort or be supportive at all, either in short or long term.

20. Failure to keep the sponsor, champion(s) and other stakeholders current on the progress of the project and/or selection of inadequate report elements (e.g., no meaningful metrics).

21. Failure to select the right systems for analysis, that being the most important systems to the organization that offer the greatest payback potential.

22. Committing to do analysis on too many systems at once or in sequence before seeing any return on investment from the first ones analyzed.

23. Failure to ensure that any other initiatives being implemented concurrently with RCM projects don't interfere or supplant them.

24. Lack of analysis team empowerment or second-guessing of results by those who did not participate.

Summary

The guidance provided in this section can help organizations dramatically improve their odds of success and increase the benefit of RCM to the mission. In summary, if an organization can affirm the qualities on the left side of Table 7, it will greatly reduce the chance of experiencing adverse outcomes shown on the right.

Peer conferences such as the International Maintenance Conference (IMC), RELIABILITY 2.0, Solutions 2.0 and Reliability Performance Institute (RPI) events provide invaluable networking and experience-based learning.

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Table 7 – Best Practice Strategies to Avoid Adverse RCM Outcomes

Focus on These	To Avoid These
Clear, understandable goals, objectives and expectations Clear understanding of a wholistic system of reliability (CRL) Strong and continuous management support Dedicated staff Ownership and continuity of assignments to the project Preparing a charter/contract up front that details who will be on the team, who will facilitate, when and where they will meet, who will report results and who will manage implementation Processes and systems selected to gain best results Strategic and rapid implementation Accurate measurement of results	Results underutilized or ignored Time and budget overruns Deferred or truncated programs No funding or manpower allowance for implementation A living program never properly established to provide for feedback on new or missed items No follow-up to ensure prompt implementation of new maintenance requirements No attention paid to long-term benefits realized from the analysis (i.e., benefits phase is too short to document return on investment) which, in turn, results in RCM being underutilized and full potential never realized

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4.0 Completing an RCM Study

The RCM analysis phase, from initiation to completion, is the most straightforward part of an RCM project. At this point, the organization knows why it is conducting an RCM project, who is involved and how, and has committed the resources required to be successful. Practitioners have found that most organizations do not struggle with the RCM analysis itself, but rather with identifying the correct assets to do it on and then implementing the results. Following the SAE standards referenced in this guide, along with more detailed guidance according to the methodology and training received, will keep the RCM team on track through the analysis phase.

RCM and the approaches that adhere to the definition of RCM provide a technical methodology that, when applied correctly, delivers a beneficial result. Therefore, the role of the project manager at this phase is to make sure the RCM methodology and the process of applying it are carried out correctly and according to plan. The best way to do this is through feedback based on metrics and team comments.

Analysis Phase Metrics

The following RCM project commitment metrics may be useful to sustain momentum during early phases of an RCM project and to gain acceptance of the new program from personnel unfamiliar with RCM and its benefits. More is not necessarily better; be careful to balance the amount of

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effort spent preparing for and performing the RCM project with the most efficient use of resources. An experienced RCM director and facilitator will maximize the impact of RCM, while minimizing the required investment. Some potential RCM project commitment metrics include the:

- Number of maintenance, operations and engineering personnel employed, including management involved in any way with an RCM project;
- Number of the above personnel trained or oriented in RCM methodology;
- Percentage of above trained personnel who participated in RCM analyses;
- Number of above employees qualified as RCM facilitators;
- Total labor hours allocated to performing RCM analysis to date, compared with the estimated hours required. (Note: Labor hours may be broken down further, for example, for RCM project manager, facilitator(s) and analysis team members.)

During analysis, the rate of progress may be reported using the RCM systems analysis profile, documented in publicly available sources and detailed in reference publications. For each system analyzed, the analysis profile measures the number of:

- System functions;
- System functional failures;
- Components identified and analyzed within the system boundary;
- Failure modes analyzed (critical, hidden and otherwise);
- Failure finding tasks for hidden failures (full coverage is an indication of a high quality RCM analysis);
- Total maintenance tasks specified (separated by type, including run-to-failure decisions);
- Active maintenance (including operator) tasks specified;
- Items of interest identified as other significant opportunities to improve, including safety issues, design modification recommendations, operating procedure recommendations, control system configuration, training needs, etc.

These metrics should be readily available from the RCM analysis reports or analysis software package. During the analysis, an experienced RCM facilitator, or someone in the RCM director role, will be able to identify problem areas based on the systems analysis profile and suggest corrective measures to keep the study on track. At the conclusion of the analysis phase, the RCM systems analysis profile is an effective tool for communicating benefits provided by the study.

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Non-maintenance task improvements, also referred to as items of interest, potentially offer significant opportunities, but can distract the team. RCM facilitators and project managers may occasionally have to restore emphasis on specific maintenance tasks and capture just enough details on other non-maintenance task recommendations, including:

- Design modifications,
- Safety issues,
- Operating procedure changes,
- Control system configurations,
- Training needs, etc.

Such items should be recorded as one-line entries and discussion of them curtailed as soon as possible so the RCM project does not get diverted from its goal. They should be further considered during the implementation phase.

The nature of the maintenance strategy recommended by the RCM analysis is conveyed by tallying the number of RCM tasks and the percentage of the whole that are:

- Time directed (split by non-intrusive and intrusive),
- Condition directed,
- Failure finding,
- Run to failure.

The RCM-derived maintenance strategy should be as non-intrusive as possible, favor condition-directed tasks, emphasize failure finding, and employ run to failure decisions where risk and economics permit. One way to measure the benefit of the RCM study, if fully implemented, is to compare RCM-derived tasks with the legacy PM program. Note that some RCM methodologies intentionally make this comparison only after the analysis is complete to avoid predisposing the analysis team to pre-RCM tasks. An example comparison of RCM-derived maintenance tasks and pre-RCM legacy tasks is shown in Table 8. Note that only documented pre-RCM tasks should be credited. There may be many undocumented customary rounds and PM tasks, so be sure to acknowledge these informal efforts while standing firm on the need for formalized means of specifying and tracking maintenance tasks.

