Reliability-Centered Maintenance's Role in

Asset Performance Management

THE RCM PHILOSOPHY IS THE KEY TO COST-EFFECTIVE ASSET MAINTENANCE

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Effective asset performance management implies the optimization of the production output and the total cost of ownership, as well as the maintenance strategies that support both. It is in the area of defining maintenance strategies that Reliability-Centered Maintenance (RCM) proves to be of indispensable value.

Reliability-Centered Maintenance is a maintenance philosophy that sets forth a structured method for determining how best to maintain production-related assets safely and economically.

The concept was born out of the experience airlines gained with the maintenance of civil transport aircraft over several decades. The concept became known to other industries with the publication of the book *Reliability-Centered Maintenance* by Stan Nowlan and Howard Heap in 1978.

Until then, it was commonly believed by engineers that most equipment had a fixed lifespan within reasonable limits. It was generally accepted that effective preventive maintenance was simply a matter of keeping comprehensive records of how long things lasted, then scheduling corrective action or rework just before they failed.

The publication of the book, the result of twenty years of work at United Airlines, provided statistical evidence that:

- Most pieces of equipment cannot benefit from a limit on operating age at all. For these, scheduled rework or overhaul will have no effect on improving reliability and, in some cases, will increase the chance of failure.
- There are, in fact, four preventive maintenance tasks, and they are not all effective in every situation.
- The true objective of a maintenance program is not to prevent the failure, but rather to prevent its consequences.
- Modification and design play an essential role in the development of a maintenance support program.
- In some instances, it is better to do nothing and simply live with the failures.

In response to these new insights, Nowlan and Heap proposed a structured method of analysis and decision-making that changed the way maintenance was viewed. RCM was born and has since revolutionized the effectiveness of maintenance support programs forever.

Nowlan and Heap's most significant contributions were:

- A clear definition of the objective of maintenance support based on the consequences of the failure
- A clear understanding of the applicable criteria for effectiveness of each of the four preventive maintenance tasks.
- A structured and formalized decision-making process for identifying the complete preventive maintenance strategy and support function.

Over the past 25 years of consulting in reliability and maintenance, I have come to better appreciate the role that Reliability-Centered Maintenance plays in the practical aspects of effective asset performance management. This role is a significant one that is based on the following key realizations:

1) The RCM process will identify the maintenance activities necessary to ensure the asset's reliability safely and economically. In this respect, it provides the key component of a proactive asset maintenance strategy.
2) The principles of RCM are universal and can be applied to all production-related assets.
3) In some cases rigorous formal RCM analysis is truly justified.
4) The most significant impact of RCM stems from the clear understanding of the objective for maintenance support in each situation.
5) In practice, the formal approach provides a wealth of valuable information for other business decision-making processes, including:
    - Critical spare parts identification
    - Spare parts holding, management, and procurement requirements
    - Key agreement required between operating and maintenance
    - Specific requirements with respect to failure data collection, data structures, and analysis.

Practical Aspects of Implementation

Years of practical application in industry have also highlighted some seemingly formidable challenges for the maintenance strategy designer:

- The outcome of the RCM analysis is typically a vast number of inspection tasks which can create an administrative nightmare within a company's existing maintenance management operating system and CMMS.
- Inefficient packaging of the inspection tasks leads managers to believe they do not have sufficient staff to carry out the inspections or process the feedback effectively.
- A number of organizations embarking on a formal RCM development program experience a significant drain on their experienced staff's time and seem to get bogged down in the detail. The process grinds to a halt before they achieve any meaningful improvements in reliability.
- In an attempt to alleviate this problem, they tighten the requirements on their critical analysis, reduce the number of equipment studies, and leave the less significant equipment without formal preventive maintenance coverage or, even worse, with an ineffective and often costly strategy.

The good news is that the above difficulties can be overcome if sufficient thought is put into the process at the outset.

