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Maintenance Is Really **NOT** the Problem

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Contents

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ON THE COVER
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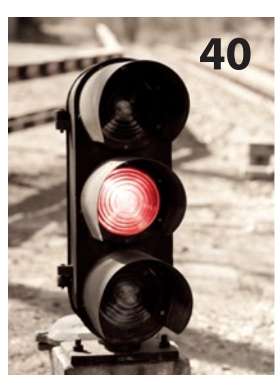
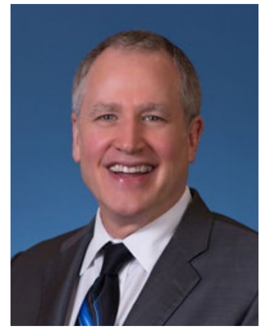
Features



Elements

Editorial



Being a Reliability Leader

The 941 Certified Reliability Leaders that have taken the journey know there are two parts of the process required to master reliability leadership.

The first part is about **learning and knowing** the Uptime Elements Reliability Framework and the second part is about **being** a reliability leader and practicing the effective exercise of reliability leadership.

All things that can be mastered begin with the acquisition of a ***specialized language*** that contains words, concepts and ideas. An example would be a doctor in medical training studying the specialized words, phrases and concepts related to the practice of medicine.

At Ross University School of Medicine, they provide the following advice to medical students: *"Clear use of language is essential for communication with both colleagues and patients—you cannot succeed as a physician without a good command of language. You are about to start learning a new language, the language of medicine. The more you think about what words mean,* ***the more fluent you can become and the more effectively you will be able to think in this new language****. Your task as a medical student will be much harder if you do not pay close attention to language, both technical and non-technical."*

Another example is a musical student, who begins by learning the musical words and phrases that express the concepts involved with performing music.

A Pennsylvania Academy of the Fine Arts instructor relates this musical mastery of wisdom: *"So, what is the goal of a music education? I would say to* ***communicate*** *musically or, in other words, to learn and speak the* ***language*** *of music. Using the word language in this context does not refer to reading the written musical language (although that is good), but instead means speaking a language in the broader sense of understanding, as well as communicating the grammar, vocabulary and syntax so that* ***ideas*** *and* ***creativity*** *can be shared.*

"Music begins as an elegant and simple system that is rooted in physics and nature, these natural physics are expressed in our musical system, from the design of our instruments to the names of the notes, and these elements are essential to a functional and growing understanding. ***This may begin to sound like a lot of book learning and not a lot of just playing music and having fun, but, in fact, it is exactly about 'playing music' as well as enjoying the creative process. For that to happen, a teacher must be equipped with a fluent and vernacular command of that language."***

These examples of learning the language of medicine and music are what we call **learning and knowing** and they are as important as the practice of reliability leadership itself. We could say this is the world of reliability leadership ***as known***.

Although a medical student, musical student, or reliability leader student may master the specialized language, that does not give them access to ***being*** a doctor, a professional musician, or a reliability leader. To ***be*** a doctor, professional musician, or reliability leader requires more than knowledge; it requires the individual to discover how to dwell in the world being mastered. This is especially true for reliability leaders.

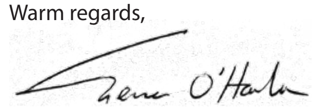
To **know** about being up at bat in a major league baseball game is VERY different than **experiencing** being at bat in a major league baseball game.

In our work, we have found that actually creating reliability leaders – rather than transferring knowledge about reliability leadership – requires the use of methodologies and techniques that are different from those generally employed in commercial training related to asset management, reliability, or maintenance.

I hope we can find a way to work with you to expand this important work. We are committed to our mission of discovering and delivering ways to make asset managers, reliability leaders and maintenance professionals safer and more successful.

The pages of this *Uptime* Magazine edition represent some of that work ***as known***. Perhaps, we will get a chance to collaborate with you directly in 2016 or 2017 to represent the work ***as lived***.

Warm regards,



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Leadership for Reliability

RELIABILITY®

IN THE NEWS

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Reliabilityweb.com is Traveling to These Upcoming Must-Attend Events!

RELIABILITY LEADERSHIP INSTITUTE presents The IIoT Summit

The Industrial Internet of Things (IIoT) Summit

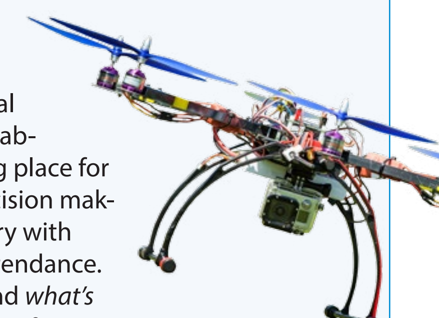
Reliabilityweb.com and PTC (a global provider of technology platforms and solutions, including the technology platform, ThingWorx®) have teamed up to present the Industrial Internet of Things (IIoT) Summit in Fort Myers, Florida on August 2-3, 2016. This interactive workshop will bring together IIoT thought leaders to discuss key topics relevant to the delivery of solutions, while also helping asset owners and operators better manager their critical infrastructure.

Internet of Things World Congress

Reliabilityweb.com will be attending the Internet of Things World Congress in Barcelona, Spain on October 25-27, 2016. This gathering is the largest global event focused exclusively on the Industrial IoT.

Presented by Fira Barcelona and the Industrial Internet Consortium, this event brings together over 8,000 attendees, 200 speakers and 140 exhibitors for three days of academic conferences and exhibitions, including live Testbeds.

Drone World Expo



Drone World Expo (DWE) is known as the defining event for commercial applications of UAS technology. Established in 2015, DWE is the gathering place for thought leaders, end-users and decision makers in the commercial drone industry with more than 2,100 stakeholders in attendance. The event showcases *what's now* and *what's next*, defining the business landscape for individuals and companies looking to leverage the technology. DWE is held in San Jose, California on November 15-16, 2016.

Reliabilityweb.com is excited to be a part of this special event!

Reliability World Caribbean

Reliability World Caribbean unites reliability and maintenance professionals from the Caribbean and Latin America. The 10th edition will be held September 15-16, 2016 and hosted by Bacardi Corp at their manufacturing plant in Cataño, Puerto Rico. The event will feature Reliabilityweb.com's Terrence O'Hanlon and will include the Certified Reliability Leader Workshop and Exam.

Seeking innovative and energetic presentations for **The RELIABILITY Conference** (TRC) co-located with **The Internet of Condition Monitoring** (IoCM) Summit, April 24-28, 2017, in Las Vegas, Nevada. Submission deadline: August 31st.

TRC-2017

Best known for its broad range of case studies focusing on the elements of asset performance, resulting from reliability and asset management. This year's theme: Creating a Culture of Reliability®.

IoCM-2017

This educational and networking event encompasses the latest information on the Industrial Internet of Things (IIoT) wireless sensing, predictive analytics, cognitive computing, remote monitoring and cloud-based asset condition management and predictive maintenance.

reliabilityconference.com

Northern California (NoCal) AMP Chapter Launch

The Association of Asset Management Professionals launched its first U.S. Chapter. The event took place July 25th at the NASA Ames Conference Center in Moffett Field, California. NoCal Chapter members were treated to a tour of the world's largest wind tunnel, as well as a half-day CRL training and the inaugural chapter meeting where roles and responsibilities were introduced.

A Special Welcome to Joel Levitt

Bestselling author, Joel Levitt, has joined the Reliabilityweb.com team as Director of Leadership Projects for the Reliability Leadership Institute. Joel will focus on expanding capabilities for the Uptime Elements™ Reliability Framework and continually improving the Certified Reliability Leader management system. In addition, he will facilitate CRL workshops and training courses.

Maintenance TIPS

Have You Considered Making the Internet of Things Part of Your Asset Performance Strategy?

Like it or not, the Industrial Internet of Things (IIoT) is changing the way you use information, which means it is changing the way you make decisions. Are you ready for it?

The IIoT makes getting good asset information urgent, which means you need to start planning now. As volumes of data grow, how will you manage to make decisions on proactive corrective actions required to keep your assets running safely and reliably? For better asset performance, and better operational control, IIoT is an opportunity to make better information-driven decisions. In fact, the IIoT has the potential to make our everyday work lives better – for maintenance professionals, reliability leaders and asset managers.

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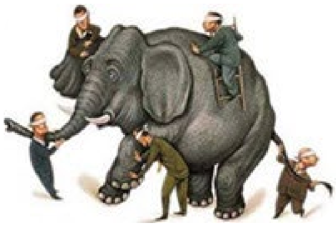
Cooperative Development of Reliability Based Maintenance



When plant or corporate management states a goal, such as "Maximize Equipment Reliability," successful realization of that goal requires the existence of some alignment between the personnel responsible for implementing processes and executing tasks necessary to realize the goal. Often, though, the Reliability Manager, the Maintenance Manager, and the Production Manager visualize very different models of success. They therefore follow different, perhaps incompatible, paths intended to reach the goal. Enterprise Asset Management (EAM) processes, such as Reliability Based Maintenance (RBM), are absolutely necessary in order to orchestrate all activities related to goals that affect more than one department.

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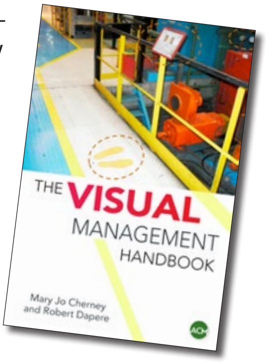
Pressure Gauges Instant Checking

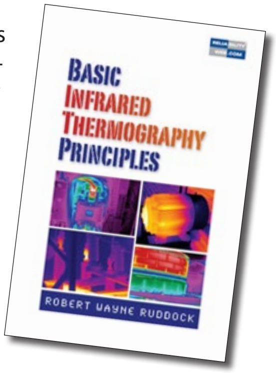


Similar to fluid level indicators, a green and red zone marked on a gauge allows instant checking for compliance without the need to know figures, which have been defined by experts beforehand. Caution! When maintenance has to replace one of these gauges, they should have the zones written down in their standards to ensure the new one is correctly marked.

Mary Jo Cherney & Robert Dapere
The Visual Management Handbook
www.reliabilityweb.com/bookstore

Radio Waves

Radio waves are produced by electrons when they are agitated. The radio band of the electromagnetic spectrum is from 100 kilometers down to 0.1 centimeter.



All objects in the universe give off radio waves, as all objects are above absolute zero (-459ºF). Radio telescopes are one of the main tools used by astronomers today. They have given us a great deal of the information we now have about the universe. By analyzing the radio waves given off by celestial objects, scientists have been able to determine features, such as the surface temperature, of many planets.

In addition to naturally occurring radio waves, there are many forms of manmade radio waves.

In 1886, an American dentist, Mahlon Loomis, sent the first wireless telegraphy between two kites.

In 1893, Nikola Tesla, in St. Louis, Missouri, demonstrated wireless radio signals and filled a number of patents.

Guiglielmo Marconi used Tesla's patents and began to develop a radio system in 1895. He was the first to send a telegraph signal (a form of radio wave) in 1896. In December 1901, Marconi successfully conducted an experiment in which the first transatlantic radio signals were sent and received. The first broadcast of the human voice took place in 1906 in Massachusetts.

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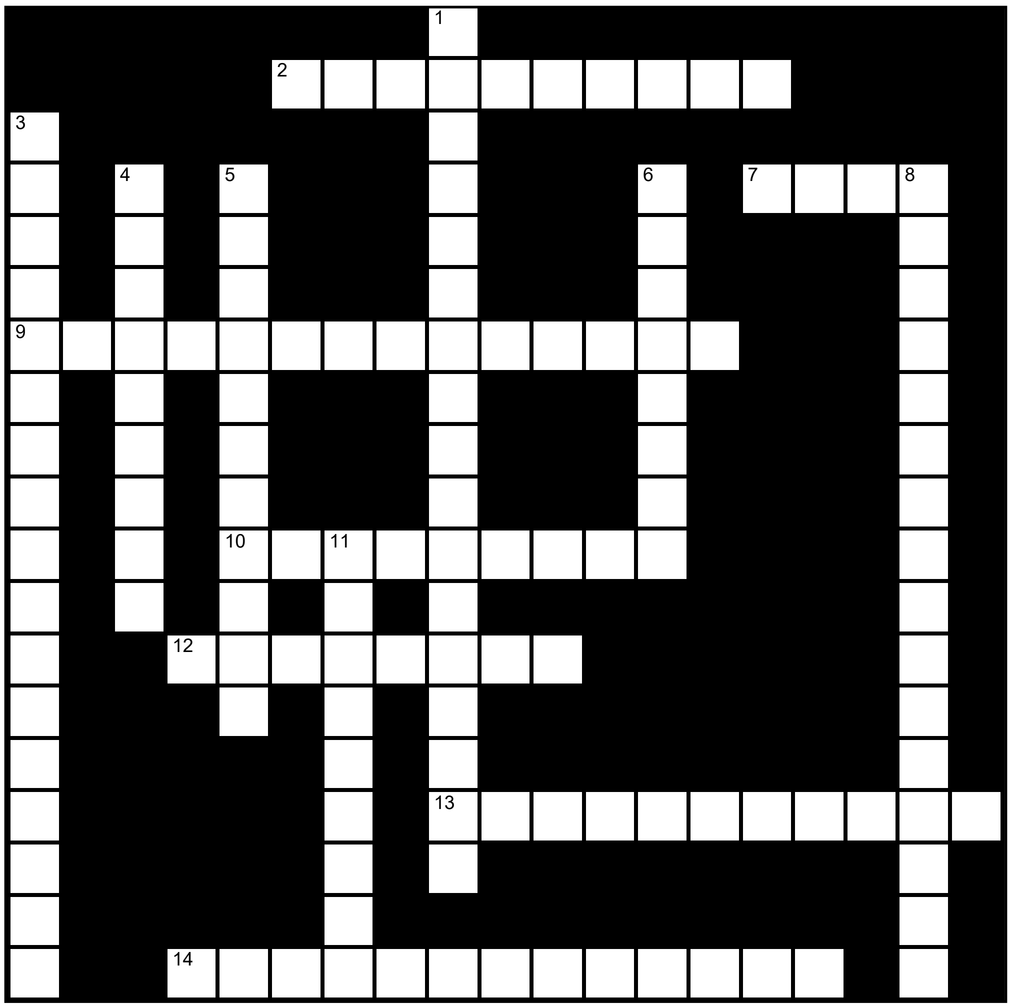
Crossword Puzzle

Created by Ramesh Gulati



ACROSS

2. A person or group of people who have the total responsibility for the operation and maintenance of asset(s), including capital improvements
7. A Japanese lean word for overburden or unreasonable work
9. The fitness of an asset to perform its intended function effectively and efficiently without being degraded while protecting health, safety and the environment
10. Any substance interposed between two surfaces for the purpose of reducing friction and/or wear between them
12. An established norm or requirement generally presented in a formal document that establishes uniform technical criteria, methods, processes or practices
13. A predictive maintenance technology used to determine the quality of the lubricant oil and/or condition of equipment being lubricated
14. A safety practice to ensure an asset is inoperable, safe and properly tagged when it's down for inspection or being repaired

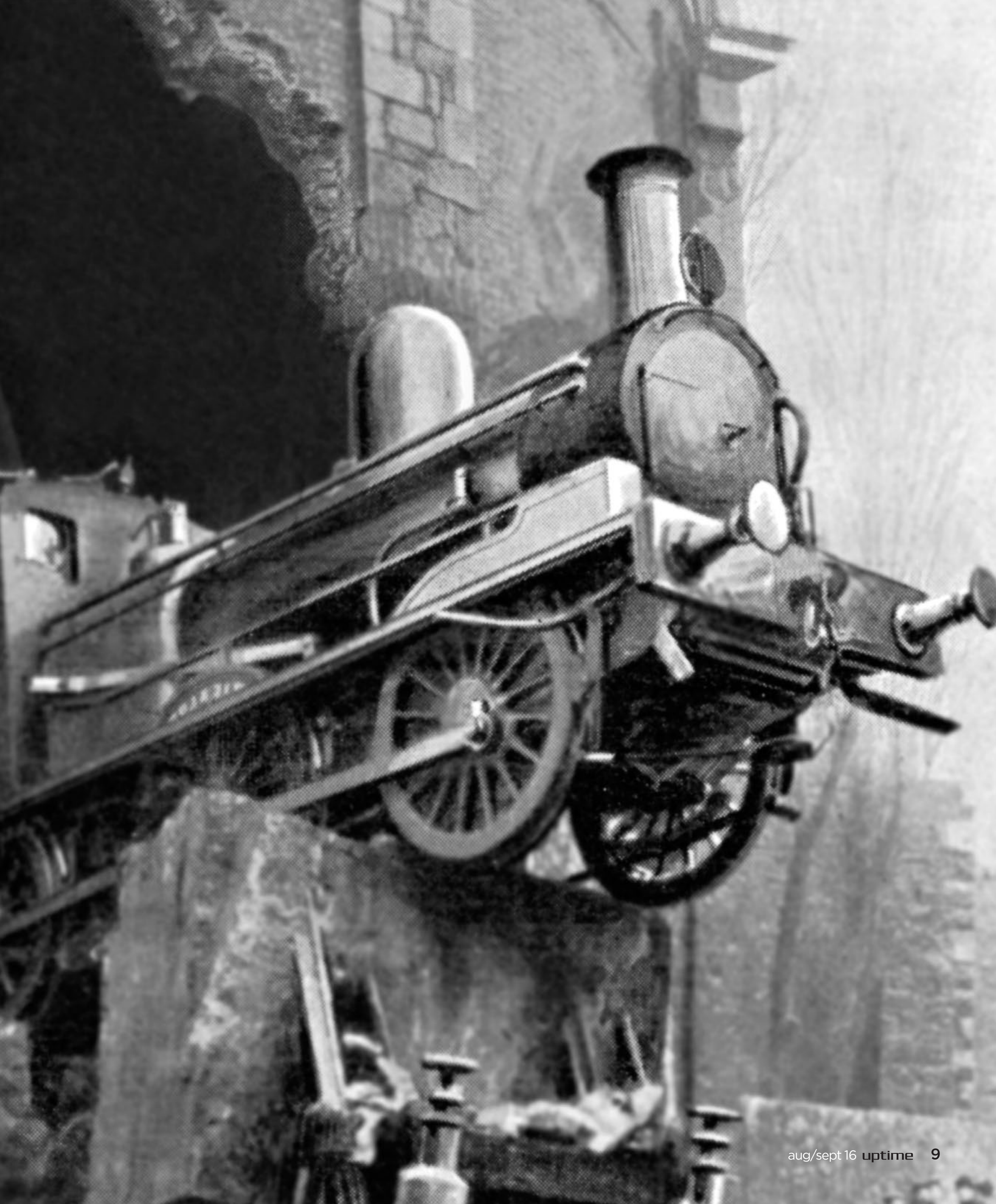
DOWN

1. The identification of a defect - nonconformance and its removal
3. Anyone who helps another person, a machine or a gadget to do a better job to improve reliability
4. An arrangement where an external organization performs part of an organization's function or process
5. A ranking of assets according to potential operational impact
6. A condition in which one of the feet on a machine does not sit flat on the base - the foot or base may have been damaged causing misalignment and initiating vibration when tightened
8. Network of physical objects, such as devices, components or machines, using embedded technology to communicate with each other with minimal human intervention
11. A standard measurement or reference that forms the basis for comparison

See page 64 for answers.