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Table 8 – Comparison of the Number of RCM-Derived and Pre-RCM Legacy Preventive Maintenance Tasks

Task Type [Sample of 147 (42%) of Failure Modes]	**[Name of] System**	
	RCM	**Current (Pre-RCM)**
Time Directed - Non-Intrusive (TD) - Intrusive (TDI)	 61 (32%) 28 (15%)	 39 (20%) 43 (23%)
Condition-Directed (CD)	29 (15%)	11 (6%)
Failure Finding (FF)	43 (23%	4 (2%)
Run to Failure (RTF)	29 (15%)	--- ---
None	--- ---	93 (49%)
Total	190	190
Total Active PM Tasks (not including RTF)	161 (85%)	97 (51%)

One can also compare the **similarity** of RCM tasks with the pre-RCM legacy program (current tasks) by counting the number and percent of total of:

1. RCM tasks that are the same, more or less, as current documented tasks.
2. RCM tasks that are essentially the same as modified current documented tasks.
3. RCM tasks with no corresponding formal current documented task.
4. RCM run to failure decision specified with no current documented task.
5. RCM and current documentation specify very different tasks for the same failure mode.

The value delivered by RCM often will be evident in #3 from Table 8. However, all five are a one-time set of metrics to provide an understanding of the nature of changes that must be made to implement the new RCM-based maintenance strategy.

The number of selected tasks or follow-up action items for each category (e.g., task, RTF or other decision, design modification, operational procedures change recommendation) should be documented in RCM implementation progress reports. In addition, the number of tasks identified in Table 8 should be used as a target for which implementation progress is reported. It is important to remove tasks that may be justifiably canceled from the PM program as soon as possible.

Analysis Team Feedback

If one of an organization's objectives is to increase the culture of reliability and proactive ways of thinking, then comments on the RCM analysis phase should be collected from each RCM team member. The comments will offer powerful feedback to improve the process, increase buy-in and

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morale, encourage further application of RCM, and support acceptance and implementation of the RCM-specified maintenance tasks, especially if included in the management presentation detailed in the next subsection.

Management Presentation

Many organizations have used the completion of the analysis phase as an opportunity to communicate the benefits of RCM to management and staff. The metrics and team feedback discussed in this section provide an excellent context to reinforce the value of RCM and gain commitment to implement the results.

Be sure to include the following items in the management presentation and have involved staff present for as much of it as possible.

1. RCM drivers and desired outcomes
2. Selected system and supporting data
3. RCM team and project commitment metrics
4. Systems analysis profile
5. RCM and pre-RCM task type comparison
6. RCM and pre-RCM task similarity comparison
7. Key findings (major risks mitigated, etc.)
8. Design modifications, operating procedure modifications and other secondary benefits
9. Team feedback (in their words, presented by them)
10. Next steps

RCM Analysis Phase Final Report

The final report from the analysis phase preserves the RCM study for the future and provides a basis for implementation of the RCM-specified maintenance strategy. The final report should be created from software exports of the RCM steps, plus information included in the management presentation.

The final report, and the study metrics included in it, also may be used to compare efforts on future RCM projects and to orient and train personnel new to RCM. In the latter instance, the numbers are useful for giving such personnel an idea of the magnitude of the effort involved in an RCM analysis project.

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5.0 Implementing the RCM Study

"Implementation is the graveyard of RCM" is a saying, quoted by Doug Plucknette, author, *Reliability Centered Maintenance using RCM Blitz* (ISBN 9780983874164), that underscores the importance of this section. One of the main reasons why RCM projects achieve limited success is a failure to plan adequately for the implementation based on the results of the analysis. Illustrated previously in Section 2.0, Figure 3 shows that after the decision phase, the phases of an RCM project should overlap. RCM projects achieve the highest level of success by commencing implementation even before the analysis phase is complete and carrying the implementation through to completion. In a survey conducted in early 2005 by **Reliabilityweb.com**, respondents clearly pointed out that the hard part of any RCM project was the implementation phase. If readiness to implement isn't carefully planned, expected and communicated by the appropriate stakeholders, implementation may not ever occur.

Successful implementation requires accountability. The organization must specifically identify these minimum items to be successful:

- A specific individual (not a position) who is assigned responsibility for the overall implementation. The RCM champion is typically, but not necessarily, this person.

- Implementation broken down into tasks by priority. Each task is assigned to a specific responsible person and given a due date.

- The RCM champion tracks and communicates the overall status of implementation by percent complete and schedule compliance.

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- A sponsor actively supports the champion. The RCM sponsor is typically, but not necessarily, this person.

Implementation Basics

Implementing RCM-specified maintenance tasks involves the coordination of many different parties, including maintenance management, operations, safety, procurement, stores, training, planning/scheduling, and craft persons. Some of the required activities include:

- Compilation of RCM tasks into craft- or trade-specific jobs or time intervals (referred to as task packaging).
- Identification of required maintenance and operations task resources (e.g., money, time, manpower).
- Coordination with governing authorities or other parties affected.
- Procedure writing, walk down and approval.
- Asset tagging and data development.
- Procurement of special tools, parts and consumables needed to carry out the procedures mandated by the RCM-derived maintenance strategies.
- Training, or at least orientation, on the new procedures for those who are to perform them, including maintenance, operations, planning, scheduling, stores and purchasing.
- Planning and scheduling of new RCM-based procedures.
- Data entry into the computerized maintenance management system (CMMS) or enterprise asset management (EAM) system. (ISO14224 compliant equipment hierarchy makes implementation much easier. If an organization has a standard hierarchy supported by RCM software, the failure modes and mitigating tasks will align more easily with the CMMS if both use the ISO standard. Although the ISO14424 document is aimed at the oil and gas industry, it can be easily adapted to almost any operation with little effort.)
- Initial first-time execution on the system that was the subject of the RCM project. (Baselining the PM program allows for consistent measurement and provides a basis for continued improvement.)
- Reviewing and addressing items of interest (e.g., design modifications and other non-maintenance recommendations).

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RCM implementation may seem like a complex project unto itself. Successful implementation requires a detailed implementation plan that lists what must be done, who is responsible for doing it and when the work must be complete. The plan is ready for execution when all of those involved in authorizing change, committing resources and carrying out activities, including the RCM maintenance strategy, fully understand the plan and agree to carry it out. If an organization has an established management of change procedure, take maximum advantage of it.

Implementation Tracking

Implementation-focused metrics provide measures that signify progress towards implementing an RCM-based maintenance program. Using numbers identified during the analysis phase as a basis, the metrics concentrate on the number and percentage of each category that has been fully implemented (e.g., new task, modified task, cancellation of specified old program tasks, design modifications, operational procedure changes, etc.).

Organizations with multiple RCM studies in progress or in concurrent implementation may need a way to track the status of each study and the teams responsible for completing the work. An example status report is shown in Table 9. An organization may elect to break out the status report by task type (e.g., time director or PM, condition-directed or PdM, failure finding or operator, etc.) or craft. There is also the option to track the number of tasks implemented compared to the number identified in the RCM study, as well as the percent complete.