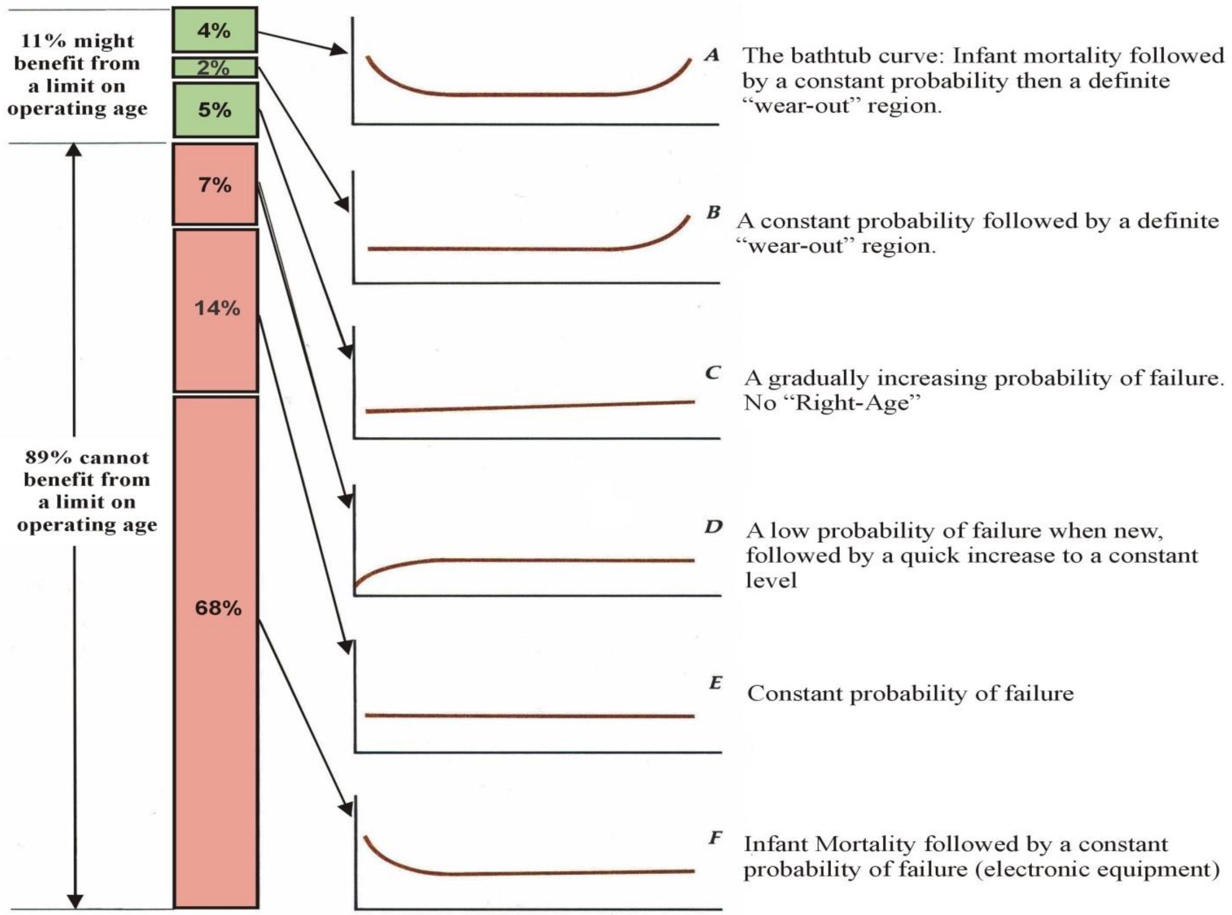
The Heart of Reliability-Centered Maintenance

To truly comprehend the benefits and implications of Nowlan and Heap's work, it is necessary to examine more closely the fundamental concepts underpinning their philosophy.

Since publication of the book, work in the field has contributed much to confirm these principles and concepts, but little to improve them. Whether the intention is to embark on a full, detailed analysis or not, there is considerable benefit to be derived from a thorough understanding of the principles and concepts, and a conscious consideration of their implications when developing maintenance support strategies.