Maintenance Is Really NOT the Problem

by R. Keith Mobley



In late May, *Uptime* Publisher Terrence O'Hanlon posted on LinkedIn that attendance at maintenance conferences has dropped significantly. Responses to his post offered plausible reasons, including budget constraints, lack of or recurring content, and total saturation. While these are no doubt contributors, there may be one more growing reason for this decline: more and more organizations are finally recognizing that maintenance is not the source of their competitive or financial problems. This article provides proof for why this reason may be on point.

> "One operator can wreck a machine faster than 10 maintenance technicians can repair it"

Fifty years ago, many were convinced that maintenance was at the center, if not the entirety, of the problems that plagued industry. Because of this belief, the focus was on building world-class maintenance organizations. Success followed success and the number of companies able to achieve and sustain world-class maintenance grew significantly. The problem was, and still is, that having a world-class maintenance program is not enough. Perhaps it's time everyone acknowledged the truth about maintenance and its role in both plant performance and reliability.

First, effective maintenance is essential and no one should suggest otherwise. It is also true that most maintenance organizations are far from world-class. But, you need to look deeper to glean the reasons for their failure. You must recognize and acknowledge that all asset failures and downtime—regardless of the forcing function—result in higher maintenance costs and a flurry of maintenance activities to repair them. Always remember the old adage that one operator can wreck a machine faster than 10 maintenance technicians can repair it. It's true!

There are many reasons why maintenance fails to sustain world-class performance. The most common are insufficient budget, insufficient time, lack of management support and poor maintenance management. Only the last one is controllable by the maintenance organization.

Asset failures are not the only external force that drives maintenance efficiency down and cost up. Maintenance is frequently called upon to provide labor and budget to support operations and underfunded capital projects. This drains maintenance's resources and budget, hampering the ability to perform sustaining maintenance. On average, maintenance organizations give up 30 to 40 percent of their budgets and labor hours to these non-maintenance activities. Unfortunately in traditional plant cultures these external drains are not controllable by maintenance management. Expectations for cross-functional support are created by executive management and enabled by a broken organizational structure, neither of which can be corrected without a broader, non-asset definition of reliability.

Finally, maintenance does not control its own destiny. It is dependent on other plant functions that must effectively cooperate and coordinate their activities with those of maintenance. The more critical relationships include production, which controls the downtime for sustaining maintenance; procurement and materials management, which ensure the proper parts and materials; engineering, which ensures configuration control; and human resources, which provides the skilled technicians. All of these depend on executive management, their strategic business plan, and the sales and marketing functions that provide the manufacturing backlog that drives everything. In truth, the sales function is the tail that wags the dog. If it provides a consistent backlog of standard products, normal lot sizes, reasonable lead time and a profitable price, a reliable plant is achievable. If any of these variables change, the entire plant, starting with the production schedule, must react to the variance—forcing the entire organization to become reactive. For all of these reasons, the majority of plants evaluated over the past decade are undermaintained because of the first two reasons and enabled by the latter.

What too few organizations understand is that even world-class maintenance will not resolve the performance and financial issues that most plants endure. Take an honest look at what the transition from highly reactive to world-class maintenance would do to improve overall plant performance. If one looks at maintenance cost, the results would be eye-opening. First, it should be based on the maintenance required to sustain asset reliability over the assets' useful life. Depending on the industry, sustaining maintenance requires 400 to 1,100 hours per year of planned downtime, plus the time required to perform in situ preventive maintenance tasks. This level of maintenance is an investment that is absolutely essential to business. Yet few plants meet this criterion. As a result, any attempt to improve maintenance effectiveness will require a significant immediate investment, typically 12 to 18 percent of current maintenance expenditures, to return undermaintained assets to maintainable condition and an increase in annual expenditures to provide minimal sustaining maintenance for the remaining life of the assets and plant. Rather than reducing labor and materials costs, most plants will need to increase them to have any assurance of asset reliability.

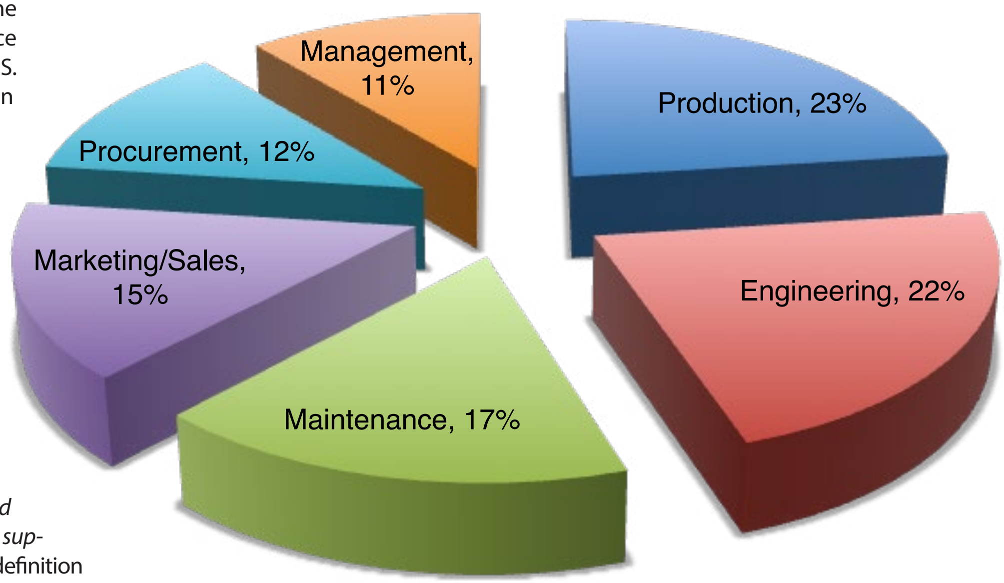
Even though maintenance expenditures may seem high, in a typical organization total maintenance costs, including contract services, are less than five percent of the total cost of goods sold (COGS) and in a world-

class organization, less than two percent. Therefore, from a pure cost standpoint, maintenance is a minor contributor. In addition, the difference between the costs in a reactive versus world-class maintenance organization is, at best, two to three percent of COGS. The change is so small that it has minimal impact on competitive costs. One could zero maintenance costs—not a good idea—and it would still not be enough.

Maintenance has a reliability role, but it is not what many assume. First, one needs to define reliability. When presented with reliability, most think of physical assets and too often in engineering terms, such as mean time between failures (MTBF), mean time to repair (MTTR), etc. But much more is required before a business, plant, or organization can be considered reliable.

By definition, a business, plant, or organization must be consistent—*able to maintain established (world-class) standards or repeat all requisite tasks to support those standards with minimal variation.* Yes, this definition applies to maintenance, but it must also apply to all other functions in the organization before the organization can be considered reliable. Reliability starts with a viable strategic business plan, effectively executed by marketing and sales, and then cascades down throughout the organization. Only when all functions and all employees are able to consistently maintain world-class standards in all business and work processes, procedures and practices can an organization be called reliable.

Asset Reliability Losses



> **The absence of enforced standardization in all processes, procedures and practices throughout the organization is the real root cause of reliability issues**

So, if maintenance is not the problem, who or what is? One trait shared by all non-world-class plants is instability. Instability is caused by inconsistencies in decision-making, planning, scheduling, execution and measurement of all business and work activities—not just maintenance—from the boardroom to the factory floor. The absence of enforced standardization in all processes, procedures and practices throughout the organization is the real root cause of reliability issues, including those exhibited as asset failures and high maintenance costs. To be reliable, all organizations must eliminate variability and its resultant instability across the entire organization, not just maintenance.

Data compiled between 1985 and 2015 confirms the asset reliability outcome and functional distribution of this instability. The data shows that only 17 percent of asset reliability issues result from maintenance deficiencies.

The dominant reason for asset reliability losses is the inherent weaknesses in the asset's design, compounded by years of undocumented, uncontrolled changes and modifications. All assets have inherent weaknesses that are either not understood or ignored by the design engineers or vendors. These weaknesses predetermine the asset's reliability and 95 percent of the asset's total cost of ownership. The absence of a viable management of change process has, for decades, permitted unlimited, uncontrolled changes and modifications. At 22 percent, this is the largest contributor to chronic asset reliability problems. It should be obvious that, at best, maintenance can only become better at reacting to these problems because it lacks the means to correct them.

The 15 percent contribution of the marketing and sales function is misleading because at least one half of the 23 percent attributed to production is driven by the composition of the incoming backlog generated by sales. When combined, at least 27 percent of the asset reliability problems are attributable to them.

The remaining 12 percent attributed to production stems from instability in the mode of operation, ranging from scheduling to execution of recurring operator tasks (e.g., start-up, changeovers, shutdowns, etc.). In most plants, a quick look at the output shift-to-shift and day-to-day clearly shows just how radically operations vary. Operating inconsistency is the most significant contributor to lost capacity, revenue and operating profits.

As proven, reliability is not a maintenance problem. Yes, maintenance should be included, but a world-class maintenance function does not make a world-class plant. A world-class maintenance function will not improve reliability in its holistic definition. A world-class maintenance organization cannot improve asset reliability. Asset reliability is a design function and the best that maintenance can do is maintain inherent reliability.

Keith Mobley *is Principal SME for Life Cycle Engineering. He has earned an international reputation as one of the premier consultants in the fields of organizational performance optimization, reliability engineering and effective change management. He has more than 50 years of direct experience in corporate management, process optimization and reliability engineering. For the past 25 years, he has helped hundreds of clients worldwide achieve and sustain world-class performance. www.lce.com*

How to Develop an Industrial Internet of Things Solution

by Tomasz Puk

Phase 1: Providing a Solution

As a follow-up to "How to Develop an Industrial Internet of Things Solution" in the Feb/March 2016 issue of *Uptime* magazine, this article introduces a series that provides further details about the approach to develop Industrial Internet of Things (IIoT) solutions. The series of articles is based on first-hand experiences of designing, developing and delivering (IIoT) services.

Each of the three articles will be dedicated to the three phases of the IIoT product lifecycle.

1. **Providing a Solution –** Starts with a new product idea and is focused on evaluating market potential for a new product concept, as well as understanding technical and managerial aspects behind developing it.
2. **Research and Development –** Focuses on the development of the product, its components and subsequent product releases. This phase is also used for further mastering of the business model and evaluating intermediate product versions with clients.
3. **Service Delivery –** Starts at the moment the first product version is made available to clients. The goal of this phase is uninterrupted delivery of the service and providing value to clients and users.

Providing a Solution

This first article focuses on the providing a solution phase. So what is this phase all about? Well, many will say providing a solution is the most important of the product lifecycle phases. This is the phase where you must verify if your product idea matches what the market expects. You have to create a shared product vision and its prototype and, finally, you need both technical and managerial plans for the development and delivery.

Unlike the old approaches to product development, you don't need to spend too much time in this phase, around three months should do. That's because the new process assumes several iterations along the whole IIoT product lifecycle, so just spend enough time here to make an informed go/kill decision. To learn more, a good reference is *The Four Steps to the Epiphany* by Steve Blank.[1]

The iconography in Figure 1 presents the major steps specific to the providing a solution phase. Starting with the people and their roles, roles are usually divided into two team profiles: product and engineering.

PRODUCT TEAM	ENGINEERING TEAM
Product Manager	Project Manager
Sales	Business Analyst
Marketing	Architect
Business Development	UI/UX Designer
	Developers

Both teams need to work very closely together; it is crucial for working out a solution that is justified from both the business and engineering perspective.

Figure 1: Main activities in the providing solution IIoT product phase

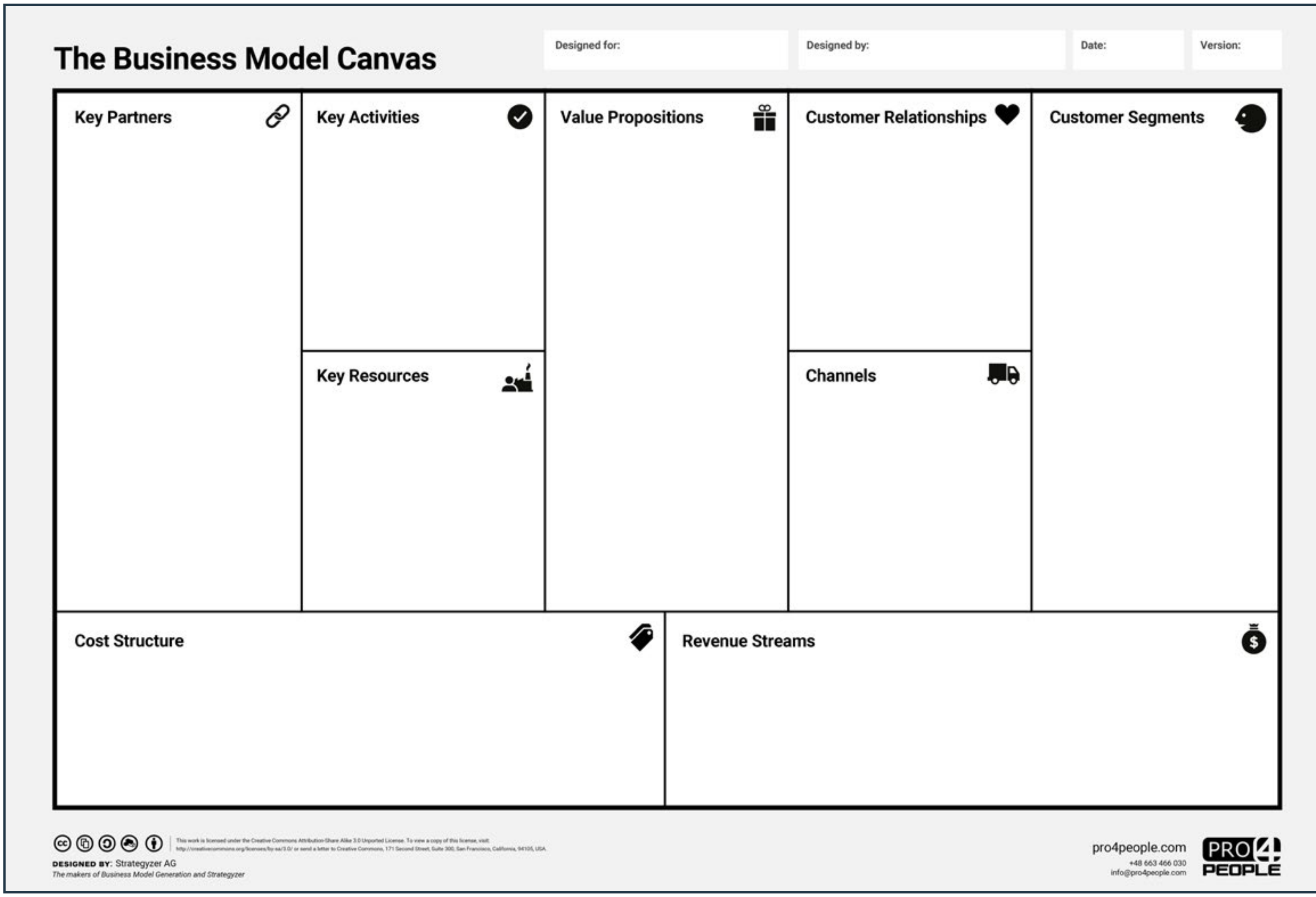


Figure 2: The business model canvas template[2]

Business Model and Value Proposition

The business model and the value proposition are the most important components in the providing a solution phase. Two good tools to use are the business model canvas and the value proposition canvas proposed by Alexander Osterwalder. They usually take the form of a multi-day workshop focusing on the business model and value proposition. It is a great exercise in forging a common product vision, challenging it and sharing with the whole team.

In addition to these canvases, a documented hypothesis on your product, customers, channel/pricing, demand creation, market types and competition should be the outcome of such a workshop. For that purpose, you can use the customer discovery templates from *The Four Steps to the Epiphany*. The participation of the whole product team and representatives of the engineering team is required in order to share the product's vision.

You might think you're done when you have everything documented, but not really. The business model, value propositions and your hypotheses will be the most often challenged, updated and modified parts of your product lifecycle documents. Think of these documents as a good, solid starting point to hold direct meetings with your customers and initiate the customer development process. This ongoing activity, which should be executed along all IIoT product lifecycle phases, is represented by the spiral in the Figure 1 iconography.

Solution Architecture

When you have your product vision documented in its first version, it's time to start working on the IIoT architectural solution. The goal of preparing a solution architecture is to propose how the product vision will be implemented in a technological dimension. Within the solution architecture, you will have to find answers to these questions:

Edge Devices: What type of devices will be used? Does the solution use sensors, meters, or actuators? Are you going to use one of the existing edge devices or build your own? What is the cost of such a device? Will it be running off batteries or the mains? How long is the device going to be running off batteries? What protocol will be used for communication with the backend system? How will the user perform its installation and configuration? Is the hardware device firmware going to be updated along its lifecycle? What security measures does it require?

Connectivity: What type of connectivity will be used to enable the edge device to communicate with the backend application? What is the security of the selected channels? What is cost of the selected channels (e.g., SIM card, Wi-Fi router)? Does the connectivity require any intermediate device, such as a gateway or mobile phone? What is the reliability of the selected channel? How much energy of the edge device's batteries is consumed by the communication system?

Backend (Internet Services): Where is the data from the edge devices sent (e.g., cloud service or client deployed service)? Is there a separate backend application for each client (a single tenant) or is the data separated within one system (multi-tenant)? After what time will clients expect the processed data to be available? How long should this data and information be stored and available? What is the backend application infrastructure cost? What effort does it take to make the backend application operational (service delivery)?

Frontend (Web Browser Application): What authentication/authorization is required? How do clients access data from the backend? How can they access the data and information? How will the data and information be presented? What web browsers are going to be supported? What other devices (e.g., mobile devices) will be used to access the data? What different levels of privileges should the users have?