Table 9 – RCM Study Implementation Status Report: Percent Complete by Implementation Category

Implementation Category	Study 1	Study 2	Study 3 (etc.)
RCM Analysis % Complete May track system selection, team selection, information gathering, etc., separately	100%	100%	75%
Task Packaging Review % Complete	100%	100%	10%
Maintenance and Operations Task Development	100%	100%	5%
Maintenance and Operations Task Open Issues Review	100%	90%	----
Task Development Punch List	100%	50%	----
% PMs Reviewed (Flag Reviewed PMs in the CMMS)	100%	100%	----
% PMs Implemented (Flag Implemented PMs in the CMMS)	100%	60%	----
Baseline (Perform) PMs	100%	5%	----
Remove Pre-RCM PMs	100%	0%	----
Items Of Interest (IOIs) Addressed	100%	25%	----

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Finally, an organization may wish to measure the effort being put into implementation work. For example, Table 10 tracks the effort expended to date.

Table 10 – RCM-Based Program Implementation Labor Hours Metrics

Labor Hours by:	Last Report (Date) Hours	This Report Date) Hours
Management, maintenance, operations and engineering personnel, including training and/or orientation		
Support personnel, including procurement, contractor and any others involved directly in implementation		
Total labor hours expended to implement RCM analysis tasks		

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6.0 Measuring the Benefits

The RCM project benefits phase supports and improves the living reliability program by providing feedback on ways to improve the RCM process and demonstrating the measurable benefits RCM provides to the organization.

An organization should measure benefits relative to the pre-analysis baseline to assess the effectiveness of RCM task implementation and the quality of the RCM analysis. Start measuring immediately after implementation begins and continue well beyond the time implementation is complete. The defined time period(s) used will vary based on the type of measure and the quality and availability of the data.

RCM will improve performance. Improving reliability and lowering maintenance costs, along with several of the other measures listed in this guide, are very realistic goals. Once a system achieves its inherent designed reliability, the best an organization can do is sustain that level of reliability. Take care to change RCM recommended maintenance tasks based on results. Tweaking task frequencies due to an apparent leveling off of results (and not based on failure data) can have undesirable outcomes.

Candidate metrics selected from Table 6 in Section 3 serve as a starting point and constant reference to the same metrics tracked for the same system for the representative periods selected prior to the implementation of the new RCM-based program. A useful presentation may consist of a set of graphs with the metric(s) plotted against time and clearly showing the point where implementation began. Periods selected should be representative of what is considered the

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"normal" operating profile for the asset being evaluated. Trends will then be evident and referenced to a definite point in operating time when the positive results of the RCM project begin to emerge. These metrics, although entitled "RCM-based Maintenance Reliability Program Benefits Metrics," must be presented in a broader context since many other initiatives may affect them during the same period of time as the implementation and benefits phases of the RCM project.

An organization may also select additional metrics that go beyond the baseline measures. This guide contains a list of additional metrics in Table 11, developed through a consensus process during a workshop attended by over 100 RCM practitioners conducted March 9, 2005 and based on earlier collaborations from May 2004 to January 2005.

Only a few of the metrics in this guide may be meaningful to an organization. It may also have other metrics specific to its needs that this guide does not contain. In the consensus workshop, it was suggested without any objection that as few as six or eight metrics may be all that are needed to make the case for an RCM project and to determine benefits derived from it. Metrics should be collected on the system studied prior to the decision to proceed with an RCM project and for a sufficient period of time that provides a true comparison of before and after performance.

Table11 – Additional RCM-based Maintenance Reliability Program Benefits Metrics

Metric	Desired Trend Direction
PM Compliance	Up
Preventive Maintenance labor hours as a percentage of total maintenance labor hours performed (see Note 1)	Up
On-Condition or Condition-Directed Maintenance as a percentage of total maintenance labor hours, including all labor hours for restoring abnormal conditions found (see Note 2)	Up
Total Cost to Perform the RCM-derived maintenance program (see Note 3)	Down

Note 1: Where a metric involves labor hours, it may be useful to break out subsets by trade category (e.g., Electrical, Mechanical, etc.)

Note 2: Maintenance labor hour expenditures described in this guide do not include those labor hours expended by **operators** who perform PM and condition monitoring tasks as part of their job responsibilities.

Note 3: It has been useful in some instances to distinguish between labor hours and replacement parts cost for repair of the primary system separately from collateral damage costs to secondary systems.

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RCM on a New System

Comparative measures are not possible when performing RCM on a new system with no available history or maintenance plans. In this case, use the established measures to confirm that system performance is sustained at desired levels. An organization also can use the system analysis profile to measure and explain the benefits of the different maintenance types, possibly in the context of the Electric Power Research Institute (EPRI) study about maintenance cost per horsepower as shown in Figure 5.

Note: The source of the conclusion of the EPRI maintenance cost per horsepower study is for illustration purposes and should not be relied upon for financial calculations.

Figure 5: Maintenance cost per horsepower

Look for the "Hump"

Because RCM tasks may lead to correction of many problems previously tolerated, the metrics from Table 11 may be deceiving shortly after implementation and may not be well received unless analyzed and explained very carefully. For example, it is not uncommon to see an initial, temporary growth in work orders, cost of replacement parts and labor hours for maintenance (the "hump" or "bow wave") as RCM action items are implemented. This is due to the fact that many problems either not evident or tolerated under the old program are identified for correction under the new program. This hump in work orders, parts requisitions and associated costs and labor hours must be overcome before positive results, reflected in other benefits, such as improved reliability, availability, product quality and throughput, are realized in other metrics. It may take 12 to 18 months to work through this. For that reason, any of the metrics used during the benefits phase should be tracked for at least this long or longer after the end of the implementation phase of an RCM project.

Some chronic problems may not yield to an RCM solution or other methodologies, such as root cause failure analysis follow-up actions. It may be useful to report metrics, such as failure rates, on these items separately or with caveats explaining the situation.

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If the Results are NOT There....

Finally, if the organization is not seeing measurable benefits, the RCM-specified maintenance strategy may not actually be in place. Audit the maintenance program by comparing the in-place PM program to the recommended RCM tasks to see how well they match. Corrective maintenance events also might be evaluated to determine if the failure mode(s) represented by each event should have been prevented by an RCM-specified task. An example of this approach was documented by the Metropolitan Sewer District (MSD) of Greater Cincinnati in the October/ November 2011 issue of Uptime Magazine in an article titled, “Applying Best Practices to Improve System Availability at Metropolitan Sewer District of Greater Cincinnati (MSD).” www.uptimemagazine.com

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7.0 Sustaining an RCM Program

With the achievement of a successful RCM project, the organization is now experiencing positive results and is ready to sustain and increase the impact that RCM can provide. The following cultural and organizational factors will affect the long-term success of RCM efforts.