During their 20 years of study, Heap and Nowlan identified these age-reliability patterns on the aircraft fleet at United Airlines

Figure 1 - Age-Reliability Patterns



Unless you operate a fleet of similar equipment you are unlikely to get the failure patterns displayed in ***Figure 1***. Consequently the real question becomes, “How do we maintain our assets in a safe and economical way right now, in the absence of this type of information?” The answer lies in the complexity of the equipment in question, and the assumptions one makes.

In the failure patterns shown above, only A, B, and C can possibly benefit from a limit on operating age before rework or overhaul. The study found these patterns applied to simple equipment with dominant failure modes which were invariably wear-related.

The curves like D, E, and F were typical of complex equipment which typically had a large number of possible failure modes. Failures tended to be random in nature. Virtually all electronic systems exhibited curve F, i.e., infant mortality followed by random failure.

These statistics lead to the realization that typically:

- A limit in operating age before rework or overhaul should only be imposed on simple equipment with known dominant failure modes that are wear-related - a total of only 11% of the items studied.
- Complex equipment should be expected to exhibit random failures, and be handled accordingly. This covered the remaining 89% of equipment studied.

Objective of an Asset Maintenance Support Strategy

One of the most significant contributions of the RCM process is that it serves to clarify the objectives of the maintenance strategy. When considering failures, it becomes clear that the objective is to prevent the consequences, and not necessarily the failure itself.

The Four Consequences of Failure and Corresponding Objectives

The philosophy identifies four categories of failure consequences and precisely defines an objective for each.

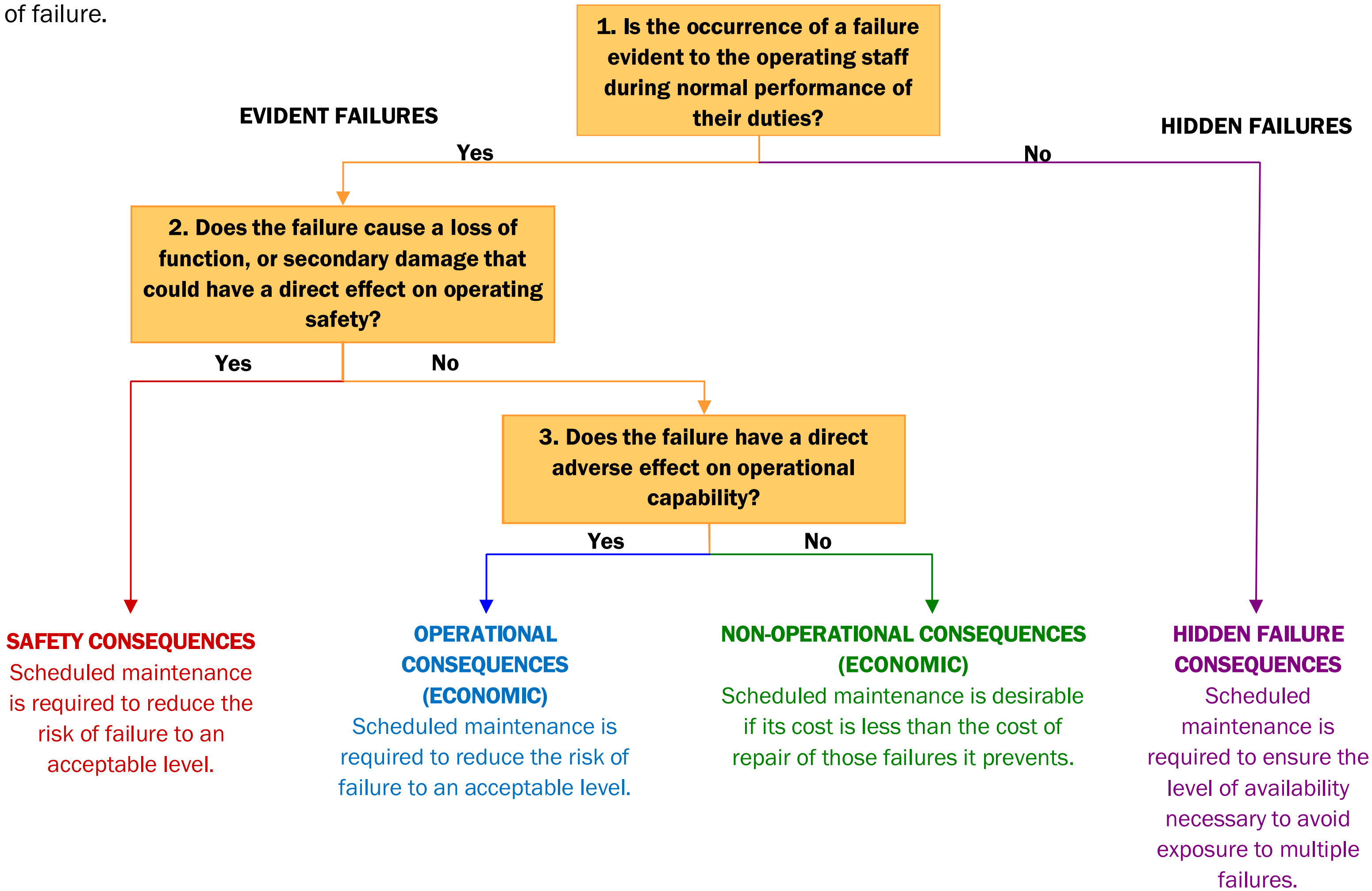
1) *Safety Consequences* - The objective is to reduce the risk of failure to an acceptable level.
2) *Operational Consequences* - The objective is to prevent the failure if the cost of prevention is less than the combined consequences of production loss and repair cost.
3) *Non-operational Consequences* - The objective is to prevent the failure if the cost of prevention is less that the cost of the repair.
4) *Hidden Failure Consequences* - The objective is to ensure the level of availability necessary to avoid exposure to multiple failures.