Mobile: Which mobile clients will be used to access the data (e.g., iOS, Android, phones, tablets)? Are mobile clients used to execute preliminary configuration of the edge devices at the installation site (e.g., Wi-Fi configuration or parameter setups)? How is the mobile application presenting the dilemmas of asynchronous communication between edge devices and a mobile application?

These are just a few of the questions for which the architecture should provide the answers. It does not have to be 100 percent ready, but it should be detailed enough to enable the project manager to break down each architectural decision into a work package so the engineering team can start working on the first prototype.

You must verify if your product idea matches what the market expects

Technology Selection

Technology selection is another important activity in the technological dimension. Its goal is to provide a short list of technologies – a technology stack – to be used in the project. Since at this moment you already have a product vision documented in the business model and the related document and the solution architecture, you can choose those technologies that will meet such requirements.

With a conscious selection of the right technologies, you can significantly lower infrastructure expenditures, speed up development, as well as bring down its cost. Usually, these technology issues need to be addressed:

- Programming language and the technology stack for the edge device;
- Infrastructure as a cloud service provider;
- Backend programing language and the technology stack;
- Relational databases for storing processes information;
- NoSQL databases for storing a large amount of data;
- Desktop client programming language and technology stack;
- Mobile client programming language and technology stack;
- Development and continuous integration environments;
- Automatic testing technologies.

It should be stressed that nowadays there are a lot of mature and reliable technologies, such as database servers and development environments, that are free of charge. They are mature enough to be used for your product development without spending up-front licensing or infrastructure costs at this point. Another advantage of specifying the technology stack is the possibility to select an external software development company with the competencies aligned with your technology stack selection.

Program/Project Initial Planning

OK, you have a product concept, solution architecture and a technology stack. Now it's time to turn them into a plan of actions that will take you from where you are to the go live or product launch milestone. As you may have already concluded from the previous paragraphs, there's a lot of work to do. You will have to start a program that coordinates these projects:

1. Edge device development;
2. Backend/web applications development;
3. Mobile application development;
4. Building a service delivery team.

For this, you will need a project/program manager on board. A program management plan (PgMP) and project management plans (PMPs) should be prepared. The accuracy of the software development schedules and effort estimations will be quite low at this stage, but you still need these calculations to make an informed go/kill decision. Integration of all the projects is a very important aspect of the program/project planning. You will have three engineering teams working in parallel on the components of a single solution. Their integration should be the priority from the very first days of the project.

Another outcome of this activity is a high-level product road map for the program's duration. It should be more detailed for the next quarter. This will enable your development teams to start working efficiently while you are preparing further details with the product team.

User Interface/User Experience Concepts

User interface (UI) and user experience (UX) concepts are the first activity on the third main stream of the solution providing phase. The goals of this stream are to build a life prototype that will be used to verify client interest in the solution, check the technical feasibility of the assumed solution architecture and convince the business stakeholders to invest in the IIoT solution.

During this phase, users will be interacting with quite complex technical solutions. At the same time, you want to make the technology totally transparent so they can focus on the purpose of using the IIoT system (e.g., monitoring a pump's performance). Users will be interacting with various elements of the system, including:

- An edge device – installation, configuration, status identification;
- A mobile device – initial configuration, data/information feeds, notification;
- A web application – reports, summaries, complex tasks.

The purpose of the UI/UX work is to design and implement the system in such a way that users are guided all the time through various scenarios of using the system and can understand and use the system for their business purpose. It is not as easy as it sounds. There are some major challenges for the IIoT systems, such as asynchronous communication. What is that? Here's an example: With a traditional lightbulb, when you switch the light on, it lights up immediately. But to do the same with a mobile application and an intelligent lightbulb, it may take some time because of the communication schema/delay. You need to design the application in such a way that this approach is clear to users. It gets even more complicated if your measurement device communicates with the backend system only twice a day, for example.

So this gargantuan work starts right here, just a few moments before your solution prototype development.

Prototype Solution/ Prototype Evaluation

It is the prototyping that differs the most modern IIoT development from old product management principles. With the current technology status, maturity of the available technology stacks and ready to use hardware and cloud platforms, there should be no problem with launching a first product prototype in around three months. You already have taken part in the projects where the first working systems were presented after three months or even four weeks if a backend solution was already available.

The goal of this activity is to verify your technology providers, but most of all, present the live and working solution prototype to customers and gather their feedback on your product concept. From that moment on, the business model and product concept should be the subject of continuous adaptation and readjustment to market needs. You should work with your clients on the working prototype to verify that the assumptions you made about the product really resonate with client expectations.

Go/Kill Decision

Finally, you have come to the end of the solution providing phase. You should invite your IIoT program sponsors and both the product and engineering teams as you present the outcomes of the providing solution phase, the business model, value proposition and all hypotheses made about the product, together with the market research. Next, explain what the solution architecture is going to look like, what technologies were selected and how that will impact the final cost of the overall IIoT solution.

Present the live solution prototype proving the technological feasibility of the solution, along with the testimonials from the first meeting with clients when presenting the working prototypes.

Last, but not least, present the program and project plans, including the time, cost and resources required to execute the program.

If you have done your job well, it should be enough to take your product team to the next phase – research and development, starting with the "Go To Development" gate. If you failed, don't worry. IIoT will surely come with another project to your organization and you have just gained a lot of experience to get ready for it.

Interested in learning the next steps? Be sure to read the upcoming article, "How to Develop an Industrial Internet of Things Solution Phase 2: Research and Development."

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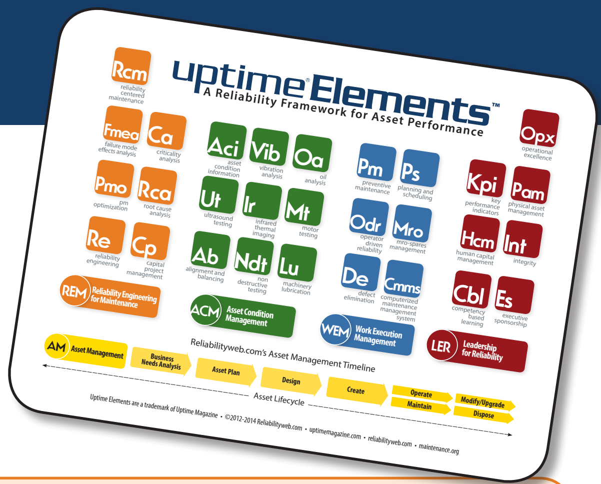

An aligned eco-system of service companies and training companies are now offering deeper support for your reliability journey. They not only support the Uptime Elements framework, they are practicing Certified Reliability Leaders.

REM – Reliability Engineering for Maintenance

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ACM – Asset Condition Management

lelubricants.com | ludeca.com | sdthearmore.com | theultrasoundinstitute.com

WEM – Work Execution Management

armsreliability.com | emaint.com | nexusglobal.com | peopleandprocesses.com | consultpsa.com | sdi.com

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From Screwdrivers to Testers: Vibration Analysis Comes of Age

by John Bernet

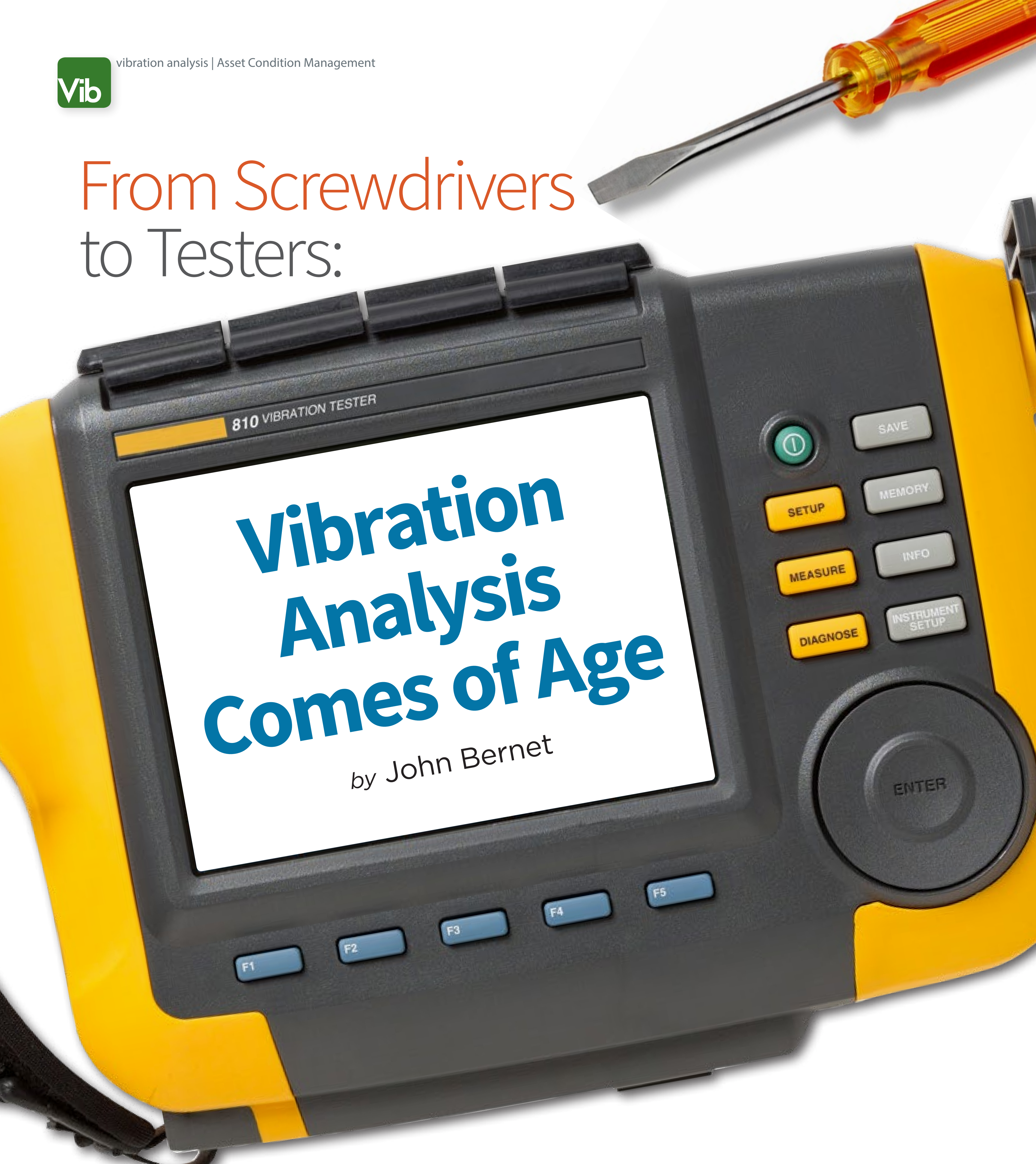

Figure 1: Understanding vibration analysis can change a run to failure system to a condition-based, proactive maintenance program

Most machines have rotating parts and those rotating parts vibrate. Measuring how and how much those parts vibrate can tell you a lot about the health of a machine. Whether it's the rumble of worn bearings or the shaking, shimmying, or thumping of loose, misaligned, or unbalanced parts, machines have a tale to tell those who are willing and able to listen.

The art and science of measuring and interpreting those telltale rumbles and shakes is called vibration analysis and it has been around for decades. Although historically the domain of specialists operating specific instruments for corporations and government agencies with mission critical equipment, vibration analysis is also employed by mechanics using a makeshift stethoscope or similar tool. Vibration analysis on rotating machinery has gained in popularity over more than four decades because thousands of faults can be identified without stopping the machine or tearing the machine down. Recent developments in vibration sensors, data acquisition and analysis technologies, however, are making vibration analysis cheaper, easier and more widely available.

Vibration analysis is a critical component of a condition-based maintenance system. An alternative to the run to failure strategy, condition-based maintenance measures machine health, which doesn't require tearing a machine down to find out its condition. When a machine condition fault comes up, a repair is scheduled when it's needed, not before and not too late.

HOW IT WORKS

Through analyses of patterns and amplitudes of vibration peaks at specific frequencies, rules and algorithms have been developed to diagnose problems with machines. This is accomplished by securely attaching a sensor, typically an accelerometer, to the bearings of a machine and measuring the vibration frequencies that transmit from the rotating shaft through the bearings into the outside metal surface of the machine and then into the sensor.

Among the most important mechanical faults that vibration analysis can reveal are:

1. **IMBALANCE** – A "heavy spot" in a rotating component that causes vibration when the unbalanced weight rotates around the machine's axis, creating a centrifugal force that causes advanced wear in bearings and seals and wasted energy.

2. **MISALIGNMENT** – High forces that result when machine shafts are out of line. For example, misalignment forces on the shafts, a motor and pump will cause advanced wear to the bearings and seals, resulting in wasted energy.

3. **WEAR** – As components, such as bearings, drive belts, or gears, become worn, they may cause vibration. When a roller bearing race becomes pitted, for instance, the bearing rollers will cause a vibration each time they travel over the damaged area. A gear tooth that is heavily chipped or worn, or a drive belt that is breaking down, also can produce vibration.

4. **LOOSENESS** – Vibration that might otherwise go unnoticed may become obvious and destructive if the component that is vibrating has loose bearings or is loosely attached to its mounts. Such looseness may or may not be caused by the underlying vibration.

VIBRATION TOOLS TO THE RESCUE

For the past 30 years, there have been only two tools for vibration analysis: the high-end, very sophisticated vibration analyzer and the vibration pen (or maybe the screwdriver to the ear to sense vibrations!). Recently, two new categories of vibration test tools have gained popularity to help the mainstream technician fill the void between complex vibration analyzers and simplistic pens. These new vibration tools are the vibration tester and the vibration meter. As shown, each tool has its own strengths and detects different vibration problems.

VIBRATION ANALYZER

PROS/CONS

- Essential for complex, production-critical machines
- Requires experienced operator with high knowledge level
- Produces large quantities of complex data, requiring analysis
- Large investment up-front and ongoing fees

Vibration analyzers conduct a sophisticated analysis of machine condition. They analyze vibration spectra (vibration amplitude versus frequency), create a baseline for the tested equipment and trend the results over time. This sophisticated analysis not only provides information about whether there is a problem, it also helps users understand the root cause and time to failure. However, this traditional type of vibration troubleshooting requires a significant amount of training and a strong understanding of the spectra and equipment's history.

WHEN TO USE:

- For big, complex machines with many variables, such as paper machines, multi-axis machines, turbines, etc.;
- For troubleshooting using real-time analysis, bump testing, cross channel phase and resonance testing for faults other than the four common faults previously described.

VIBRATION TESTER

PROS/CONS

- Well suited for vast majority of machinery in plant
- Fully automated machine conditioned answers without manual analysis
- Minimal up-front costs, resources and training
- Easy to use

Vibration testing provides automated diagnosis of the most common faults on most rotating machines, such as specific fault, fault severity and repair recommendation. The tester starts as a four-channel vibration data collector, but then many features and functions are modified to make it easy to use by a technician with minimal training and experience. Experienced vibration analysts may feel that they need these functions, but a large team of vibration experts working over 30 years have proven that complex and advanced troubleshooting techniques are not needed to diagnose the most common faults in most rotating machines. Put another way, you don't see a surgeon if you have a cold or the flu, you see your general practice doctor. With the vibration tester, let it help you find the most common faults and leave the advanced troubleshooting to the analyzer.

WHEN TO USE:

- For most machines with few variables, such as motors, pumps, fans, compressors, blowers, belts and gears;
- For diagnosing common machine faults (90 percent): imbalance, misalignment, bearings and looseness;
- For technicians that have many other tasks that need to get done and have no time to analyze complex graphs.

VIBRATION METER

PROS/CONS

- Multiple readings from single tool: overall vibration, bearing impact, infrared (IR) temperature, bearing health, machine health screening

When you move up to a vibration meter, you have the capability to measure overall vibration, as well as a database of real machine values to provide the user with an answer. Some vibration screening devices have a combination vibration and force sensor tip that compensates for user variance (force or angle), yielding accurate, repeatable readings. These meters also may have a four-level severity scale and an onboard processor that provides both bearing condition and overall machine health using easy to understand text alerts. In most instances, these devices can measure a wide range of frequencies (10 to 1,000 Hz and 4,000 to 20,000 Hz) in a couple of seconds and cover most machine and component types. Most are equipped with a straightforward user interface that minimizes user inputs to RPM range and equipment type. These types of meters give frontline maintenance personnel and operators a screening tool to determine which equipment is healthy and which needs further testing.

WHEN TO USE:

- To check hundreds of expendable machines and to perform a daily quick check of critical machines in-between testing by the analyst;
- For screening all machines 100 percent by using overall vibration, bearing impacts and bearing temperature to determine if a machine is good or bad. The vibration meter is five tools in one, not just one like the vibration pen.

VIBRATION PEN

(or simply a screwdriver)

PROS/CONS

- Single function; vibration number only
- Relies on experience of the operator to provide any sort of result

A vibration pen is a single-use tool that measures vibration caused by rotational and structural problems. It also can help identify some rolling element bearing or gear mesh problems.

Vibration pens are easy to use and provide a simple number that represents the overall vibration coming from the machine. However, the number requires knowledge about the machine to determine what the number means. For instance: Is this number bad for this machine? How bad is the fault? What is the fault? and What action is needed?

WHEN TO USE:

- For simple diagnostics of less complex machines.

Vibration Testing Principles

Vibration measurements are not like temperature or voltage measurements. Using electrical test equipment, you might expect to read a number that is repeatable time after time. Using a piezoelectric accelerometer to measure vibration from a dynamic machine train is a different story. That's because you aren't measuring the vibration at the source of the vibration, which is the rotating shaft. Instead, you are measuring from the bearing housing of the machine. This means you are really measuring the response of the machine's structure to the vibration from the rotating shaft inside, the components on the shaft, the bearings, the covers and the foundation. There are many random vibrations mixed in with rotating shaft vibrations. Even the repeatable vibration from the rotating shaft has many variables, such as resonance, speed and load, location, sensor mounting, environment, operational, noise, excitation and other machine influences.

> "Recent developments in the field have enabled a broader application of the practice"

To reduce random vibration, noise and variables:

- Make sure the machine is at the same speed and load each time a measurement is taken.
- Make sure the machine is running at the same operating conditions.
- Make sure the same machines in the area are running at the same operating conditions.

You can do your best to minimize random vibrations and reduce the variables, but vibration spectrum is never going to be exactly the same. The only way you would ever see this kind of repeatability is in a lab environment in space. That's why using the right tool is so critical because by the time the vibration from the rotating shaft transmits through the bearing to the outside of its housing and into the sensor that is attached with a magnet and mixed with the resonances and noise of the machine, foundation, surrounding structure and adjacent machines, there are just too many variables to expect exact repeatability.