1. Prior history of organization in change management or bureaucratic elasticity. Will it work for a while then return to what you did before?
2. Steadfastness of management and supervisor support for new initiatives. Is the organization saturated by the "Flavors of the Month or Initiative Overload?"
3. The likelihood that the recommended maintenance tasks identified will be permanently adopted.
4. A commitment to cross-functional Defect Elimination (De) teams.
5. A commitment to procedure-based maintenance? Without it, how are changes going to remain in existence?
6. A procedure-based maintenance environment that has a procedure compliant culture.
7. Maintenance requirements that are routinely performed on the basis of written schedules.
8. The ability to set aside a recurring annual budget to continue RCM.

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These factors illustrate how sustaining an RCM program is not easy. It is hard to find good technical and psychological studies on how to sustain any program. All organizations need to sustain processes and systems, but guidance that tells how to do it falls short. The maintenance reliability community needs more and better reference material. Please consider sharing your organization's successes and lessons learned in this area, perhaps at a future conference.

Sustaining performance with RCM is linked to the value and retention of maintenance strategies developed during analysis, the implementation of those strategies and the continued improvement of those strategies within the living program.

There are enablers for achieving high performance in these three areas and, thereby, sustaining results. Audit is often the first action that comes to mind and it is important, but it is not the answer. There is so much more to this subject. Some proven enablers of how to sustain RCM are:

1. Set and follow a strategic vision or direction to guide improvement.

2. Involve senior managers visibly in key improvement and living program activities for their own understanding and to signal commitment.

3. Appoint and rely on a champion or change agent to own the effort.

4. A simple, yet formal, process to document and review improvement ideas from the shop floor.

5. Operations and maintenance involve as many affected staff as possible and make decisions in teams about the way they work and encourage experimentation.

6. Changes to maintenance strategies are formally introduced through training to ALL involved.

7. Make time for following standards every day, in every shift and check on them.

8. Monitor improvements made by RCM and formally communicate the results.

9. Focus senior and middle managers and supervisors on supporting enablers 1 through 8 through ownership by setting improvement targets and making people responsible for reaching those targets.

Highly successful organizations adopt a continuous improvement approach with these elements that can be described as a living reliability program. Note that continuous improvement is not the same as continuous change. If an organization is seeing results, it needs to be very careful in what it changes. The living reliability program establishes the resources (including budgets), roles, expectations and skillsets needed to gather additional feedback to continue improving the RCM maintenance strategy (e.g., adjusting periodicity).

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As shown in previous sections, the RCM project defines maintenance strategies based on the identified failures modes. These strategies are implemented into the Enterprise Asset Management (EAM) and Computerized Maintenance Management System (CMMS) and executed as part of the work execution processes. With a living program, failures are analyzed with tools, such as root cause analysis and other defect elimination methods. Those findings are then reviewed in conjunction with the results from the previously completed RCM project. The maintenance strategies are either validated or modified with the new data and implemented in a closed loop (continuous improvement) fashion back into the EAM/CMMS to be executed.

Summary

This Reliability Centered Maintenance Project Manager's Guide presents many things that those in charge of maintenance reliability for an organization should take into account before committing to and starting an RCM project. There are many pitfalls to avoid in order to bring the project to a successful conclusion. It must be appreciated that the whole effort may take a long time, up to several years in all, but the results of past successful projects have proven that it is worth it.

This guide does not favor any RCM methodology (e.g., RCM 2, classical RCM, RCM variant or derivative). Nor does its approach discriminate against any analysis method (e.g., team-based or analyst-based).

This guide increases the chances for success of a project by calling attention to causes of previous failures and providing the most meaningful basis for proving success – metrics during decision and all ensuing phases of a typical RCM project. It provides a comprehensive menu from which metrics may be selected to aid in deciding whether or not to proceed with an RCM project.

Once the decision is made to proceed, this guide provides metrics to use to evaluate project progress during analysis and implementation phases, and results during the benefits phase. Many of the metrics are representative of those used in the past on actual projects. Other metrics may be added or substituted, as long as the principles of comparison for like systems and operating conditions are followed.

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8.0 Glossary and References

History and Contributors

The following list of publications is an integral reflection of the material covered in this guide. Each of them is a highly significant contribution to the industry and is worth the time to read them to learn more about achieving success with RCM. This guide also includes many representative works developed by organizations that put the knowledge contained in these references to work. The RCM Project Manager's Guide was developed using the following sources in real-world applications by practitioners:

• Nowlan, Stanley F. and Heap, Howard F. *Reliability Centered Maintenance*. San Francisco: Dolby Access Press, 1978.

• Smith, Anthony M. and Hinchcliffe, Glenn R. *RCM: Gateway to World Class Maintenance*. Oxford: Butterworth-Heinemann, 2003; ISBN 9780750674614.

• The Association for Maintenance Professionals. *Certified Reliability Leader Passports and Complete Body of Knowledge*, ISBN MMCRLBOK, MRO Zone bookstore.

• Reliabilityweb.com. *Uptime Elements – A Reliability System for Asset Performance Management*.

• RCM Overview Workshop at 2004 SMRP Conference.

• RCM Key Performance Indicators Workshop at the 2009 Reliability Centered Maintenance Managers Forum. www.maintenanceconference.com

• Hansen, Robert C. *Overall Equipment Effectiveness*. New York: Industrial Press, Inc., 2001; ISBN 9780831131388.

• Gulati, Ramesh, Kahn, Jerry and Baldwin, Robert. *The Professional's Guide To Maintenance And Reliability Terminology*. Fort Myers: Reliabilityweb.com, 2010; ISBN 9780982516362.

• Plucknette, Douglas. *Reliability Centered Maintenance using RCM Blitz™, Second Edition*. Fort Myers: Reliabilityweb.com, 2011; ISBN 9780983874164.

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• Moubray, John. *RCM II – Reliability-Centered Maintenance, Second Edition*. New York: Industrial Press, Inc., 1997; ISBN 9780831131463.

• SAE International. SAE JA1011 - Evaluation Criteria for Reliability-Centered Maintenance (RCM) Processes.

• SAE International: SAE JA1012 - A Guide to the Reliability-Centered Maintenance (RCM) Standard.