Each failure is examined in a formal decision-making process guided by a decision diagram. The consequences of failure, and corresponding objectives of prevention, are examined before any preventive tasks are selected.

Understanding the consequences of failure and corresponding objectives of the maintenance strategy

Figure 2 shows the first step in the decision-making process. This ensures that for any preventive maintenance selected, the maintenance effort and cost is balanced against the severity of the consequences of failure.

Figure 2 - The Consequences of Failure and Maintenance Objectives



The Applicability of Proactive Maintenance Strategies

The RCM decision process guides the user through the choice of preventive maintenance tasks for each failure mode. ***Figure 3*** illustrates the process.

The sequence in which the tasks are selected is first on-condition, then rework, then discard. At each step there are criteria that make the task both applicable and effective.

Applicability relates to the most likely failure patterns associated with each failure mode, and effectiveness is a measure of the results that can be expected from the proactive execution of the task.

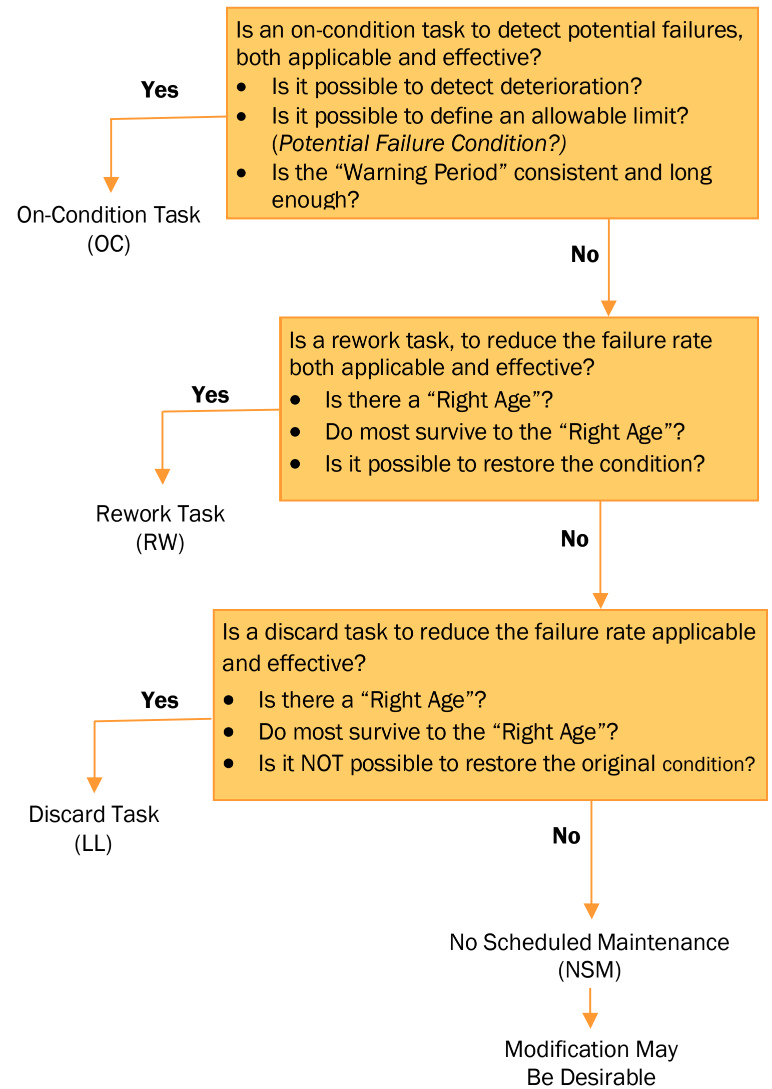
The Default Decision Process

For situations where little information is available, Nowlan and Heap provided a default answer to each question in the decision making process.