After decades of either primitive (think screwdriver) or extremely unwieldy and expensive vibration analysis, recent developments in the field have enabled a broader application of the practice. Now a critical component of condition-based monitoring programs, vibration analysis continues to evolve, with tools more easily accessible and affordable to the average user.

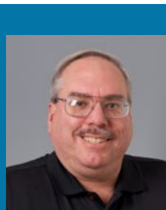

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Figure 2: At Alpenrose Dairy, regular vibration analysis provides data for trend analysis used in proactive maintenance

CASE STUDY:

The Tool that Saved the Dairy

At Alpenrose Dairy in Portland, Oregon, a vibration analysis contractor performing a semiannual check of a critical air compressor warned of bearing deterioration. One of the bearings had gone bad and the maintenance team was advised to take care of it within several months. However, the next week, the air compressor went down, limiting the plant's production.

At that point, the dairy's maintenance manager realized the outside contracting firm might not fully understand the workings of the dairy's equipment. Knowing the ramifications that down equipment could cause, the dairy decided it would be advantageous to have the capability in-house to check its equipment every couple of weeks.

After much research and consultation, Alpenrose Dairy decided to invest in a vibration meter. The maintenance team takes a reading once a month or once a week, depending on the equipment and their findings. If something different is observed, a trend analysis is built with the data. If a change in frequencies is noticed, it is immediately scheduled to be looked at by the maintenance team.

Since it is not economically feasible to test every piece of equipment at the dairy every single month, the maintenance manager prioritizes which equipment to check on a monthly or quarterly basis. Factoring into the decision are the baseline readings from the vibration meter.

By investing in a vibration meter for vibration analysis, Alpenrose Dairy now has a better idea and feel for what's going on with its equipment.

RELIABILITY

A Holistic Effort

by Alan Luedeking

The foundation of any great reliability effort is the reliability culture within the organization that sustains it. Everybody within the organization must be aligned with its ultimate goals and mission for the reliability effort to succeed. Therefore, the mission and values must be clearly communicated, with reasonable expectations for compliance.

A holistic approach to reliability-centered maintenance (Rcm) relies on good asset condition management (ACM). This, in turn, relies on accurate condition-based maintenance (CBM), which can only happen with good data. Planning and scheduling (Ps) personnel cannot do their job properly if the maintenance technicians do not feed good data into the system in a timely manner. So, one of the first steps must be to invest in a good enterprise asset management system (EAM) or computerized maintenance management system (CMMS), train all plant personnel in how to use it effectively and impress upon them how they as individuals are important to the overall reliability effort. Remember, the reliability effort relies as much on good data as the culture of cooperation that stands behind it and supports it. Everybody in the organization must understand the importance of their individual role in the wider mission of the organization and, in particular, their interaction with this data system.

Plant management must understand and respect the fact that the boots on the ground (i.e., their technicians and operators) are their best source of information. They are the ones that wrestle with the day-to-day problems and fix them. They know how the machines should sound, smell and feel. Respect their expertise and their opinions. Train your technicians. Invest in quality competency-based learning (Cbl). The knowledge and experience gained will pay off multifold in advancing the entire reliability effort. Give them the tools to do their job right. This means buying a good laser shaft alignment system, vibration analysis tools, and ultrasound leak and corona detection systems. This CBM approach will allow your organization to optimize the preventive maintenance effort (Uptime Element Pmo) required to deal with the problem.

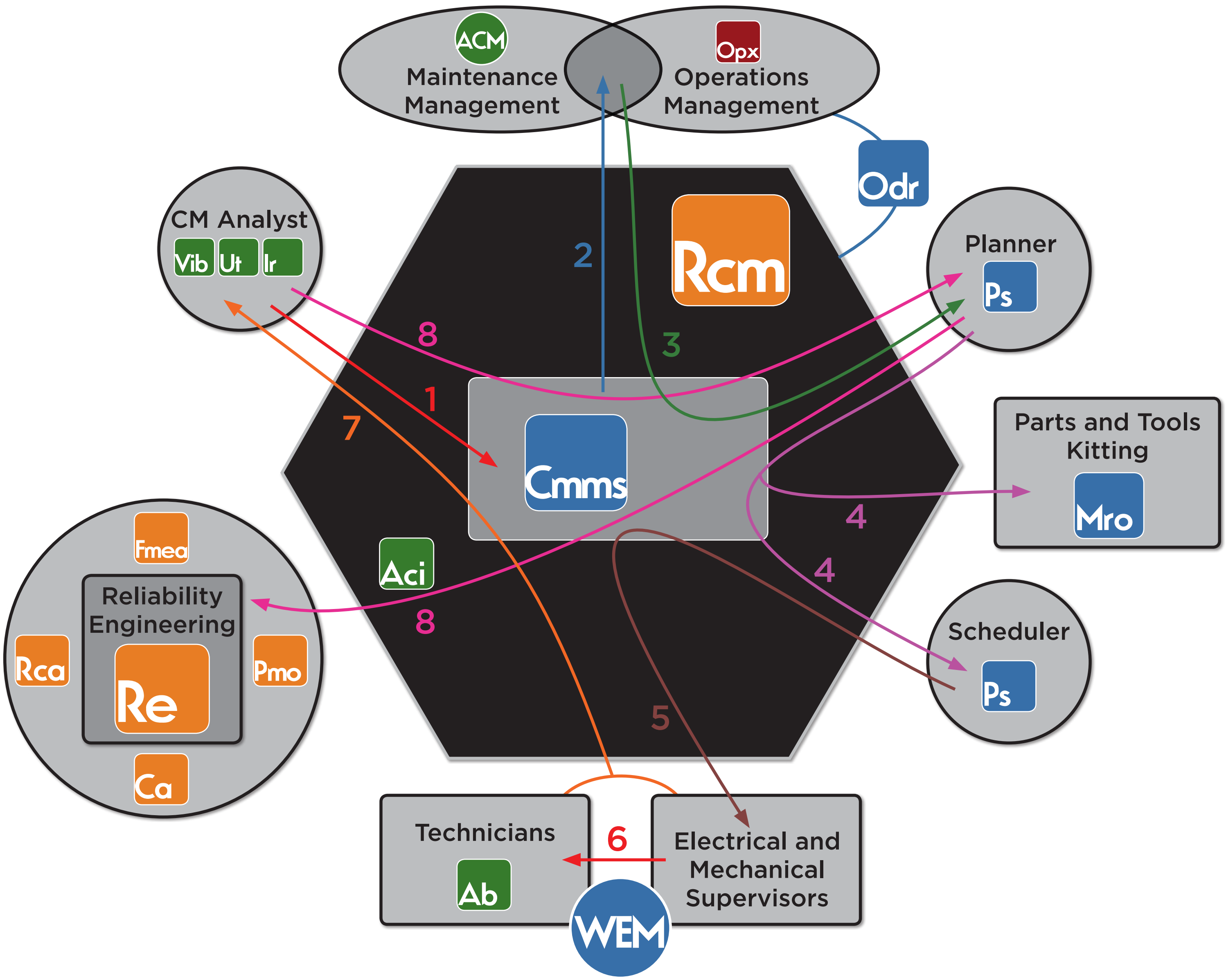


Figure 1: Maintenance reliability workflow

STAGE 1

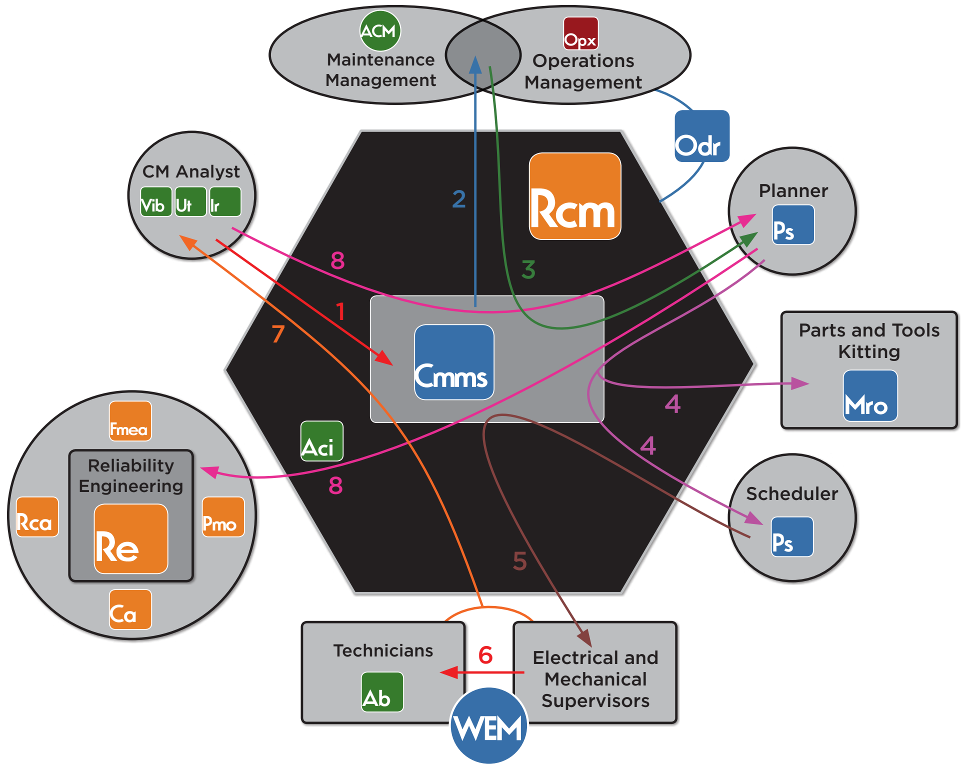
Figure 1 takes a closer look at the holistic reliability approach in a world-class program. Suppose ultrasound testing (Ut) detects a bearing fault in a critical motor early in the P-F curve. The analyst enters this data in the EAM system or CMMS and trends it. The analyst decides to request a work order in the CMMS with recommendations. This is Stage 1 in the work order process. The request must clearly state what the asset is, where it is located and why the work is being requested.

STAGE 2

The work order request now enters Stage 2, a review by management, both maintenance and operations. This double review is very important as it promotes buy-in from operations as well. The review process ensures that only truly needed or valuable work is approved. It also offers a chance for other open work orders for this asset to be combined with this one to streamline planned activity. For instance, perhaps the vibration analyst detected misalignment on this asset in the past and a work order was created to align the machine. However, the work was never carried out, resulting in the bearing damage the ultrasound analyst has now detected. The review process would catch the older open order and either cancel it or add it to the present order. This would prevent the millwright from going out to align the machine tomorrow only to have a repair technician go out the following week and remove and repair the motor, but do no alignment on it. The review process attempts to eliminate inefficiency, duplication and the occurrence of detrimental work sequences. It is also very important that this process includes a mechanism for generating feedback to the requester, particularly if the request is not approved.

STAGE 3

Once the work order is approved, it enters Stage 3, assignment to the maintenance planner for action. Only approved and truly necessary work enters the planner's backlog, as guaranteed by Stage 2. The planner's first job with the new work order is to ensure the work is properly prioritized. Two things are needed: the criticality ranking of the asset ascertained from the criticality analysis (Ca) process and its operational criticality. Both of these factors can be multiplied together to create a more accurate prioritization of the workflow. These two factors should exist for all equipment, since they are crucial



in the process of determining the priority of work. The planner reviews existing work plans (not work orders!) to see if one is already available and, if not, creates a new work plan as needed. At this stage, the planner should feel free to consult the maintenance supervisor and technicians since valuable insight may be gained for what parts, tools and equipment should be specified in the work plan. Once the work plan is complete, the planner orders the maintenance, repair and operations (MRO) spares required to complete the job. Thereafter, the planner should always verify that the parts are available and kitted (best practice). Upon kitting, the CMMS parts inventory control module will be automatically updated. The planner should not be concerned with scheduling, only with creating a good work plan and prioritizing the plans properly so they move through the system efficiently and in the right order.

STAGE 4

The work order then enters Stage 4, assignment to the scheduler, who allocates the human resources required and the necessary time to accomplish the task, with a cushion for unforeseen complications. The scheduler too should consult with the maintenance supervisors and technicians to get a better handle on time estimates to complete the job and when it might be most convenient to perform it. The scheduler must schedule the work within the failure forecast imposed by the requesting analyst and in accordance with the priorities established by the maintenance planner. This is a very challenging mission and at times can feel much like herding cats. However, a good work plan and understanding by the supervisors and technicians involved can do much to smoothen the scheduling process. Coordination with operations is crucial at this stage; operations "owns" the equipment and must sign off on the schedule to bring the asset down.

STAGE 5

Upon assignment to the appropriate maintenance and electrical supervisors, the work order now enters Stage 5. The supervisors, in turn, must assign the specific tasks in the work plan to their respective repair technicians, electricians and millwrights, and verify that MRO spares has delivered the necessary tools, parts and equipment kit to the proper location, or that a technician has been assigned to retrieve the assembled kit from the appropriate storeroom.

STAGE 6

The work order now enters Stage 6, the carefully timed work execution phase. Following all properly documented safety procedures, the electrician disconnects the motor and the repair technician performs the bearing replacement job. Next, the millwright reinstalls the motor and rough aligns it. The electrician reconnects the cabling and the millwright, who also observed all safety procedures and ensured the asset was locked out and tagged out before commencing work), now proceeds to eliminate soft foot in the motor and does a final alignment to the proper targets and tolerances. A well-trained millwright working with a good laser alignment system can save the organization many thousands of dollars in the work execution phase by properly measuring, analyzing and correcting soft foot on the machine and aligning it accurately in a shorter amount of time, thereby ensuring it will not break down again sooner than anticipated (Uptime Element Ab). Good alignment results in reduced equipment downtime, reduced MRO spares expense, lower power consumption and greater production from accurate alignment, all quantifiable benefits that go directly to the bottom line and justify the capital expense of the laser alignment system.

Once the millwright and electrician have completed their work, they report back to their respective supervisors. Stage 6 is now complete.

STAGE 7

The work order next enters Stage 7 and many things happen at once. The supervisors return the asset to active duty status in the system. Operations is notified that the asset is ready for service again and MRO spares is notified of any unused parts and supplies that should be returned and reintegrated into the MRO spares inventory. Any special tooling and equipment are accounted for and returned to the tool room. The supervisor also budgets the time, perhaps in concert with the scheduler, for the technician(s) to enter their observations (e.g., as-found condition of the bearing from physical observation, repair actions taken, parts used and time elapsed) into the work order. This data is very useful to the planner and reliability engineer. The CMMS system notifies the vibration and ultrasound analysts, who should immediately schedule follow-up data collection on this motor to ensure all is well, unless it is already on a preinstalled ultrasound online vibration data collection system. The analysts enter their the findings into the CMMS system and the work order now enters Stage 8, the final stage.

STAGE 8

In Stage 8, the CMMS system sends the work order back to the planner to be formally closed. The planner ensures all important data has been entered and distributed within the system, particularly to the reliability engineering (Uptime Element Re) department, thereby enabling key performance indicators (KPIs) needed by management and reliability personnel to be updated.

As good data accumulates, reliability engineering will take advantage of it to improve the entire maintenance reliability process. The failed, or soon to have failed, bearing may be examined to assist with failure mode and effects analysis (Fmea), thereby further informing the root cause analysis (Rca) process. The reliability engineer should review data to discover frequent failure patterns. This will help to identify training needs, drive out defects, streamline production and help to improve the design process. As the plant becomes more efficient and more productive, greater resources can be allocated to defect elimination (De), further impelling the transition from a reactive to a

A Word to CEOs:

Reliability is a never-ending journey of continuous improvement. A world-class reliability program is not achieved overnight, yet you must start somewhere.

Hcm Your first step on the road to victory is to vest your entire human capital (Hcm) in its success. True reliability excellence means that everybody in the organization feels ownership for the assets and their efforts are aligned to the mission, vision and values of your organization. Everybody matters and everybody counts, from the sweeper who makes sure the floor is safe to walk on to you in the C-suite.

Es Int Reliability is a culture, not just a goal, and it flows from the top-down. Therefore, executive sponsorship (Es) with integrity (Int) and enforcement are a must. Obtain buy-in to the culture of reliability from everybody or the effort is doomed to fail. If you start with this realization and build up the culture within your organization to sustain it, your reliability effort will ultimately succeed and you and your stakeholders will reap its rewards.

proactive and reliability-centered maintenance culture. As asset reliability improves, more time and training can be dedicated to further improving process and people flows (Uptime Element Hcm) and strengthening the important CBM programs, including vibration analysis (Vib), oil analysis (Oa) and ultrasound testing (Ut).

In a world-class reliability program, necessary work flows logically through the entire system, in a coordinated and prioritized manner, structured through a well programmed and managed CMMS or EAM system. All stakeholders in the organization work together in harmonious cooperation toward the same goal: the fulfillment of the organization's mission and vision.

Alan Luedeking, CMRP, CRL *is Executive Vice President of Ludeca, Inc. in Doral, FL. He has 30+ years experience in machinery shaft alignment and training and holds an ISO level I Vibration Analyst certificate as well as a Level I Ultrasound Inspection certificate. Besides his work, Alan enjoys spending time with his family and numismatics.* *www.ludeca.com*

Asset Condition Management

Regional oil analysis initiative moves reliability information from spreadsheets to the Cloud

Reliability Processes Upgraded Worldwide

by Steve Marshall and Forrest Pardue

Around-the-clock operation of heavy equipment in harsh, gritty conditions is the nature of the coal mining and production business. Equipment failure is not an option for an industry that services customers around the world. Some of the components cost hundreds of thousands of dollars each and production downtime losses can be immeasurable.

Reliability has long been in focus at one surface operation in the U.S. that produces tens of millions of tons of coal each year. Condition monitoring of equipment began there 15 years ago to provide early detection of deterioration and avoid costly failures. By 2013, nondestructive testing (NDT) procedures, including oil analysis, vibration monitoring, ultrasonic testing, thermography and walk around visual inspections, were in use.

Early that year, the company took steps to further improve reliability and reduce costs. By 2015, the company's various cost initiatives saved $525 million and reduced capital investments to $194.4 million. The journey that began with oil analysis – the company's largest condition monitoring expenditure – is now being expanded and rolled out globally.

Figure 1: Equipment failure is not an option in surface mining operations

Oil is the low-hanging fruit

The established oil analysis program monitored mining equipment, such as earth moving draglines, electric mining shovels, ultra class haul trucks, track dozers and motor graders. Certain systems within the coal processing plants were also monitored. Approximately 4,000 individual oil sample points were taken as often as every two or four weeks.