• Plucknette, Douglas. *Operating Context – What's Included*. RCM Blitz blog: November 2013. http://www.rcmblitzblog.com/2013/11/20/operating-context-whats-included/

• Bateman, Nicola in association with SMMT Industry Forum. *Sustainability … a guide to … Process Improvement*. Cardiff: Lean Enterprise Research Centre at Cardiff University, 2011; ISBN 0953798224.

• *The (New) Asset Management Handbook* – A Guide to ISO55000. Fort Myers, Florida: Reliabilityweb.com, 2014; ISBN 9781939740519

Information on readiness and success factors and pitfalls leading to failure of RCM projects were developed from the book titled, *Advancing Reliability & Maintenance, Second Edition*, by Jack R. Nicholas, Jr., P.E. CMRP and R. Keith Young, and *Advancing Reliability & Maintenance To Meet And Beat Global Competition* (DVD) by Jack R. Nicholas, Jr. www.mro-zone.com

This document was originally facilitated by Jack Nicholas, Jr. and was most recently updated in 2014 by a Virtual Special Interest Group (VSIG) coordinated with resources provided by Reliabilityweb.com. Participants included:

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Terminology Context

To avoid confusion between terms and phrases used in other contexts within the field of maintenance reliability, the following notes are provided.

Note 1: Corrective maintenance in the context of the metrics included in the RCM Project Manager's Guide refers to **unplanned, unexpected,** or **reactive** maintenance to restore the functional capabilities of an asset. It includes repeat maintenance required because **initial attempt(s) at repair were not successful** for any reason. It does not include maintenance that results from preventive or condition monitoring (PM and on-condition or condition-directed) tasks, which can be anticipated, pre-planned and scheduled. Corrective maintenance is a subset of emergency/demand maintenance.

Note 2: Corrective maintenance in the total productive maintenance (TPM) sense refers to actions taken to **modify** the asset to improve its performance. The labor hours and material costs for these improvements, as well as those that improve asset maintainability, should be categorized

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separately and not be included as part of any metric associated with the RCM scorecard unless the recommendation of a design improvement results from RCM analysis on an asset.

Terms, Abbreviations and Definitions

Experience in many organizations has shown that adopting a consistent use of terminology is a leading indicator of success. The following terms, abbreviations and definitions are included here as a brief and to the point reference designed to help explain those maintenance reliability terms that relate to an RCM project or program. It is not intended to be a conclusive list or fully capture the nuances of any particular term.

80/20 Rule – Known as the Pareto principle, the rule of thumb states that 80 percent of the effects of any large system can be attributed to 20 percent of the causes. See Bad Actor

Analysis Phase of an RCM Project – The period during which RCM analysis is in progress to determine what maintenance strategy should be performed on an asset. A portion of the analysis phase may overlap with the implementation and benefits phases of an RCM project.

Asset – A thing, entity, or item that has actual or potential value to an organization.

Asset Lifecycle – The phases of an asset's life span that include design, development, build, install, operations, maintenance, decommissioning and disposal.

Asset Management – The set of methods, procedures and tools to optimize the impact of costs, performance and risk exposures (e.g., availability, efficiency, quality, longevity, and regulatory, safety and environmental compliance) of the company's physical assets.

Asset Utilization – Operating (calendar) Time divided by Total (calendar) Time in a specific period (month quarter, year) times 100 to give the percentage of total calendar time that an asset runs.

Availability – The probability that an asset is capable of performing its intended function satisfactorily, when needed, in a stated environment. Availability is a function of reliability and maintainability.

Bad Actor – A system where 80 percent of the problems (e.g., failures, costs, etc.) to the organization or site can be attributed to 20 percent of the systems. See 80/20 Rule

Benefits Phase of an RCM Project – The period starting with the regular execution of the first task or other action item (e.g., the cancellation of a legacy program task proven of no value) resulting from an RCM analysis. The benefit phase may overlap the analysis and implementation phases of an RCM project. The period is characterized by adoption, calculation and evaluation of RCM-based program benefits metrics and their trends. These are used to evaluate effectiveness of efforts aimed at failure mitigation, avoidance of functional degradation, or failure elimination. This phase, usually divided into monthly or yearly intervals, may end at a time established by management, or may be ongoing until benefits of the entire RCM effort have been fully realized.

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Best Practice – A superior method or innovative practice that contributes to the improved performance of a process or an organization, usually recognized as "best" by other peer organizations.

Bureaucratic Elasticity – The characteristic of an organization that begins a new initiative and then, because of departure, shift of attention, or lack of firm leadership of the initiating manager or supervisor, returns to the traditional way of doing whatever the new initiative was supposed to change.

Capacity Factor – The ratio of actual output divided by rated output. Commonly used in the electric power generating industry, it is the ratio of actual megawatt hours produced on an annual basis to the megawatt hours that could have been produced during that period if the plant was operating at 100 percent of its rated output every hour of the year.

Champion – An individual with sufficient clout, position of authority and/or reputation within an organization who can support and defend an initiative or permanent portion of an ongoing program or methodology in the face of conflicting budget, production, or other requirements. Within the field of maintenance reliability, champions may be assigned or self-appointed to an RCM project, the predictive maintenance team, or a total productive maintenance or procedure-based maintenance initiative. Typically, the champion title does not appear on an organizational chart, although the official title of a supervisor or manager may imply that the incumbent is the logical choice.

Condition Monitoring (CM) – An equipment maintenance strategy based on measuring the condition of equipment to assess whether it will fail during some future period and then taking appropriate action to avoid the consequences of that failure. The condition of equipment could be measured using condition monitoring, statistical process control, equipment performance, or through the use of the human senses. Synonymous with condition-based maintenance and on-condition maintenance. Older terms included predictive maintenance (PdM) or non-destructive testing (NDT).

Corrective Maintenance (CM) – Repair actions initiated as a result of observed or measured conditions of an asset after or before the functional failure.

Critical Asset – An asset that has been evaluated and classified as critical due to its potential impact on safety, environment, quality, production/operations and maintenance if it fails. RCM addresses critical assets within the systems they comprise.

Decision Phase of an RCM Project – The period during which a determination is made using a selection of metrics, measures, or key performance indicators (KPIs) as to whether or not an RCM project will meet an organization's investment criteria and improvement in safety and/or economic performance. The improvement will be created through execution of a maintenance program based on principles of RCM.

Defect – Anything that creates waste, erodes value, reduces production, compromises health, poses safety risks, or negatively impacts the environment.