This has value where the failure patterns of specific failures may not be known, or we simply do not have real data to back our decisions.

In each situation, the default will steer towards safety and reduced risk, and in the worst case result in un-necessary scheduled maintenance which is not cost-effective.

Figure 3 - On-Condition, Rework, or Discard



Effectiveness and Cost-Effectiveness

Having selected a preventive maintenance task that is both applicable and effective, the task is then examined to see if it will be cost-effective in that particular situation. ***Figure 4*** shows the decision process for determining the cost-effectiveness of the task.

RCM provides a structured decision making process that:

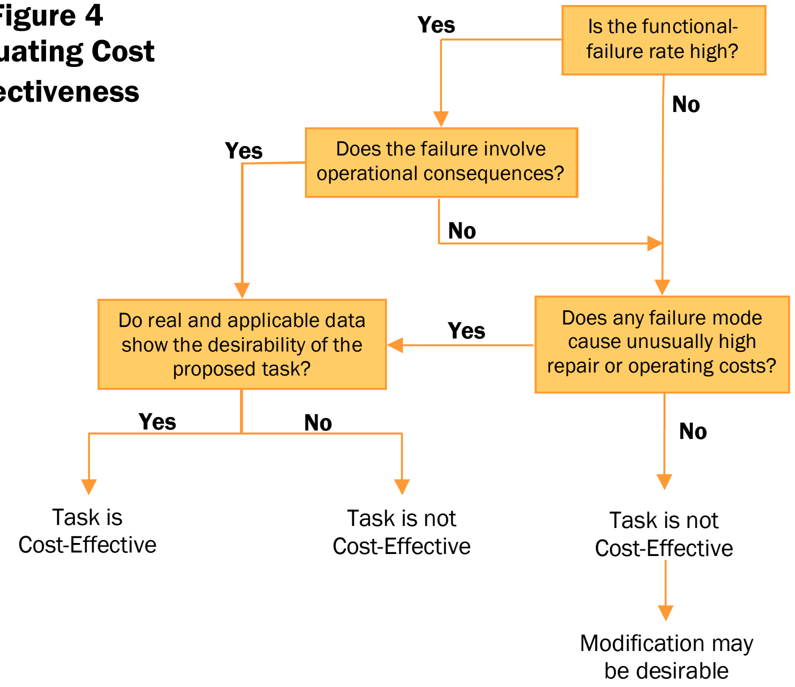
- Examines failures that may occur
- Determines what the failures' effect will be on safety and the operation
- Guides the analyst through the choice of preventive maintenance that is applicable to that particular failure based on the failure patterns expected and effective in preventing the results
- Examines the cost-effectiveness of the proposed task

In some cases the outcome may suggest that it is best to do nothing and simply live with the failures and their results. This would be true when there is no safety consequence or when the operational and repair costs associated with the failures are small.