Though it was helpful in managing machine health and meeting component replacement targets, the existing oil analysis program lacked efficiency and visibility. Information was tracked using methods ranging from a computerized maintenance management system (CMMS) to spreadsheets, technician notes and stand-alone software programs.

The spreadsheet tracking of high sample volumes was particularly prone to errors. There were incidents of inaccurate sample labeling and tracking, lost samples, inconsistent return times and overdue oil sample condition assessments. Greater automation, control, accountability and "whole picture" analytics were desired.

Following a region-wide process review in 2013, the decision was made to standardize and consolidate on a cloud-based reliability information management system for oil sample analysis management, including direct communication with the oil lab.

The Web-based approach that was selected provides a more efficient and accurate oil sample identification and tracking process. Oil sample scheduling is managed within the reliability information management system and the cloud-based, interactive results are transferred directly from the oil lab and made available to tribologists at each mine.

From a web browser, the coal company's analysts are able to:

- Review the full details in an interactive sample report;
- Apply customized alarm sets that are different from the lab's alarms;
- Create trend charts for data parameters;
- See the lab's analysis comments and add new comments or questions;
- Create a condition entry for the asset location to escalate problem visibility.

Big picture reliability comes into focus

Details of problems from flagged oil samples and the recommended maintenance actions are posted to a browser-based status condition sta-

Actions	Location Desc	Equipment Desc	Tests Completed	Status	Value Alarms	Lab Sample Code	Company	Site	Tango
	818-PD		Dec 01, 2015	Critical		1855590		- Mobile Equipment	
	522-HYD		Dec 01, 2015	Critical		1855162		- Mobile Equipment	
	[illegible]-HYD		Dec 01, 2015	Critical		1855560		- Mobile Equipment	
	353-FDRR	RIGHT/REAR	Dec 01, 2015	Critical		1855179		- Mobile Equipment	
	353-FRONT DIFF	FRONT	Dec 01, 2015	Critical		1855172		- Mobile Equipment	
	353-REAR DIFF	REAR	Dec 01, 2015	Critical		1855177		- Mobile Equipment	
	838-PD		Dec 01, 2015	Critical		1855356		- Mobile Equipment	
	376-FDL	LEFT/REAR	Dec 01, 2015	Critical		1855165		- Mobile Equipment	
	604-HYD		Dec 01, 2015	Warning		1855561		- Mobile Equipment	
	818-FWR	RIGHT	Dec 01, 2015	Warning		1855563		- Mobile Equipment	
	939-HYD		Dec 01, 2015	Warning		1855159		- Mobile Equipment	

Figure 2: Critical oil samples are sorted to the top of the list for action by the company's oil analysts *(Courtesy of 24/7 Systems)*

“By 2015, the company’s various cost initiatives **saved $525 million** and reduced capital **investments to $194.4 million**”

Integrated Condition Status Report

Filter:

			Severity	Function	Asset	Component	Technology	Days Awaiting Checkoff	Work Order Numbers	Created By	Latest Status Comments	Latest Case Recommendation
1			4	160 - 936HP TRACK DOZER	POWER TRAIN / DRIVE SYSTEM	ENGINE SINGLE	• Oil - Lab	169	• 103206972 • 103239491 • 103878143 • 103882524			•monitor sample at normal interval By: Nov 23, 2015
2			4	171 - DOZER TRACK	POWER TRAIN / DRIVE SYSTEM	ENGINE SINGLE	• Oil - Lab	198	• 103750399 • 103793095 • 103882524 • 104179922			•oil was changed resample at next interval By: 09, 2015
3			4	474 - CAT LOADER 994H	HYDRAULIC	STEERING PUMP SINGLE	• Oil - Lab	131				•system in process of complete clean out By: (Oilography), Jul 24, 2015
4			4	474 - CAT LOADER 994H	POWER TRAIN / DRIVE SYSTEM	PARK BRAKE SINGLE	• Oil - Lab	131				•system in process of complete clean out By: (Oilography), Jul 24, 2015
5			4	492 - MOTOR GRADER	HYDRAULIC	HYDRAULIC SYSTEM	• Oil - Lab	169	• 104081070 • 104129999			•change oil at next pm

Figure 3: All condition-based problems are integrated via an interactive browser dashboard *(Courtesy of 24/7 Systems)*

Condition Case Details User: TF7, Date: Dec 03, 2015, Time: 11:58:55

Location: FIELD >> 101 - 87 CU YD DRAGLINE >> DRAG TRANSMISSION RIGHT REAR >> DRAG 1ST INT GEAR P01 Locate in Tree

Equipment: Plant Tag 10007406 **Diagram(s):** Lifespan Chart

Entry	Severity	Technology	Faults
Aug 18, 2015	4	Vibration - Route	• Gear -worn/spalled teeth

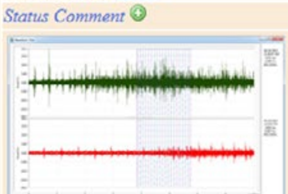
By: Steve Marshall
Case: 369

Recommendations: 8/18/15) The Amplitude has more than doubled since last inspection. The gearing and mounting bearings should be inspected as soon as possible.

Comments: 8/18/15) Vibration Amplitude has increased significantly since last inspection. 2-19-15) Not much change from last inspection. 11-12-14) Slight change since last inspection Indication is a possible chipped gear tooth seeing indication at 1 times running speed. 8-19-14) Increasing amplitude in waveform ~9g Acc. spiking to 12g Acc.

Linked Documents
101 DL Drag 1st Intermediate Gear.jpg (Measurement Data)

Work Order Request Assign CMMS
Work Order Number Assign CMMS
Details Report View
Status Comment



101 DL Drag 1st Intermediate Gear.jpg

Checkoff

Additional History

Mar 05 2 Vibration - Route • Gear -worn/spalled teeth

Figure 4: Condition case details are captured in the reliability information management system *(Courtesy of 24/7 Systems)*

tus dashboard. The dashboard, easily visible to a wide audience of authorized users, lists all known problems of an asset by severity, the number of days the problems have been open and the work order numbers.

The coal company soon recognized that its other condition monitoring technologies could also integrate with this dashboard. This would eliminate the many hours spent gathering reliability information and metrics from numerous stand-alone databases and assembling and communicating it in spreadsheets. Moreover, it would provide a complete and readily accessible picture of asset health.

> "Upgrades and system improvements are an ongoing effort"

The company chose to centralize all condition problems found via oil analysis, vibration analysis, ultrasound analysis, thermography and walk around inspections on the dashboard, which is part of its reliability information management software. This gives technicians and managers a single platform from which to track and manage all known conditions that can impact the reliable performance of equipment.

Partnership approach

To best meet its improvement objectives, the coal company worked jointly with the reliability software provider to map out key processes and adapt oil sample analysis management and reliability information management solutions to its business needs.

A jointly developed interface imports current meter hours twice daily from the company's CMMS and a budgeted life percentage calculation was developed. This allows the integrated condition status report to show the status of individual components and where they are in terms of their lifecycle relative to the targeted replacement interval.

An automated task system for oil sample selection and labeling was also developed. Previously, the machine run hours, component service hours and lube hours on sample labels were assigned manually and prone to errors. When the company's oil techs didn't adapt well to the new electronic system for generating labels, the responsibility was shifted to water spider personnel (staff who keep production materials in stock at point of use so production personnel can focus on asset tasks that create products or provide services).

Another early challenge was gaining support from the oil lab. The lab had to review its internal processes for managing oil analysis data and upgrade its systems to support electronic data transmission. Ultimately, the new system helped to improve the coal company's relationship with the lab. It streamlined some of the oil lab's work and actually reduced or eliminated its need for manual data entry, which, in turn, reduced the potential for errors.

Figure 5: The oil analysis program monitors mining equipment, such as earth moving draglines

For this company, the improved interaction between technicians, analysts and lab personnel is increasing the accuracy and control of the mine's reliability program. Maintenance personnel can more effectively manage machine component health and have greater insight into the highest priority work, the expected useful life of the assets and complete machine health histories.

Global program rollout

Due to the western region's success, efforts are underway to standardize all NDT and reliability procedures across all operations in the company's global platform, which vary in size and scope. This involves:

- Using both Web-based oil sample analysis management and reliability information management software as the single source for machine health reporting and analytics, while using the CMMS for scheduling and costing;
- Formalizing the methodology used to determine which NDT process or processes to employ based on the equipment type;
- Standardizing the associated NDT strategy and frequency in order to maximize problem detection and apply the appropriate corrective action;
- Standardizing the tracking of value, cost savings and avoidance, route adherence, condition assessment procedures, and asset health and component condition reporting.

Upgrades and system improvements are an ongoing effort and the coal company continues to work closely with the software provider on this. For example, they are currently developing a CMMS notifications link within the reliability software's condition status dashboard. They also plan to develop a senior assets review using the budgeted life status percentage to assist in risk-based assessments by the maintenance director, reliability manager and planners.

Meanwhile, the company continually adds more reliability processes, such as additional vibration and thermography routes, expanding the number of systems and components that are tracked and monitored. The company is also using mobile devices to capture field measurements and inspection data where problems found by inspection personnel can be integrated on the condition status dashboard.

Future plans include implementing a full system interface with the reliability information management software and the CMMS, and using more of the mobility, repair tracking and root cause failure analysis (RCFA) case management features available within the software.

By moving the entire organization from spreadsheets to a common reliability platform in the Cloud, the company is setting the stage for continuous improvements in asset performance, uptime and operational efficiency.

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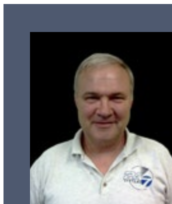

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Reliability, Resilience and Damage

Research currently being carried out by the Center for Risk and Reliability, University of Maryland[1], and funded by the U.S. Navy is aimed at quantifying reliability in scientific terms. The present study "relies on a science-based explanation of damage as the source of material failure and develops an alternative approach to reliability assessment based on the second law of thermodynamics." Current reliability calculations are predisposed to a single failure mode or mechanism and assume a constant failure rate, while this research implies that reliability is a function of the level of damage a system can sustain, with the operational environment, operating conditions and operational envelope determining the rate of damage growth.

by Malcom Hide

This article explores the areas where significant levels of damage can be controlled in order to improve system reliability.

In effect, the Center for Risk and Reliability study is looking at how the dissipation in entropy can be equated to the level of damage in a system and as the damage grows, increases the likelihood of failure which, in effect, reduces the reliability.

Reliability in an engineering context is the ability of an item to perform a required function under given conditions for a given time interval. It is generally assumed that the item is in a state to perform this required function at the beginning of the time interval and reliability performance is usually expressed as a probability. For example, an electrical relay has a 99 percent probability that it will achieve 100,000 operating cycles at full load.

Taking this a step further using the example of the relay, based on the operational environment (no impact), operating conditions (full load switching) and operational envelope (four cycles per minute, 24/7/365), the level of damage growth over time can be calculated to predict an individual mean time between failures (MTBF) for this component of 17.4 days with a 99 percent accuracy.

Since current reliability calculations are predisposed to a single failure mode or mechanism and assume a constant failure rate, for the relay example, this might be arc damage on the contacts, but spring failure or coil overheat also could be possible. The problem is that for every component, there will be several failure modes or mechanisms and each of these would generate its own failure predictions, resulting in an incoherent reliability calculation. The entropy based failure prediction, on the other hand, takes all these elements into consideration to determine a level of damage, which is then used to calculate the life of the component.

Reliability, therefore, becomes a function of the level of damage a system can sustain (i.e., resilience), with the operational environment, operating conditions and operational envelope determining the rate of damage growth.

$$\textit{Reliability (R)} \equiv \textit{Resiliance (X)} - \textit{Damage (D)}$$

Creating Resilience

Numerous satellites have been operational for many years without any human intervention. This is an indication that resilience is a function of the creation of the equipment or system and not necessarily driven by human intervention. Take the relay example and select one with an average life of 5,000 cycles and use it in the same application. Ultimately, you have built in a failure mode with an MTBF of 0.86 days. Clearly, this would be an inherently unreliable system based on the component's failure because the level of attention and repair required is excessive.

In order to improve the reliability of the system, therefore, a design review is necessary. If, instead, you select a relay that has an average life of 200,000 cycles, the MTBF increases to 34.7 days, which although still unreliable, is much improved than the first option. Fundamentally though, this design is flawed as the duty cycle on the relay is excessive and in order to improve the resilience of the system, a design change was needed. Other ways of doing this would be to reduce the number of activations, alternating the activations between multiple relays or eliminating the requirement for the activations.

Once the design is completed, the resilience creation moves into a new phase where the design is implemented. Unfortunately, this is where you start eroding the resilience, as opposed to enhancing it. This is caused by several factors:

- **Material selection differs from the material specified during the design phase –** Invariably, this is driven by price with some form of value engineering. Quite often, the reasoning behind the designer's decisions or selection of components is forgotten or ignored and, as a result, the components no longer meet the design requirements. Taking the relay example, the best priced option could well be the unit with an average life of 5,000 activations as opposed to the one with 200,000 activations. There is nothing wrong with value engineering as long as it does not corrupt the design intent.
- **Defective materials as a result of manufacturing defects –** Manufacturing defects should be picked up during quality control inspections throughout the manufacturing process. However, some manufacturing defects could be so deep rooted in the component that it would be virtually impossible to detect; and the level of detection gets reflected in the price. These usually result in early component failures or shortened life expectancy of individual components and could easily result in extensive rework to replace the defective components.
- **Defective materials due to a lack of care during the delivery process –** Delivery process covers everything from the handling of the component at the manufacturer to the transportation, storage and finally the handling of the component on the installation site. Managing the level of care during this process is very difficult, since shock, vibration, environment and storage conditions need to be considered. Lapses in these controls usually result in early component failures or shortened life expectancy of individual components, similar to those resulting from manufacturing defects.

- **Improper or poor installation of components or equipment –** Experience shows that an incorrectly installed bearing or electronic components installed without the correct electrostatic discharge (ESD) protection can both result in a shortened life expectancy due to the damage caused to the component. The future reliability of the system is dependent on the level of care applied during the installation, not only in terms of the method of installation, but also in the diligence during the installation. Examples of this would be poor wiring connections resulting in connector failures or incorrect equipment setup resulting in excessive wear. Invariably, these are usually a result of poor management of the installation contractors and a poorly executed installation test procedure prior to the equipment or system being brought into operation.
- **Live testing carried out during the commissioning phase –** Commissioning should be a series of progressive tests that prove the system meets the design parameters. However, some tests used to prove the safety of the system could be quite damaging in order to ensure the system can protect itself adequately. Consider the impact on a compressor in full load conditions when the emergency stop button is pressed. In addition to this level of testing, consider also the length of time it takes to commission a fairly large site with thousands of interlinked pieces of equipment. In some cases, such as a construction environment, this could be years, with significant environmental conditions that do not reflect the normal operating conditions.

Once the system is ready to go into operation, many of the components already have incurred a level of damage, which ultimately reduces the level of damage the system can sustain, thus impacting system reliability. Expressing it as a mathematical formula:

$$X_d = X_{des} - (D_{ms} + D_{man} + D_{del} + D_{inst} + D_{comm})$$

Where:

X_d =	Delivered Resilience
X_{des} =	Design Resilience
D_{ms} =	Damage from Material Selection
D_{man} =	Manufacturing Damage
D_{del} =	Delivery Damage
D_{inst} =	Installation Damage
D_{comm} =	Commissioning Damage

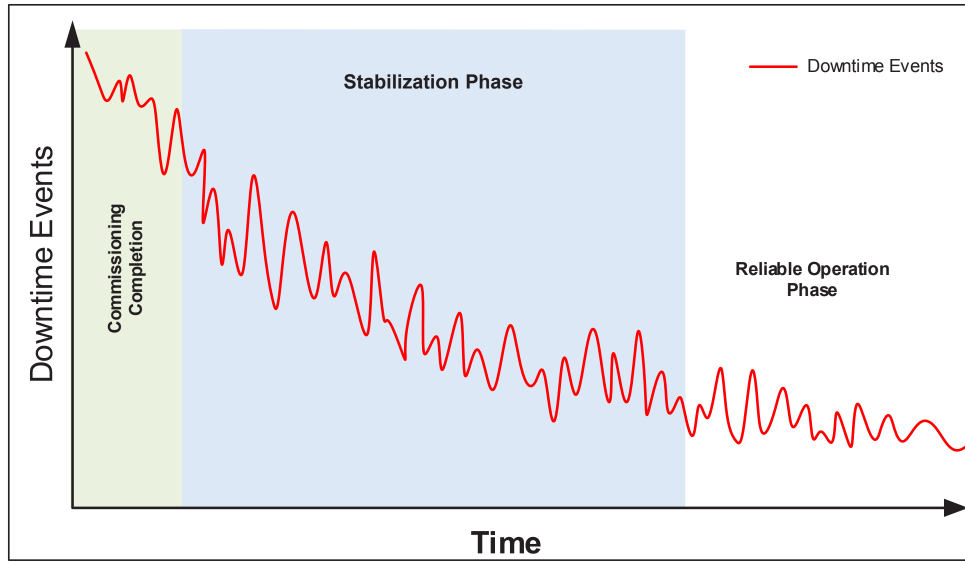

Figure 1: Post-commissioning stabilization phase

This is the level of resilience that is delivered when new equipment or a new system is installed.

Improving Resilience

Taking the installation resilience as a point in time, you need to stabilize the operation and eliminate potential damage caused by poor installation. One of the key areas of focus should be reviewing control elements, especially in relation to software related updates. Typically, a system beds itself in and when these actions are taken, the system will become more resilient (Figure 1).

Stabilization of the operation and software and timing updates are not covered in this article, but there are several systems available that can assist in identifying areas where these improvements could make the most impact on the duration of the stabilization phase. However, from an installation damage perspective, you should consider these condition monitoring activities to identify potential issues that can be remedied.

- Infrared thermography to identify equipment that may be heading into trouble in terms of hot spots and upward trends in overall temperature. Infrared thermography works well on electrical motors, electrical connections over 50v, heat loss or cold areas and failing bearings.
- Vibration monitoring to identify unusual vibration signatures and levels, as well as rising trends in vibration. Vibration monitoring is good for most rotating equipment, however, it is poor at slow rotating equipment, so it will be an issue to identify problems with transient vibration caused by equipment that stops and starts frequently. On the run-up and run-down of rotating equipment, vibration monitoring will highlight any harmonic related issues that might also cause damage if it is not properly managed.
- Ultrasound to help identify leaks and other unusually high energy noise, such as that found on pneumatics, bearings and electrical arcing.
- Oil analysis, where there is an adequate volume of oil to support it, could be used to identify systems where there is excessive wear being generated, such as white metal bearings, gear trains, or hydraulic systems.