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Design Defect – A defect that occurs during the design, fabrication, acquisition and installation phases of an asset's lifecycle.

Design Modification – An alteration to the configuration of an asset or its process, in this case driven by the RCM analysis, that improves its reliability, safety margin, or operational performance, or makes a formally hidden failure evident to operators and maintainers in the course of their normal duties.

Detection – A ranking scale that defines the likelihood of detecting a failure or effect of the failure.

Downtime – The amount of time an asset is not capable of running. It is the sum of scheduled and unscheduled downtime.

Effects – The consequences of failures.

Effects Analysis – The studying of consequences or effects of failures.

Equipment Uptime – The time period during which an equipment item is performing at design specification; the inverse of downtime.

Failure – The inability of an asset to perform its designed function.

Failure Finding (FF) Tasks – A scheduled task that seeks to determine if a hidden failure has occurred or is about to occur.

Failure Mode – The way or manner in which an asset might fail.

Failure Mode and Effects Analysis (FMEA) – A procedure to determine which malfunction symptoms appear immediately before or after failure of a critical parameter in a system. After all the possible causes are listed for each symptom, the product or process is redesigned to eliminate the problems.

Failure Rate – The number of failures an asset has over a period of time. Failure rate is considered constant over the useful life of an asset. It is normally expressed as the number of failures per unit time. Denoted by lambda (λ), failure rate is the inverse of mean time between failures.

Forced Outage – When the system experiences an unexpected failure that prevents its function.

Function – The primary and/or secondary purposes of an asset or its normal or characteristic actions, sometimes defined in terms of performance capabilities.

Functional Failure – Failure of an item to perform its primary and/or secondary purposes or its normal and/or characteristic actions within specified limits.

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Heat Rate – A measure of the efficiency of a plant in converting one form or source of energy, such as coal, oil, or gas, into another, such as electricity. Typically, this is measured in British thermal units (BTUs) per megawatt hour in electricity generating plants. The lower the heat rate, the higher the efficiency in conversion. Since fuel is the major cost factor in the production of electrical energy, heat rate is an important measure of a plant's efficiency and potential profitability. Application of the best maintenance practices can greatly impact plant efficiency.

Hidden Failure – A failure mode that will not become evident to an individual or operating crew under normal circumstances.

Implementation Phase of an RCM Project – The period beginning with preparation for execution of the first RCM-based recommendation for a revised or new maintenance reliability strategy. The implementation phase ends with initial execution of the last recommended action item of an RCM project for an asset. The implementation phase may overlap with both the analysis and benefits phase of an RCM project. Implementation involves management of change, design of the new strategy and its execution. The most successful implementations use an organized approach, such as the Shewhart plan-do-check-act (PDCA) methodology articulated in Six Sigma and other problem-solving processes. See www.isixsigma.com

Implemented Task or Decision – An RCM project action item that has been formally executed for the first time as part of an RCM-based maintenance program. For tasks, this means it has been incorporated into an approved step-by-step procedure, with or without other RCM tasks, formally scheduled and carried out at least once by personnel who have been oriented or trained, if needed, to carry it out. For RCM-based decisions, such as run to failure items that previously required a task that was not applicable and/or effective and other old program tasks for which there is no justification, this means that all steps have been taken to exclude them from the new program.

Item of Interest – Used by classical RCM and referenced in this guide, it is an issue raised during RCM analysis that cannot be solved with a maintenance task. Examples include design modifications, safety issues, operating procedures, training needs and more.

Key Performance Indicator (KPI) – A management-level performance indicator. See Performance Indicators

Lubrication Task – A time- or condition-based action involving the addition or exchange of lubricant, such as grease or oil.

Maintainability – The ease and speed with which a maintenance activity can be carried out on an asset. A function of equipment design that is usually measured by mean time to repair.

Maintenance Backlog – Represents the maintenance work planned to be done at some time in the near future.

Maintenance Program – A comprehensive set of maintenance activities, their intervals and required activities, along with accurate documentation of these activities.

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Maintenance Strategies – The activities by which equipment/assets are maintained. The four main types of maintenance strategies are run to failure, preventive, predictive and condition-based.

Mean Time Between Failures (MTBF) – The average length of time between one failure and another for an asset or component. MTBF is usually used for repairable assets of a similar type. It is calculated by dividing total operating time of the asset by the number of failures over some period of time. MTBF is the reciprocal of the failure rate (λ).

Mean Time to Repair (MTTR) – The average time needed to restore an asset to its full operational capabilities after a failure. MTTR is a measure of asset maintainability.

Overall Equipment Effectiveness (OEE) – Metric used to evaluate how well an asset performs relative to its designed capacity. It is calculated by Availability % x Speed or Rate % x Quality %.

On-Condition or Condition-Directed (CD) Tasks – See Condition Monitoring

Operating Context – The environment in which an asset is expected to be used. A system's operating context statement clearly differentiates RCM from the "streamlined versions" that use failure mode libraries and claim they are the same thing as RCM. An operating context describes the current condition, environment and culture in which a piece of equipment operates. This would include, but not be limited to the following:

- Temperature (e.g., hot, cold, or severe swings);
- Dirty or dusty atmosphere;
- Wet or dry area;
- Corrosive, erosive, or abrasive environment;
- Dark or dimly lit;
- Noisy;
- Culture (e.g., goals and expectations not clearly defined, high level of emergency/demand work);
- Operating outside design expectations or performance standards;
- Asset condition (e.g., loose, improperly supported, improperly installed, improper design, damaged);
- Improper operation (e.g., start-up, shutdown, product change, setting, speed, flow, pressure);
- Human error (e.g., I forgot, no checklists or procedures).

Operating Procedure – A detailed, step-by-step written procedure(s) and/or checklist(s) used to start up, run, or shutdown an asset in the safest, most economical, productive and effective way. Changes initiated through RCM analysis are usually intended to eliminate or mitigate failure modes resulting from human error, or to alter the way the equipment is operated in order to protect it from functional failure. This may be done to protect the environment and/or the people who might be affected by a failure or the quality of the product or service provided by it. Failure finding

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tasks are often incorporated into operating procedures as the most logical and convenient way of performing them.

Operating Speed Rate – Used in OEE calculation, it is the total number of units of product or service produced multiplied by the theoretical cycle time and divided by actual cycle time. Operating speed rate is expressed as a decimal number equal to 1.00 or usually less. See Speed Rate

Operational Excellence – The consistent attainment of business growth through the flow of value as seen by the customer. This should be communicated in specific terms that are understood by all employees.