On the other hand, in situations where the consequences are significant, or unacceptably high, a modification to the equipment may alleviate the problem. Modification or redesign can change the inherent reliability of the equipment by eliminating the possibility of the consequences.

For example, the simple addition of a standby unit could totally eliminate the possibility of a serious production loss, or reconfiguring a protection device so that it fails to safety could have the combined effect of eliminating the failure consequences, while at the same time making any scheduled maintenance unnecessary. Any proposed modifications would also be examined for cost-effectiveness where the consequences of failure are purely economic.

Figure 4
Evaluating Cost Effectiveness



RCM in the Real World - Some Practical Considerations

There is no doubt that a maintenance support strategy built on the Reliability-Centered Maintenance philosophy will provide a very sound foundation for any asset performance management strategy.

RCM principles and methodology provide the structure necessary to identify the content of a program that will maintain the capability of assets safely and economically whether the intention is to embark on a comprehensive, detailed, analysis or not.

In some cases it may be beneficial to perform a formal RCM analysis, but it is also possible to generate substantial improvements quickly by applying the ideas and process relatively informally.

Steel Pipe Manufacturer

For example, during work at a steel pipe manufacturer it became clear that a change in maintenance strategy was required if they were to meet their production targets and delivery schedule.

After making several improvements in equipment utilization and scheduling, they had become inundated with equipment failures and had reached a stage where they were behind in deliveries.

A relatively quick, informal analysis identified a substantial change in maintenance approach. For one, they realized that they did not need to repair everything. They simply needed to do what was necessary to keep running reliably between scheduled weekly maintenance service days. This new, clear view of the objective became obvious during the informal analysis and produced an inspection-based program to support more effective down days.

Combined with more effective planning and scheduling of the weekly maintenance service days, the company's reliability improved, and within one month they were ahead in production to service their deliveries. The result was an improvement of several million dollars in cash flow.

Candy Manufacturer

In another example, a candy manufacturer client of ours had moved more production into one of its facilities in order to streamline the operation. But after numerous improvements to operations, they were still unable to reach their production targets.

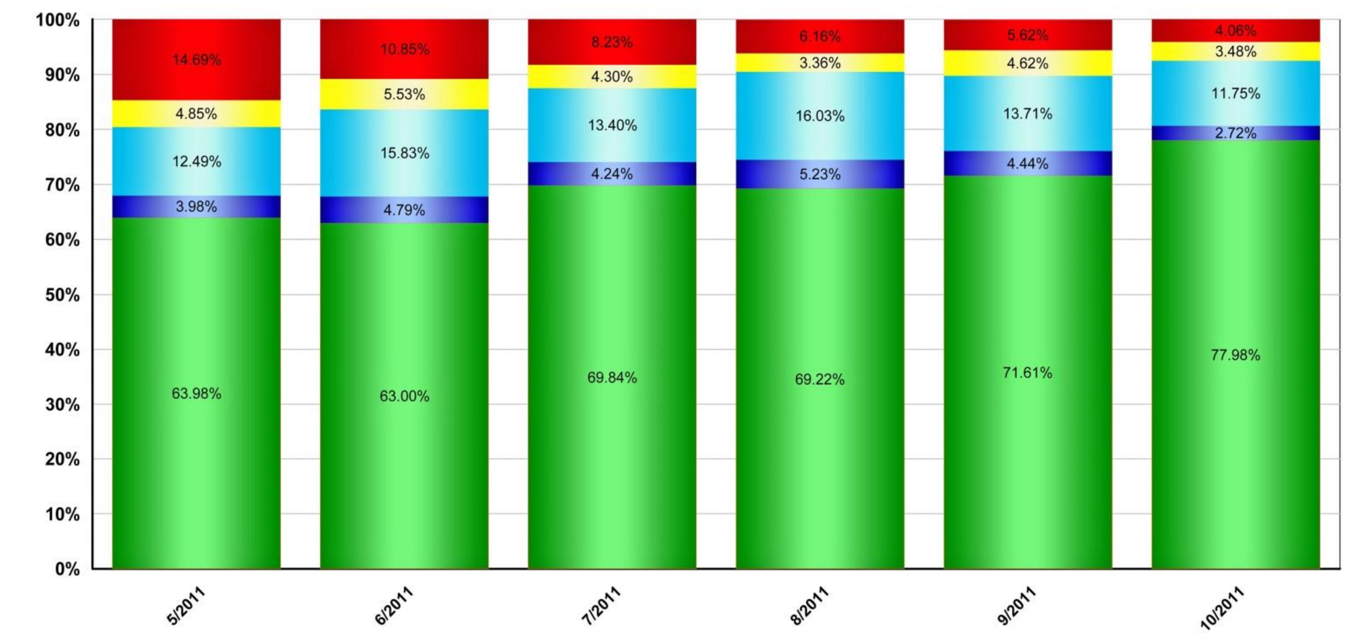
A significant source of the downtime came from failures of the moguls, candy manufacturing machines. A detailed study of the moguls and their failures resulted in a complete reconfiguration of the company's maintenance support strategy. The new approach combined an inspection-based program while the lines were running, with specific restoration tasks to be completed during sanitization and servicing breaks.