All of these, as well as other condition monitoring activities, would give you a heads up on the developing level of damage that could be averted if addressed early enough. This allows you to schedule the repairs in a timely manner to ensure the resilience of the new system can be raised to the highest possible level when the system is handed over for normal operational use.

Maintaining Resilience

Once a system goes into full production, the true art of reliability is to keep the system running at the correct efficiency and quality output with minimal intervention. In order to do so, you need to put processes in place to monitor and limit the growth in damage, which ultimately erodes the resilience of the system. Expressing this as a mathematical formula:

$$X_t = X_d - D_{life}$$

Where:

X_t =	Aged Resilience
X_d =	Delivered Resilience
D_{life} =	Damage Caused by Operational Life

And D_{life} is directly proportional to these elements:

- **The level of care applied to the system:** You know that if you take care of the equipment, identify failures and take corrective action prior to them failing, the equipment or system tends to retain its reliability longer because you don't allow it to suffer from secondary failures. Take a gland that comes loose on an electrical panel as an example. When you see it is loose, you tighten it, thus reducing the risk of ingress of moisture in the panel and limiting the likelihood of corroded connectors.
- **The level of maintenance performed on the system:** You know from experience that if you only apply breakdown maintenance on equipment or a system, the frequency of failures will escalate to an unsustainable level. At this point, you would be running from one breakdown to the next, almost making it impossible to set a preventive maintenance (PM) program in place. Alternatively, you could be over maintaining items to the extent that you are taking systems off-line for unnecessary inspections purely on the off chance you might find some hidden failure that might be lurking.
- **Human error and poor workmanship:** When components are replaced or you perform any invasive inspection (i.e., you go beyond the level of removing safety guards and start dismantling equipment to perform an inspection), you introduce the potential for human error. Some estimates are that between 50 and 70 percent of equipment failures are a result of human error. This may be a result of incorrect methodology used to replace the part or reassemble the equipment, lack of training or skill required for the task, or errors caused by bad practice or poor workmanship.
- **Replacement parts must conform to design requirements:** When replacement parts are purchased, they need to conform to the system's design parameters, otherwise you have the potential of changing the resilience of the system, similar to the relay selection in the earlier example. Furthermore, a system may be designed in a way that a particular failure is built in to protect the rest of the system from significant damage. If you change the failing part with one that is more robust, you have, in effect, changed the design parameters. As a result, you may have moved the failure to another component, which could be far more catastrophic. Procurement processes and component specifications should avoid this possibility.
- **Quick fixes that are not correctly managed:** When the equipment or system is running and a failure occurs, you are forced to apply a quick fix to get the system running to meet the demand. If you don't go back and do a permanent repair and continue to run with the quick fix in place, the cause of the original failure is still present and the level of damage is potentially increasing. This is a cultural issue that is fostered when the maintenance crew is rewarded for its rapid response to issues and not for long-term system improvements.
- **Using the equipment or system outside of the designed parameters:** The equipment or system was designed to perform in a specific manner and as long as it is used in that manner, it will usually perform reliably. But if you change the operational processes and do not change the design's intent, the system or equipment may become less reliable and far less efficient.
- **Residual equipment life:** Using the relay example, if the relay selected provides an MTBF of 15.4 days (100,000 cycles) with an accuracy of 99 percent, on day one of the relay's life, you have almost a 100 percent likelihood of a failure-free day. But on day 16, you would have nearly a 100 percent likelihood of a failure. The same applies to a system; as time progresses, the level of damage on the components will grow to a point where aged resilience is significantly reduced. As a result, the system's reliability is significantly lowered.

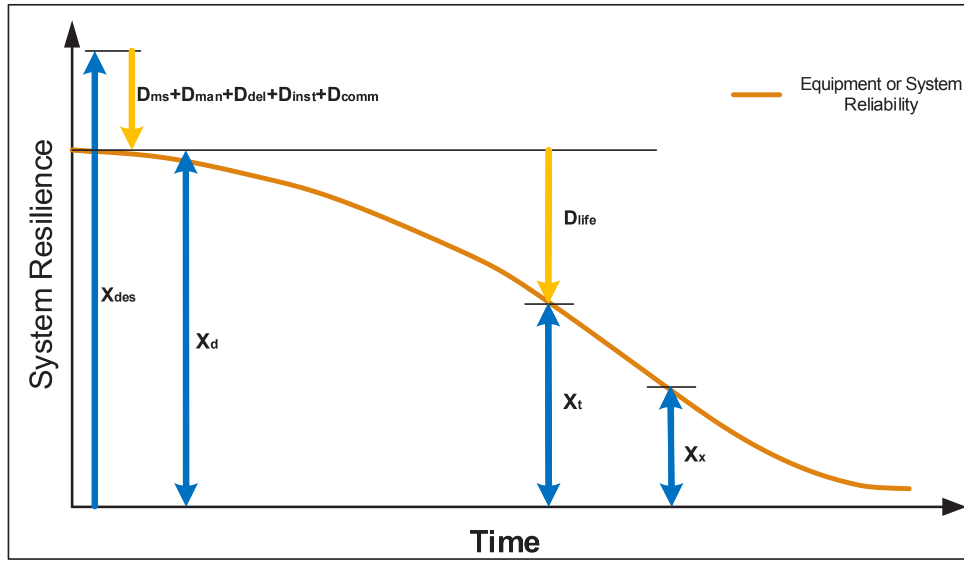

Figure 2: System resilience over time

It is clear from the list of elements that many are within the power of the operators and maintainers to manage and control, while the residual equipment life is more a function of design.

Conclusion

Reliability is a function of the level of damage inflicted on the system and, therefore, should equate to X_t at a point in time, as shown in the Figure 2 graph.

At a point in time (X_x), when the resilience of the equipment or system is less than what is necessary to retain the level of reliability that is expected, the system becomes inherently unreliable. Once the equipment or system has reached this point, experience shows that very little can be done to rebuild the level of resilience to support the required reliability. The cost of maintenance at this point starts escalating, as more manpower is required to resolve the number of faults. Also, as the number of faults increase, so do the number of component replacements. Equipment or system availability at this point becomes more of a function of manpower and MTTR than system reliability.

Organizations need to change their perspective on the role of maintainers. As this article shows, maintainers need to be focused on minimizing damage to the equipment or system, as this ultimately improves the level of reliability as time progresses. In addition, organizations should look to find ways to quantify the elements within their control in order to predict the level of resilience at any point in time.

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Malcolm Hide is an independent maintenance consultant and has over 35 years of experience in maintenance and design. He has worked in the steel, oil & gas and food processing industries, and due to this broad range of experience, Malcom has been able to apply his knowledge of asset management and maintenance requirements to many environments and applications. www.stratmaint.com

...do the majority of injuries occur during asset failures?

...do the majority of reliability initiatives fail?

...do major asset breakdowns keep occurring?

We ask the question WHY
but we fail to understand WHY...

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The Human Factors' Influence on Maintenance Reliability Management

by Krishnan Shrikanth

P People **P** Process **P** Productivity

Human factors play a vital role in influencing maintenance reliability management in an organization. This article presents some specifics on the influence of culture and leadership in the process and chemical industries.

In a world where globalization is dynamic and workforces represent cross-cultural borders, it becomes imperative to take into consideration the key pillars to organizational effectiveness. The first P, PEOPLE, focuses on the interrelationship of people and groups within any organization and takes these factors into account when designing and administering the organization. People have an impact on profitability since leadership and workforce behaviors play a role in process assets and operational excellence.

Human Cultural Factors in Management

Culture refers to an organization's values, beliefs and behaviors. The key enablers in creating the culture are enhanced by how the strategic leadership framework is developed. This framework consists of creating a vision and mission, ensuring availability of resources and empowering people to achieve organizational excellence. It has been well established that social and psychological factors are important to worker satisfaction and productivity. Considerable advancements in the motivation model by Maslow, Herzberg, McClelland and McGregor apply in understanding worker motivation. More recently is the introduction of participative management and self-empowered shop floor teams, reflecting the Japanese concept of the autonomous operator maintenance team. As the industrial climate changes the style of human factors, management also changes.

Maintenance Reliability Management Behavioral Characteristics

So, what is the maintenance reliability excellence culture? It's a culture where every human cultural factor has an influence on the organization's efforts toward achieving its maintenance reliability objectives.

Human behavioral factors that could influence maintenance reliability are broadly classified under six categories. Details for each influential factor from a cultural perspective are presented.

Safety Culture Behaviors: In many organizations, a safety manager or plant manager is responsible for safety. This is absolutely not accepted behavior since it is everyone's responsibility to ensure a safe work environment. Maintenance tasks and reliability improvement efforts are closely related to field safety. Some key influencing factors are practices related to safe work permits, confined space and vessel entry protocol, lockout-tagout policies, electrical work for high voltage panels permits, excavation work permits, regulatory inspections and environmental permits from an equipment maintenance standpoint. The degree of influence and drive from management to maintenance reliability teams to take over this challenge is one of the most important cultural factors. Management's commitment and leadership drive for safety should be part of the organizational culture.

Equipment Ownership: This factor involves the degree to which the maintenance workforce or operators feel a sense of personal ownership for the equipment or area of the plant. Where ownership exists, the equipment tends to be operated and maintained correctly. One key step is to move toward small, self-empowered, plant-oriented, operator maintenance teams comprised of five to seven members. Each team is responsible for operating a designated plant area and focusing on efforts, such as lubrication, minor adjustments and servicing. This means operators need to be trained in superficial maintenance and they have to own it.

This is well characterized by concepts like total productive maintenance (TPM) or operator-based maintenance (OBM).

Figure 1: Elements of maintenance reliability influenced by human behaviors

Functional Organizational Structure: To build and manage effective, collaborative global teams, you must focus on the people/organizational factor. Balancing a traditional hierarchy maintenance reliability national structure versus the global/matrix structure, which is becoming more popular with globalization and working across cross-country borders, needs continued management support to transition the same.

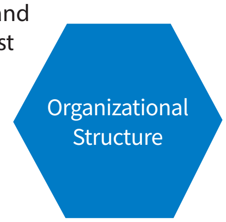


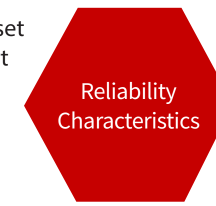
Figure 2: Elements of a functional organizational structure impacting the maintenance reliability culture

We versus them polarization: The production/maintenance conflict is well known and goes something like this: "Production ran and damaged it and we mend it." In other words, "They operate it incorrectly and never let us have the equipment for proper maintenance." The production view is: "We make the money and maintenance does not understand our objectives – we give them the plant for a shift and they keep it for a day." The "we" versus "them" syndrome indicates an amount of polarization in the organization.

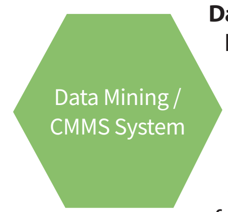
Outsourcing maintenance alliances on human factors: The sense of ownership becomes more challenging with this type of organizational structure. However, there are ways to make this alliance a success factor. One consideration is to deliver a level of service tied to key performance indicators (KPIs). In this way, the contractor alliance brings in the right skilled workforce with expertise in functions like job planning, stores management, etc. This impacts the motivation of all production maintenance teams, as well as job security and morale of maintenance employees.

Centralized versus decentralized maintenance structure: This is another example of a cultural impact to the production unit. The key to cultural effectiveness is how well management strategies are aligned to cater to the maintenance structure.

Repair versus capacity assurance function: The mind-set change requires maintenance reliability functions to support capacity utilization at the minimum designed levels. This allows the organization to get more from current or existing facilities with proper balance to safety, quality and cost factors.

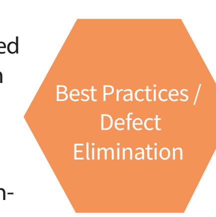


Structured maintenance and reliability programs: Programs, like reliability-centered maintenance (RCM), risk-based inspection (RBI), predictive maintenance (PdM), condition-based maintenance (CBM), turnaround management and critical safety/regulatory inspection regimes, contribute to eliminating premature failure of the asset. The impact is felt with improved production capability and reduction in overall facility costs.



Data Mining and Analytics: With recent trends to utilize lean, Six Sigma approaches to improve reliability performance and minimize variability in production processes by using principles of statistical process control, trend analysis and threshold set point reviews, the quest for data gathering and analytics is gaining increased importance. Data varies from operational performance data, like pressure, temperature, flow rates, etc., to vibration analysis, oil analysis, infrared thermography results, ultrasonic testing, electrical motor current analysis, partial discharge/corona detection, computerized maintenance management system (CMMS) data capture, quality and integrity, and many more. How to consolidate all the data in a common platform and make a meaningful analysis poses a challenge to the reliability function.

Best Practices in Maintenance and Operational Areas: Based on benchmarking studies from various industry sectors with several statistical data mining, there are certain prescribed practices worth considering to enable higher plant capacity utilization and lower total costs. Maintenance practices should focus on process and behavioral safety aspects, plan-



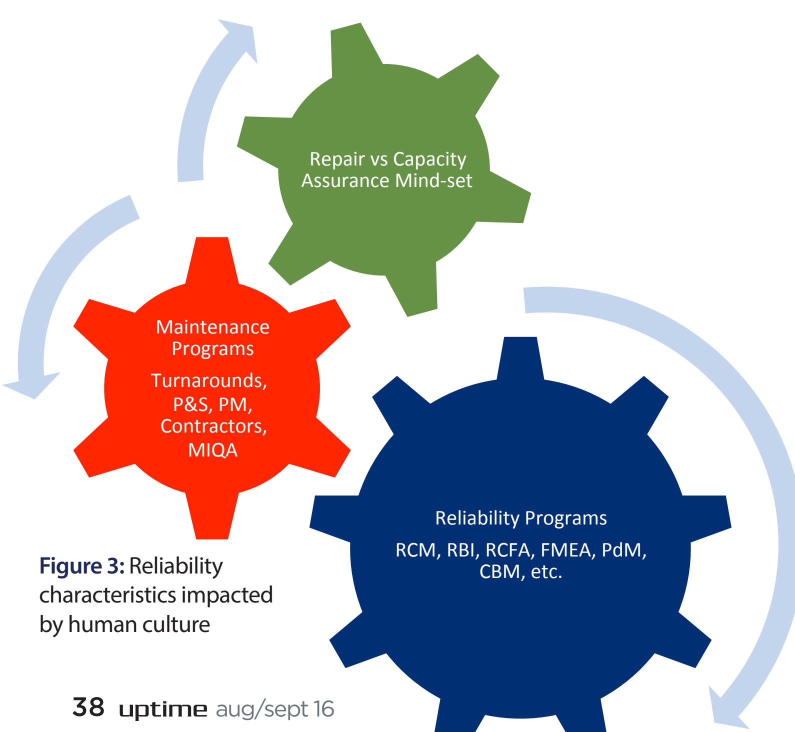


Figure 3: Reliability characteristics impacted by human culture

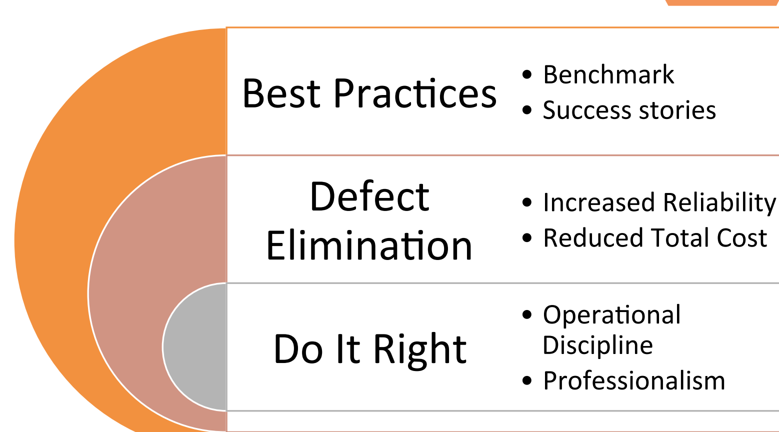


Figure 4: Best practices / sustainability characteristics impacted by human culture

ning and scheduling, skills development and training, operator maintainer relationship and involvement, and analysis tools and techniques. Operational practices should provide the ability to detect abnormalities accurately and quickly, set optimal asset conditions and promote TPM and OBM concepts. The impact can be felt on the number of run to failure cases versus planned maintenance strategy execution, leading to higher team motivation and morale.

Defect Elimination/Do It Right Maintenance Quality: Quality of work is defined as "do it right the first time, always." But human errors made during preventive maintenance (PM) or CBM tasks may eventually lead to additonal failures. This may be due to incorrectly installing a replacement part, using the wrong material of construction, or using defective parts not identified with proper tagging. Also contributing to poor quality are the skills of maintenance or contractor personnel on the task. So, how is a "do it right" culture achieved? Some proven ways to overcome defects are: provide training and procedures for critical and complex assembly systems, use a proper checklist, use the right calibrated tools and perform quality root cause failure analysis (RCFA) and failure modes and effect analysis (FMEA). Equally important is how management appreciates and rewards quality work among the team, such as recognition for reduced rework, improved uptime and reduced total costs, as a result of effective maintenance quality practices.

Conclusion

Clearly, human dynamics in maintenance reliability is a challenging management function to keep the dynamics of unit reliability, safety, cost in balance with market demand and customer expectations. These factors are gained more from experiencing and managing a maintenance reliability function, with the type of asset, manufacturing industry, culture of the country you work in and your personal cultural fit playing key roles in shaping the characteristics of a good maintenance reliability organization.

Many KPIs reflect the impact of your cultural factors. The most important KPIs are the safety performance of the plant and the balance of reliability (availability) to total cost of the unit. Some contributing KPIs are lowest downtime, highest uptime, zero breakdowns, zero accidents, highest overall equipment effectiveness (OEE), best scheduling compliance, lowest maintenance cost to estimated replacement value (ERV)/replacement asset value (RAV) ratio, increased maintenance effectiveness, etc.

All of these require some cultural change or paradigm shift of the maintenance reliability approach.

Is your organization ready?