Operations Personnel – Personnel working in the operations department.

Performance Indicators – A variable derived from one or more measurable parameters, which, when compared with a target level or trend, provides an indication of the degree of control being exercised over a process (e.g., work efficiency, equipment availability). Synonymous with performance indices.

Pilot Project – An initial effort undertaken to test the feasibility of applying results on a broader scale and to determine whether such an initiative can be successful given the culture, resources required and benefits expected of it when applied throughout all applicable assets.

Planned and Scheduled – Activities in maintenance where resources are determined in advance and time is estimated to carry out the work.

Planned Maintenance – Tasks carried out on a regular, scheduled basis. These tasks may be predictive in nature (e.g., condition monitoring activities) or preventive (e.g., cleaning/changing filters, checking/adjusting clearances, etc.) to prevent an asset from deteriorating or breaking down.

PM Compliance – PM tasks accomplished, divided by PM tasks scheduled or required, multiplied by 100 and expressed as a percentage.

Predictive Maintenance or PdM Task – See Condition Monitoring

Preventive Maintenance (PM) – An equipment maintenance strategy based on replacing or restoring an asset at a fixed interval regardless of its condition. Scheduled restoration tasks and replacement tasks are examples of preventive maintenance tasks.

Proactive Maintenance – The sum of all maintenance work that is completed to avoid failures or to identify defects that could lead to failures (failure finding). It includes routine preventive and predictive maintenance activities and work tasks identified from them.

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Quality Rate – The number of good units divided by the total number of units produced. A factor expressed as a fraction or a decimal number equal to or usually less than 1.00. Included in the calculation of OEE and total effective equipment performance.

Reactive Maintenance (RM) – Maintenance repair work done as an immediate response to an asset failure, normally without planning and unscheduled. Synonymous with breakdown and emergency maintenance.

Reactive Work – Maintenance activities that occur with little or no notice. These activities interrupt the weekly maintenance schedule and cost two to four times as much as when they can be planned and scheduled.

Reduced Speed – Losses incurred when equipment or assets are allowed to perform at less than design speed or capacity. Synonymous with capacity losses.

Reliability – The probability that a system will perform satisfactorily for a given period of time under stated conditions.

Reliability Centered Maintenance (RCM) – A systematic and structured process to develop an efficient and effective maintenance plan for an asset to minimize the probability of failures. The process ensures safety and mission compliance.

Run to Failure (RTF) – A maintenance strategy or policy for assets where the cost and impact of failure is less than the cost of preventive actions. It is a deliberate decision based on economical effectiveness.

Scrap Rate – The amount (e.g., tons, widgets, etc.) of irreversibly damaged product divided by the amount of total product in the same units produced by an asset. Damaged product must be scrapped, meaning recycled or disposed of and generally can't be sold at a price that recovers its total cost of production. Usually expressed as a percentage of throughput or output.

Showstopper – A problem so bad that is attracts the attention of senior management.

Speed Rate – The ratio of theoretical cycle time divided by actual cycle time where theoretical cycle time equals ideal speed (equipment capacity as designed or highest accredited speed, if higher) and actual cycle time equals run time divided by actual amount produced. This yields a decimal number equal to or usually less than 1.00. Used in calculation of total effective equipment performance (TEEP).

Subject Matter Expert (SME) – An individual widely recognized for knowledge and expertise in maintenance and/or operation of an asset. SMEs may be in-house or from an outside source, such as from an original equipment manufacturer. He or she also may be a retiree whose expertise was not fully captured prior to retirement and is hired as a consultant for a limited period, such as for the analysis and/or implementation phase of an RCM project.

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Task(s) – Specified maintenance action(s) taken to mitigate, prevent, or identify the onset or presence of an actual functional failure in an asset.

Task Periodicity – Frequency with which a specified maintenance action is taken on the same asset.

Throughput – The number of units of product or service delivered in a specific period of time. May be expressed in tons or barrels, gallons per day, week, month, or year, widgets per hour, megawatt hours, etc. Synonymous with output.

Time Directed (TD) Tasks – Tasks directly aimed at failure prevention and performed based on time, whether calendar time or run time.

Time Directed Intrusive (TDI) Tasks –A type of TD task that defines actions requiring asset or process interruption where human error or just executing the task may cause a functional failure upon resuming operations after inspections, adjustments and lubrication tasks require shutdown/ restart, tagout, opening, or disassembly. Intrusion implies introduction of induced risk of functional failure caused by the maintenance action itself. A goal of an RCM project should be to minimize time directed intrusive maintenance tasks

Time Directed Non-Intrusive (TDN) Tasks– A type of TD task that defines actions that do not require process or asset interruption, equipment shutdown, tagout, entry, or disassembly, thus minimizing the possibility of human error that could cause a functional failure.

Total Cost of Replacement Parts – Money spent annually to replace failed, worn, or scheduled replacement components on a given asset or an entire facility. A subset of total cost to perform maintenance.

Total Cost to Perform Maintenance – The total cost of labor, material, including cost of replacement parts, and overhead charged to a specific asset or an entire facility over a set period of time. Includes all maintenance support personnel costs, including indirect labor, contracted and outsourced maintenance and related expenses, such as transportation, packaging, storage and handling, training, and annual capital investment in tools, instrumentation and materials used to maintain an asset, as well as allocated cost of utilities, insurance, taxes and factory supplies and consumables used by maintenance personnel in their daily work.

Total Effective Equipment Performance (TEEP) – A measure of how well an organization is creating value from its assets. TEEP = utilization x availability x performance x quality = utilization x OEE.

Total RCM Program Decisions – The sum of all TDI, TDN, CD, FF tasks and RTF decisions.

Unscheduled Downtime – The amount of time an asset is not capable of running due to unscheduled repairs, such as repair work not on the finalized periodic (e.g., weekly, monthly, or annual) schedule, plus the amount of time beyond that formally allocated for scheduled downtime or scheduled outage. For example, if a formally scheduled outage runs eight hours longer than

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scheduled, the eight hours should be categorized as unscheduled downtime and added to the total for the period(s) to which the metric applies. Downtime includes time waiting for parts. A unit that is capable of partial functionality is **not** down if it is operating at some level of output meeting minimum quality standards.

Work Order – A document used to request, plan, schedule, track and report all maintenance activities.

Yield – Throughput minus waste or scrap. Yield may be categorized into grades by level of quality, such as prime, seconds, etc.