Although it took a while for the equipment to respond to the new strategy, there were slight improvements almost immediately. Within weeks they were able to achieve a 22% increase in productive operating time stemming from increased mogul availability.

Performance of moguls over the first six months of operation of the new maintenance support strategy.

The red bars at the top of ***Figure 5*** shows the steady reduction of downtime due to mogul failures over the first six months. The green at the bottom of the bars shows the steady increase in productive operating time over the same six months.

Figure 5
Candy Manufacturer- Mogul Uptime



Hours	May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11
Mogul Maintenan	245.54	194.97	114.13	93.42	65.70	43.57
Non Mogul Maint	81.03	99.47	59.58	51.02	54.02	37.33
Mogul Operationa	208.83	284.50	185.77	243.18	160.23	126.00
Non Mogul Oper.	66.60	86.17	58.75	79.38	51.88	29.18
Available Hours	1,069.49	1,132.65	968.27	1,050.42	837.17	836.09
Operating Hours	1,671.50	1,797.75	1,386.50	1,517.42	1,169.00	1,072.17

...In Conclusion

Reliability-Centered Maintenance is a maintenance philosophy that includes a systematic approach to determining how to maintain equipment safely and economically.

RCM is an invaluable business solution for companies with production-related assets and has become a foundation for asset performance management by identifying the best maintenance activity for each type of equipment failure.

In situations where equipment failure is inevitable, the structured RCM process will ensure a maintenance strategy that will minimize or eliminate the consequences.

The central problem addressed by the RCM process is how to determine which scheduled maintenance tasks, if any, should be assigned to equipment, and how frequently. The decision diagrams guide the program designer through the process. The outcome is a structured, systematic blend of experience, judgment and operational data to identify preventive tasks that are both applicable and effective.

In situations where the consequences are purely economic, the cost-effectiveness analysis process will minimize unnecessary maintenance expense, and the default strategy provides confidence where data and experience may be lacking.

The RCM process recognizes the partnership between maintenance and design, acknowledging modification as an important alternative to eliminating consequences where maintenance cannot, resulting in a maintenance support strategy that is centered on realizing the inherent safety and reliability capabilities of the asset, and in alignment with the company's business objectives and strategies.

About Gary Dobson

The past two decades have taken Gary to seven countries on three continents where he has developed a formidable record of success in a wide range of industries. His expertise includes the application of Reliability-Centered Maintenance for improving maintenance and reliability strategies, and the use of advanced Critical Path Techniques for managing industrial outages and refurbishment projects.

He is well versed in traditional and emerging methodologies, and has worked extensively with various client technology systems including Oracle, JD Edwards, DataStream, and SAP. He has developed custom software for both web-based systems and hand-held devices.

Gary has an engineering degree and 25 years of international consulting experience in the area of maintenance and reliability. And is the Asset Performance Management Practice Leader at USC Consulting Group.

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