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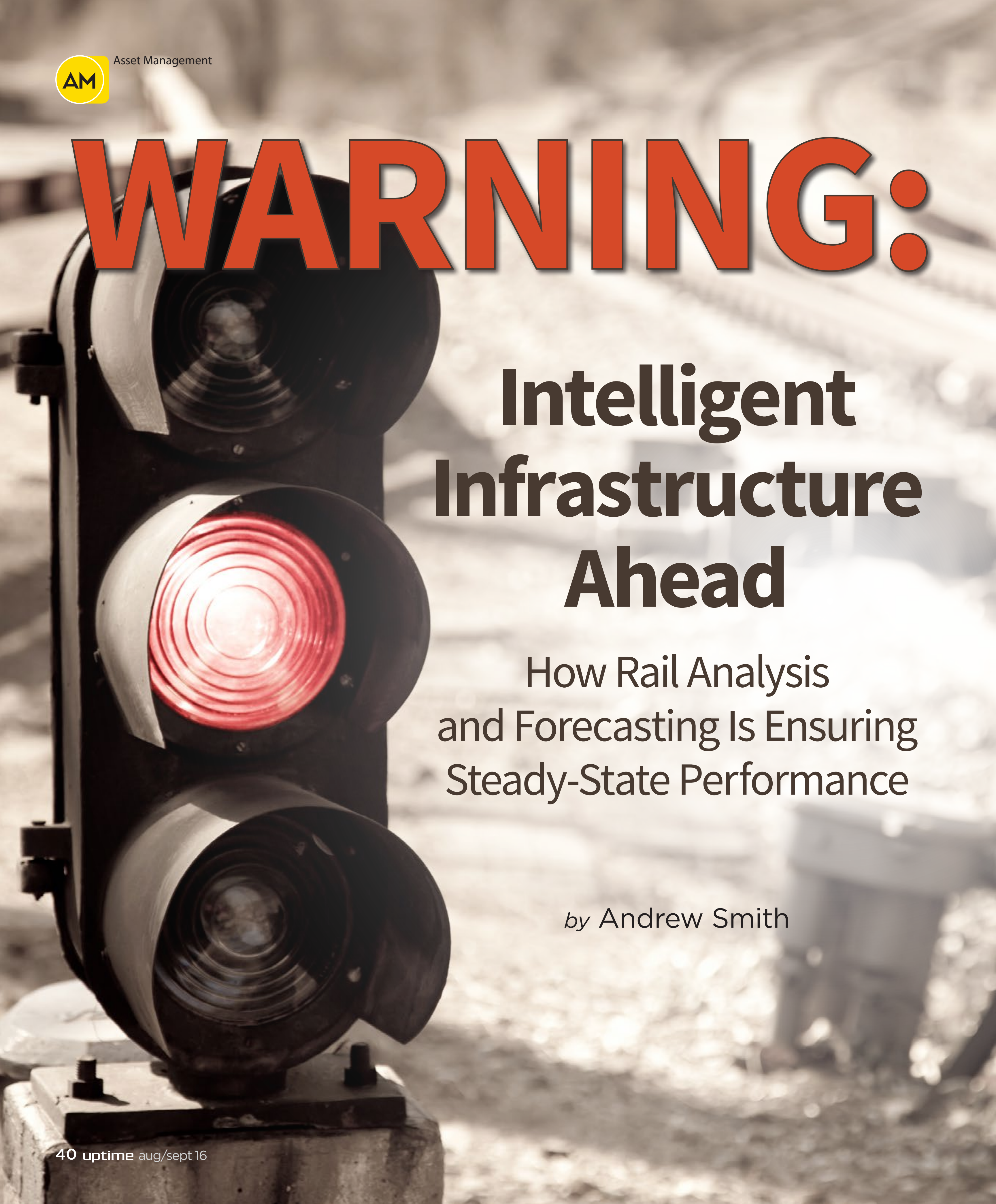


WARNING:

Intelligent Infrastructure Ahead

How Rail Analysis and Forecasting Is Ensuring Steady-State Performance

by Andrew Smith

Seldom do railways have the resources to maintain their infrastructure at a level that ensures steady-state performance. Rather, they are faced with prioritizing maintenance actions to optimize safety and reliability under the burden of constrained resources. Given this reality, railway operations are finding the solution to work more efficiently lies in using information technology. By harnessing the vast amount of existing rail corridor data in a prioritized plan and then assigning the work and monitoring the execution and results with software, many railways are doing more with less resources. This strategy is called linear asset decision support (LADS) and it not only results in steady-state asset performance under constrained resources, it also can improve the asset condition and provide a positive return on investment.

The Challenge

Managing a reliable and safe rail corridor is typically performed with insufficient information and limited resources. Having simple to use and readily available asset location and condition information to prioritize the use of limited resources (e.g., people, materials, equipment and work windows) can dramatically affect the rail corridor's reliability, safety and profitability.

Typical Rail Asset Data

A lack of data relating to a rail asset is rarely an issue for rail operators. Around the world, vehicles measuring multiple aspects of the network routinely collect gigabytes of data. The issue is not, "Do we have the data?" but "What do we do with it now that we have it?" Rail data is often stored in multiple, disparate silos, with little or no ability to view these data sets together.

Data Issues

Rail measurements are also prone to errors of various types:

- Location errors that occur when a feature recorded against the track is in the wrong location;
- Flat lines and spikes;
- Calibration errors that occur when the data recorded is incorrect because calibration settings used to convert raw measurements into usable data are incorrect;
- Filter warm-up errors occur when the first piece of data in a recording or after a gap within a recording is not valid because filters used to derive it take time to generate valid data;
- Environmental issues (e.g., sunlight can blind optical systems) and many measurement devices are sensitive to temperature, moisture, or vibration;
- Low speed issues (e.g., accelerometers are less accurate at lower speeds) and some instrumentation (e.g., laser scanners) might need to be set to disable automatically at lower speeds for safety reasons;
- Deterioration of instrumentation: the instruments used are measuring in a harsh environment and are prone to knocks and dirt.

Typical Recordings

Track Geometry

Track geometry is a description of the location of the tracks in space. Rather than exact X and Y coordinates, engineers are more interested in the variation of the geometry along the track. Items, such as unevenness in the geometry of the rail or variation in the gauge between rails, can cause ride discomfort and increase the risk of derailment.

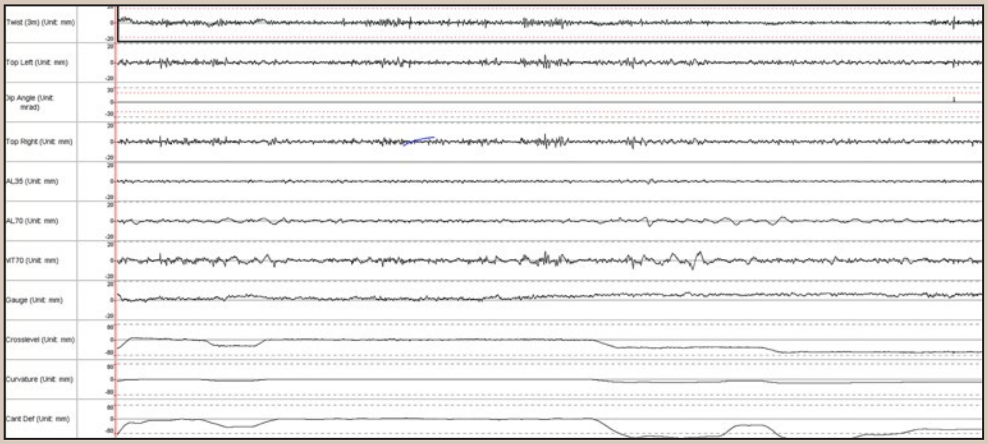


Figure 1: Typical track geometry data visualization

Rail Profile

Rail profile is a measure of the wear on the top and side of the rail. Trending this data helps determine where the rail is approaching the end of its lifecycle and whether it needs replacing.

Traction Power: Overhead Line and Conductor Rail

Traction power comes in two variants: overhead line and conductor rail. Overhead line is generally a high-voltage alternating current (AC) system suspended above the track. Conductor rail is usually a low-voltage direct current (DC) system with more current.

Asset Location and Attributes

Data relating to asset locations and asset attributes is recorded for information, such as the location and age of the rails, as well as for related assets, such as bridges, stations and switches. This data set should provide all the information required to define the linear referencing system for the railway. Any asset that may influence maintenance or renewal decisions should be included.

Maintenance Records: Historic and Planned

Historic maintenance records should be included for several reasons:

- To allow assessment of the effectiveness of historic maintenance actions;
- To ensure trends in deterioration take into account maintenance that has taken place;
- As a record to allow best practices to be understood and communicated throughout the workforce.

Planned maintenance activities should be included to compare them to the predicted future state of the network.

Ultrasonic

Ultrasonic data allows engineers to look inside rails in a nondestructive manner.

Video

When video is synchronized against all other data sets, it provides context as to what is happening around the assets.

Typical Forms of Analysis

There are a number of standard forms of analysis. While the details may vary according to vehicle types, line speeds and units used, the principles are constant for most rail networks.

Alignment

As mentioned previously, measurement data suffers from a number of issues that can prevent optimal decision-making. One of the key issues is the accuracy and reproducibility of the location system used with the measurement system.

For rail measurement data, accuracy and reproducibility are defined as:

- Accuracy: How well can the location be identified in the real world?
- Reproducibility: If the same feature is recorded multiple times, how close together are they reported?

This distinction is important, as a systematic location error would make data reproducible, but not accurate. For example, if there is always a 20-meter error in the reported location of a fault, but the data is highly reproducible, then a fault will be reported repeatedly at exactly the same location. However, the reported location is 20 meters away from where the fault lies in the real world.

Data Cleansing and Validation

As noted previously, data can suffer from numerous issues. The most common of these are spikes and flat lines. Each can be relatively easy to handle provided that care is taken not to remove valid data.

Segmentation

Segmentation is the logical "cutting up" of the track network into lengths of track that can be

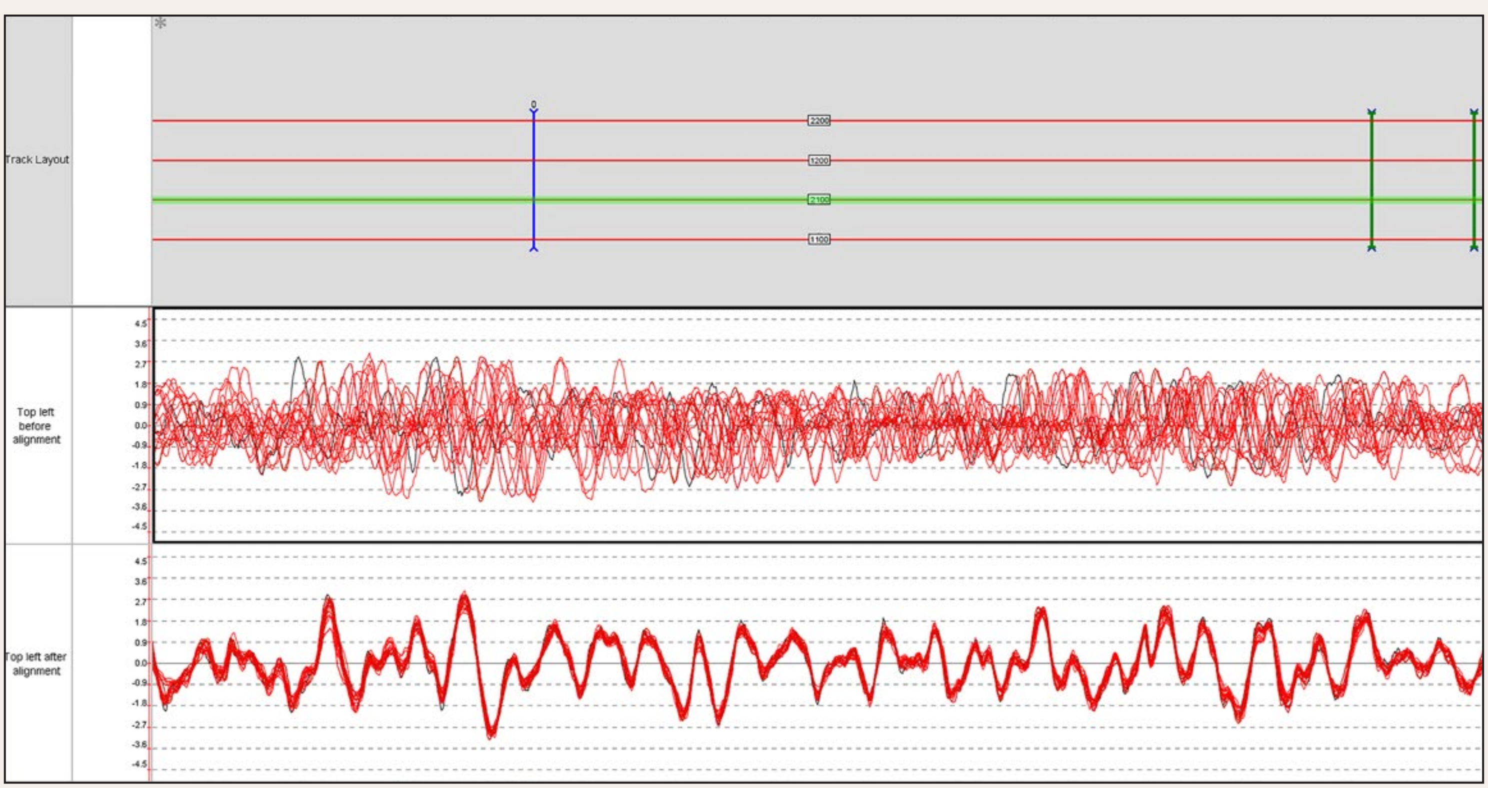


Figure 2: Track geometry data before and after validation and alignment

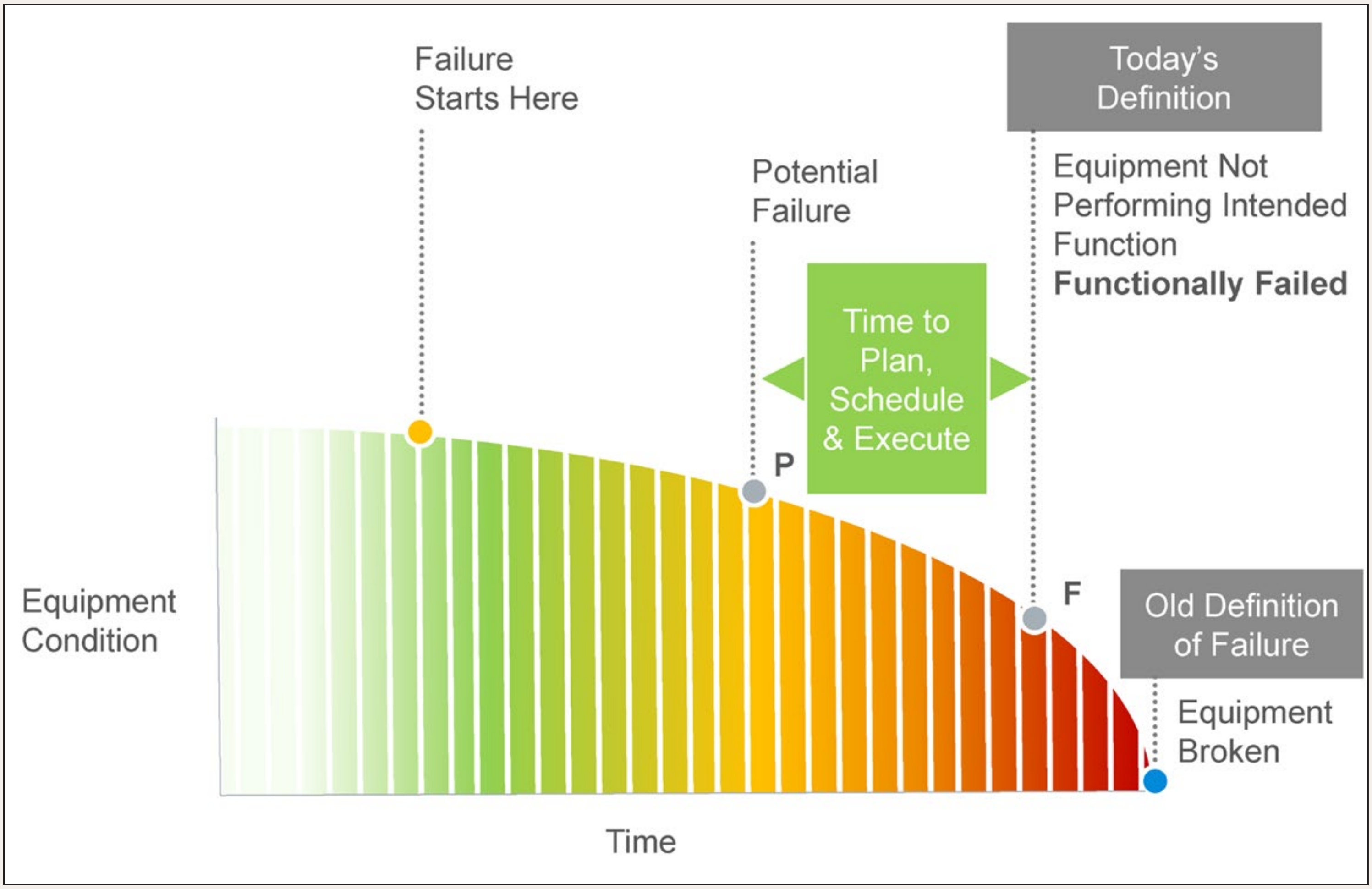


Figure 3: Names of key dates in the deterioration of an asset

analyzed separately. This is done for a number of reasons:

- To group together similar lengths of track;
- Some channels require a calculation of the variance of the channel over a length to derive a track quality index;
- To visualize track condition more easily;
- To report maintenance requirements in manageable lengths of track.

Segments are normally chosen based on what they need to represent and how they are going to be calculated.

Quality Index Generation

Once data has been aligned and cleansed, and an appropriate segmentation has been defined to apply quality indexes, quality indexes can be generated.

A quality index is a function applied to measurement data over a segment that represents the quality of the asset within that segment.

The value of a quality index should be capable of being affected by certain classes of maintenance. The index should be used as a measure for what the state of the asset is and how effective maintenance has been.

Thresholding

As well as defining track quality indexes, network maintainers need to know if there are any localized issues in the network that require attention. This is determined by taking track geometry measurements and applying thresholds to them.

Trending

Trends are mathematical functions that can be used to estimate future values of track quality indexes.

There are two basic mechanisms for trending future values of data:

- Extrapolation from observations – Where multiple measures of a track quality index have been derived, a best fit line can be drawn through the data and then extended into the future.
- Applying a mathematical prediction to the most recent observation – Where insufficient data exists to produce a best fit based on observations, it becomes necessary to predict values based on a theoretical model.

Prediction

Once a trend function has been derived from aligned and cleansed data, future values can be predicted.