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Appendix 1 – Readiness for Change Checklist

Change Readiness Assessment

Topic		Disagree									Agree
		1	2	3	4	5	6	7	8	9	10
1.0 Leadership											
1.1	There is a common vision for change										
1.2	Leaders are committed to change										
1.3	There is a strong sense of urgency for change										
1.4	Leaders understand trust and respect each other										
1.5	Leaders are modeling new values and behaviors										
1.6	Leaders are taking the time and effort to win support from other staff										
1.7	There is a history of successful change in this organization										
1.8	Leaders have no other motives that conflict with this change agenda										
1.9	Change will be supported by the current management style and behavior										
	Subtotal										
2.0 Vision for Change											
2.1	The rationale for this change is clear and compelling										
2.2	I have a clear understanding of the roadmap to achieve the vision										
2.3	I understand what this change means for me										
2.4	I understand what I need to do to achieve the vision										
	Subtotal										

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Topic		Disagree									Agree
		1	2	3	4	5	6	7	8	9	10
3.0 Change Strategies											
3.1	The current approach to change will work well in this organization										
3.2	There is clear authority and accountability for this change process										
3.3	There is a clear project structure for keeping change on track										
3.4	Problems that emerge will be dealt with effectively in a timely manner										
3.5	There is an understanding of the issues involved and sufficient time has been allowed for the change process										
3.6	Related projects will be well coordinated with this change initiative										
3.7	Change progress is usually well monitored and shared with everyone										
3.8	The current organization structure will support this change strategy										
3.9	The existing job descriptions will support this change strategy										
3.10	The change team is working effectively with each other										
	Subtotal										

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	Topic	1	2	3	4	5	6	7	8	9	10
		Disagree									Agree
4.0 Overcoming Resistance to Change											
4.1	Employees are encouraged to provide constructive feedback on this initiative										
4.2	Commitment of middle managers is being won before they are expected to lead change										
4.3	Managers have the skills needed to be successful at change management										
4.4	There are rewards and recognition for participating in the initiative and consequences for not doing so										
4.5	There is two-way communication on the change initiative; everyone who needs to know is in the know!										
4.6	Everyone who will be impacted is clear on how change affects them and what they need to do differently										
4.7	Employees are encouraged to change rather than being coerced into change										
4.8	This change process is a win-win for everyone (e.g., company, clients, employees)										
4.9	Staff expect this change to succeed										
4.10	Staff will be given adequate training to achieve the new skills and behaviors to be successful										
	Subtotal										
5.0 Managing Staff Performance											
5.1	Company policies, rules and processes are being changed to support this initiative										
5.2	Change will be supported by current compensation, appraisal and career development processes										
5.3	The desired level of cross-functional cooperation is in place for this change to take place										
5.4	Staff will genuinely work to support this change process, rather than give the impression that they are supporting change										
5.5	Change will be supported by current skill development processes (e.g., training programs etc.)										
	Subtotal										

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Appendix 2 – RCM Implementation Team Charter Example

Team Mission/Objective:

Ensure that the RCM program is implemented uniformly throughout [Organization]:

- Monitoring and tracking the success of the RCM project.
- Development of a rollout plan for RCM implementation for the operations division.
- Implementation of RCM recommendations and associated tracking/reporting.

Team Facilitator(s):

Steering Committee Member(s):

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Team Recorder:

Team Members:

Deliverables and Schedule:

1. Develop operations division RCM rollout plan. [DATE]
2. Develop procedure for RCM implementation. [DATE]
3. Develop metrics for RCM pilot and rollout. [DATE]
4. Implement RCM recommendations. [DATE]

Key Activities:

- Develop RCM rollout plan.
- Develop procedure for RCM analysis reports and RCM implementation.
- Discuss training requirements for RCM implementation.
- Review results of RCM analysis progress.
- Report team progress at monthly facilities asset management program (FAMP) steering committee meetings.

Expected Benefits:

Expected benefits from implementation of team activities and deliverables include:

- Consistent approach for the RCM effort.
- Lessons learned that will make the RCM process more effective.
- Development of an RCM rollout schedule that will focus RCM analysis efforts.

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Appendix 3 – RCM Analysis Team Contract Example

Objective

On [month, date, year], we will be performing an RCM analysis on [system]. The objective of this analysis is to develop a complete maintenance strategy, including a list of maintenance tasks, operations procedures, maintenance procedures and required training, along with spare parts stocking recommendations.

The RCM Facilitator will provide:

- Four hours of RCM participant training.
- Facilitation of a complete RCM analysis that includes functions, functional failures, failure modes, failure effects, a complete maintenance strategy and spare parts strategy.
- Provide assistance in prioritizing RCM tasks.
- Provide assistance in the development of an implementation strategy.

The Client/Site will provide:

- An RCM analysis implementation manager.
- A large comfortable room for the analysis.

• A projector, two easels, easel pads, markers, masking tape.

• The undivided time of the RCM team for the entire length of the analysis.

Jointly, the Facilitator and Client will provide:

• A complete operational history report.

• The names of people selected to participate in the analysis.

• Drawings, procedures and equipment history needed for analysis.

Schedule

[Month, Date to Month, Date] from [Time: a.m./p.m.] until [Time: a.m./p.m.], [Frequency: daily, weekly, once a week, etc.]

[Place, including building, conference room number, etc.]

Endorsements

Participant	Role	Signatures
Person 1	RCM Facilitator	
Person 2	Sponsor	
Person 3	Analysis Implementation Manager	
Person 4	RCM Team Member	
Person 5	RCM Team Member	
Person 6	RCM Team Member	
Person 7	RCM Team Member	

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Created in 1999, Reliabilityweb.com provides educational information and peer-to-peer networking opportunities that enable safe and effective maintenance reliability and asset management for organizations around the world. Activities include:

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Uptime Magazine **(www.uptimemagazine.com)** is a bi-monthly magazine launched in 2005 that is highly prized by the maintenance reliability and asset management community. Editions are obtainable in print, online, digital, Kindle and through the iPad/iPhone app.

Reliability Performance Institute Conferences and Training Events

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Other Causes

Reliabilityweb.com has financially contributed to include industry associations, such as SMRP, AFE, STLE, ASME and ASTM, and community charities, including the Salvation Army, American Red Cross, Wounded Warrior Project, Paralyzed Veterans of America and the Autism Society of America. In addition, we are proud supporters of our U.S. Troops and first responders who protect our freedoms and way of life. That is only possible by being a for-profit company that pays taxes.

I hope you will get involved with and explore the many resources that are available to you through the Reliabilityweb.com network.

Warmest regards,
Terrence O'Hanlon
CEO, Reliabilityweb.com

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