There are normally several key condition values that need to be tracked. They are failure starts, potential failure, functionally failed and broken. These values are derived from either

"Once a trend function has been derived from aligned and cleansed data, future values can be predicted"

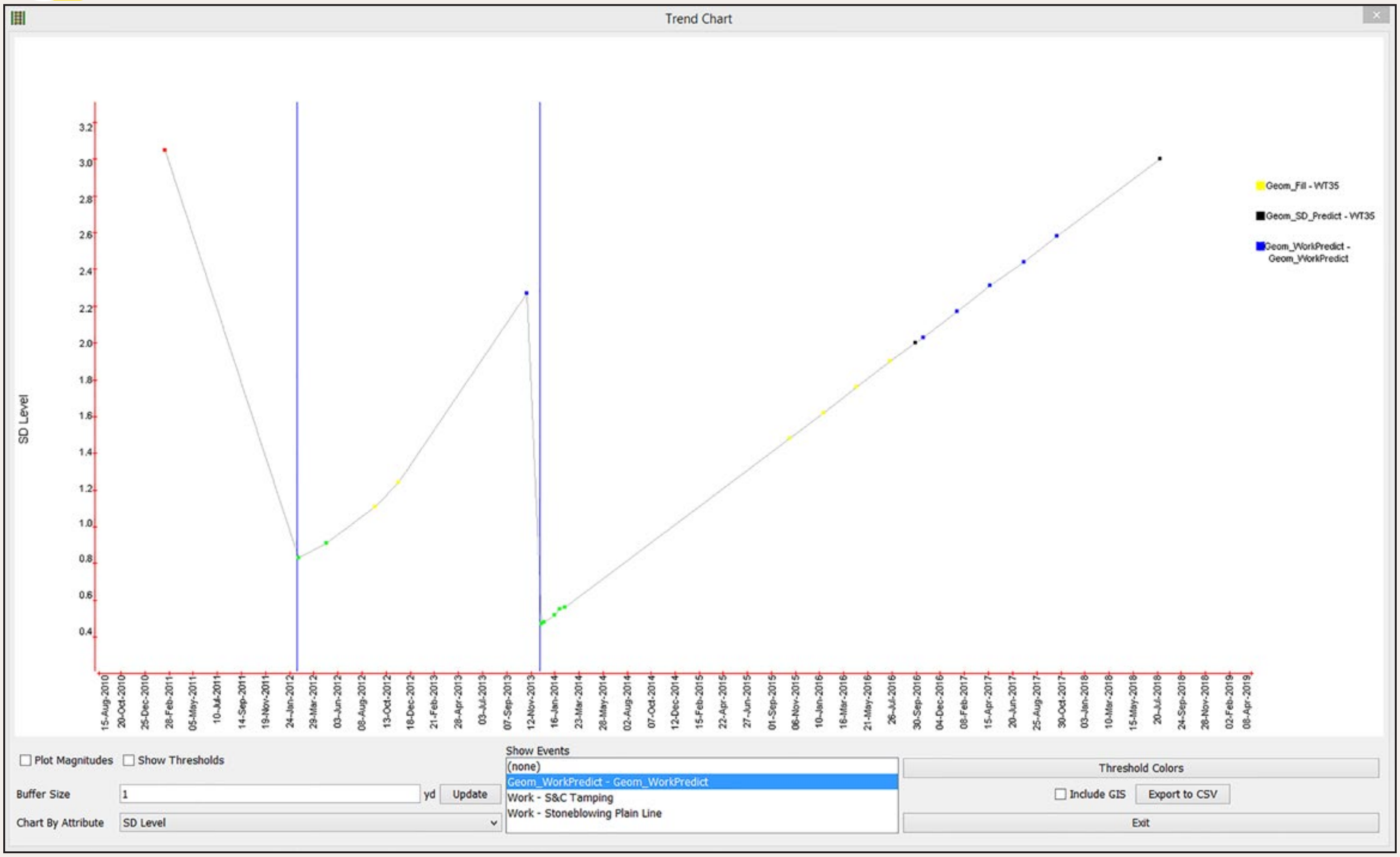


Figure 4: Asset deterioration including a maintenance event

thresholding measurements or deriving quality indexes.

Other Uses for Data Measurement

Validation of Maintenance Effectiveness

Analysis of asset condition before and after maintenance can be used to derive the effectiveness of maintenance.

Asset deterioration typically looks like a sawtooth diagram, where the asset condition (Y-axis, where higher values equals worse condition) deteriorates over time (X-axis, most recent date to the right).

“Engineers are able to make better informed decisions about maintenance, renewals and life extensions”

Track Recording Coverage

Most rail operators have required monitoring intervals for tracks. These intervals are usually based on line speed or track criticality, with the fastest and most critical tracks monitored more frequently. The actual interval can be derived from the measurement data and then compared to the schedule to ensure inspections adhere to the required standards.

Conclusion

While track measurement data needs to be treated carefully to understand its limitations, it contains a wealth of information that can benefit maintenance and renewal maintenance engineers. Using software applications that place the focus on the analysis and forecasting of data trends, engineers are able to make better informed decisions about maintenance, renewals and life extensions. From detecting errors in imported data, deriving statistics and exceedances from measurement data, and predicting deterioration, these predictive analytical tools will be critical for success as the rail industry continues to expand at an increasing rate.

Rail asset managers should take note. Prepare for the challenges that lie ahead and turn them into competitive advantages. Include LADS in your rail infrastructure asset management strategy. The result will be steady-state asset performance, even under constrained resources, reliability and safety, at the lowest possible cost and a positive return on investment.

Andrew Smith *is a solutions executive, rail and transit, with Bentley Systems. He has more than 25 years of civil engineering software experience, with 20 years focused on rail and transit solutions globally. Prior to his current position, Smith led Bentley's professional services team for rail for 6 years and provided technical leadership and rail operations and maintenance to Network Rail during the roll out of a linear asset decision support system.* *www.bentley.com*

Figure 1: Corbion's Blair, Nebraska, operation is a BRC certified food grade, GMP facility

Large manufacturing facilities depend on heavy equipment. But without a proper maintenance strategy, these assets can lead to countless issues, often expending or exceeding budgeted resources. Any manufacturing organization looking to successfully bridge this resource gap must implement an organization-wide reliability program to save money, time and frustration. This program must develop into or from a cultural basis to evolve into a sustainable business strategy.

Corbion exemplifies this rule. Functioning as a truly global supply chain, the organization is a global leader in sustainable ingredients, manufacturing for certified compostable polylactic acid (PLA), lactic acid, lactic acid derivatives and their food grade counterparts. The organization depends on proven reliability practices to maintain high performance levels in its manufacturing processes.

Today, Corbion's Blair, Nebraska, facility boasts a 2.2 percent maintenance cost to replacement asset value (RAV). Its overall equipment effectiveness (OEE), the metric for equipment availability, performance and quality, is approaching 90 percent.

Just 10 years ago, Corbion's OEE was a serious problem. In 2005, the company started a process to improve reliability organization-wide. These efforts culminated in Corbion being nominated for Emerson's 2015 Reliability Program of the Year award.

The Need for Reliability

The company's path toward sustainable plant reliability started with its Blair operation. With an annual production of approximately 120,000 metric tons encompassing some 56 active SKUs, the plant of 71 employees maintains production operations 24x7, 365 days a year.

From late 1999 through 2005, the Blair facility operators, maintenance staff and engineers fought an unending, uphill battle trying to keep the plant operating at any predictable product quality or output capacity. In 2004, maintenance expenditures were $480,000 to $500,000 per month, resulting in a maintenance cost to RAV of 6.5 percent. This level of expenditure was not sustainable, as return on investment was not meeting expectations. Higher maintenance costs were destroying profitability; moreover, the unreliable nature of the facility created undue pressure on the facility's staff, to the point of demoralization.

In 2005, Corbion began working toward its ultimate goals of 1.6 percent maintenance cost to RAV and 96 percent OEEf. OEEf is OEE plus issues in operations' control, such as non-quality losses, speed losses, operational failure, equipment failure and functional losses. (Figure 2). Corbion's starting points for OEEf and OEE were in the mid-70s to mid-60s, respectively, during the 2004 calendar year.

How Did Corbion Do It?

Accomplishing such aggressive improvements meant facilitating a cultural change within Corbion. Before implementing a reliability program, the maintenance rule of thumb was run to failure (RTF), then figure out how to get the plant running again as soon as possible. This RTF philosophy had major impacts on both uptime and safety at the plant.

First and foremost, maintenance technicians frantically trying to reverse an unplanned shutdown are not safe. Corbion values safety above all else and while it has always provided its tech-

Corbion Ushers in Change with a Focus on Reliability

by Vincent Mancini

nicians with the tools and equipment they need to be safe, under rushed conditions, even the best safety equipment is marginalized by perceptions associated with and temptations of using shortcuts to shorten downtime.

Corbion also often failed to analyze the root causes for equipment failures as its focus was to return the plant to a running state. In many cases, equipment ran to failure over and over on preventable issues, simply because the maintenance team was too busy for proper equipment failure analysis. The resulting short-term, reactive repairs to equipment were costly, as it is hard to perform efficient, quality repairs when technicians are rushed.

> "Corbion's Nebraska facility boasts a 2.2 percent maintenance cost to RAV and an OEE approaching 90 percent"

Finally, the RTF culture created an environment where technicians were often incentivized for failure and poor execution. Operators and maintenance team members who waited too long to address problems, or who didn't have proper data to predict issues before failure, would often earn overtime pay for the unnecessary and unplanned outages. With more money in their pockets, they had little reason to desire change.

In order to facilitate change, Corbion needed to change the plant's *run to failure* culture to a *why did it fail* culture. The company needed to help operators, maintenance technicians and managers understand the chain of consequence. It was essential for everyone, on every level, to understand that the job they do and the quality of product they produce impacts every other level of the organization.

Corbion began its process by holding team meetings and increasing training to help employees on every level understand that instead of simply fixing problems, they need to prevent them. Operators and maintenance technicians were encouraged to find the root of the problems and think about solutions. People working on equipment are best equipped to see the chain of consequence. For example, when a technician discovers a valve with a recurring failure, his or her reliability training encourages the person to dig deeper. Perhaps the technician finds a failure in the solenoid, but with the focus now on the chain of consequence, the technician continues to evaluate to determine why it failed. In doing so, the technician may discover the solenoid failed because it had rust in it, which is a consequence of no filter in the line, which resulted from the original design.

Technicians are encouraged to follow the chain of consequence and, more importantly, thoroughly document their discoveries in the computerized maintenance management system (CMMS). Keeping detailed records of maintenance activities in the CMMS allows Corbion to accurately measure and analyze the impact of those changes. With retained data, the company can see what works and what does not, and apply that knowledge to future maintenance issues.

Because of this thorough attention to detail, instead of replacing a valve that will simply run to failure yet again, the technician comes up with a solution to prevent future failures and improve quality of production. Thus, the process will run longer and more reliably, improving the operator's job quality, the overall product quality and Corbion's bottom line, and freeing up the technician to focus on other problems.

Corbion developed a new compensation structure that rewards reliability rather than failure by incentivizing the staff for doing the job correctly. If the plant is running properly, operators can meet their planned production goals without extra labor and stress. Moreover, Corbion tied product performance and product quality to the bonus structure, giving operators and maintenance technicians extra incentive to ensure all processes are running at peak performance.

Results

Within the first 24 months of starting its reliability program, maintenance expenditures were down to $230,000 per month, a more than 50 percent reduction, resulting in an immediate savings of nearly $3 million at the Blair facility.

Because of those early savings, Corbion was able to sustain and build the program, leading to even greater successes. The plant now fully plans two weeks ahead with parts and three weeks ahead for work orders on equipment. As a result, the plant is operating at 99 percent planned work for its maintenance crews. While the facility still has occasional emergency maintenance issues, they almost never involve manufacturing equipment or processes. The total hours of emergency work dropped to 0.95 percent of overall mainte-

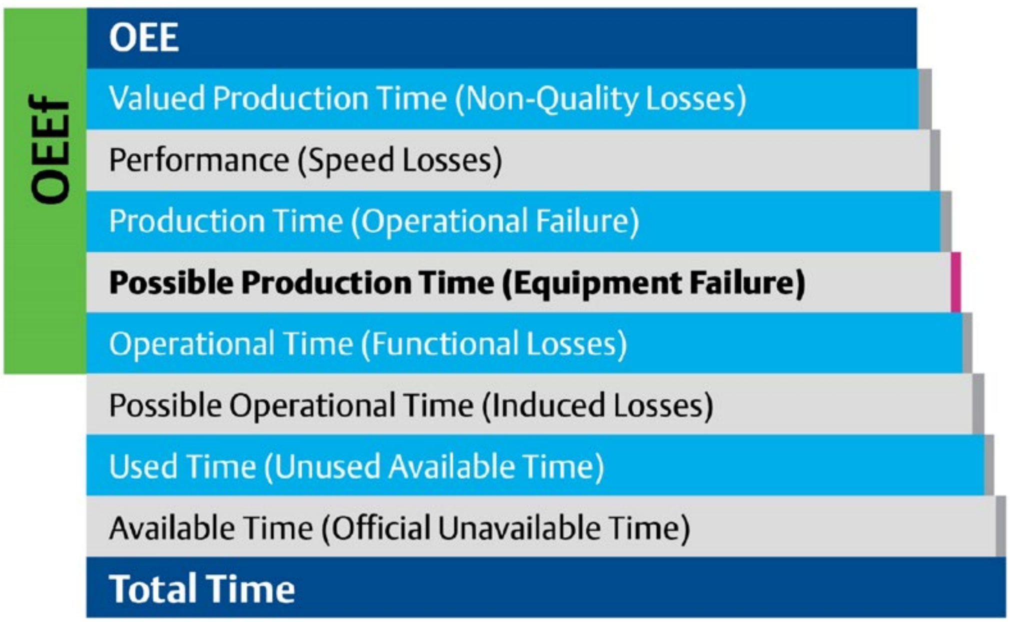


Figure 2: OEEf is comprised of OEE variables plus issues within operation's control (non-quality losses, speed losses, operational failure, equipment failure, and functional losses)

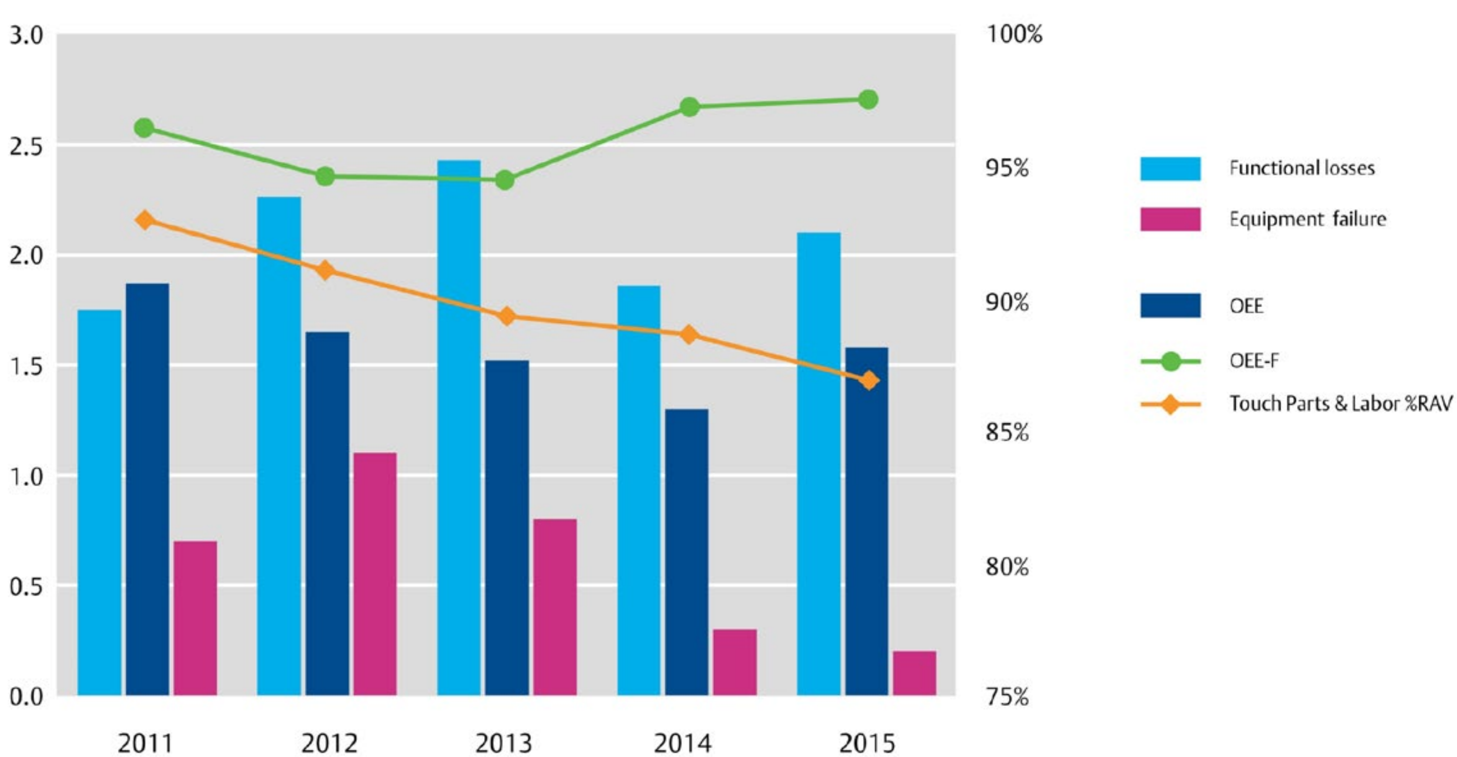


Figure 3: Corbion was able to maintain and improve OEE and OEEf while reducing maintenance cost by reducing equipment failure

nance labor (3 to 4 hours per week) from 10 percent (45 to 52 hours per week) just five years ago. These reductions allowed maintenance full-time employees and total hours to actually drop over the same time period.

> Corbion needed to change the plant's *run to failure* culture to a *why did it fail culture*

Not all reliability fixes with a big impact were expensive. Automating the tempered water system cost approximately $3,700. That system resulted in a savings of $1,500 per month since implementation. In fewer than 10 weeks, it paid for itself.

The facility was able to bring its total plant uptime into the 90 percent range, and more importantly, keep it there. In 2015, the company experienced only 22 metric tons of product loss out of 60,000 to maintenance-related activities within its control. OEE for critical operations is consistently reaching 88 to 91 percent. In short, the plant is running leaner and more efficiently than ever (Figure 3).

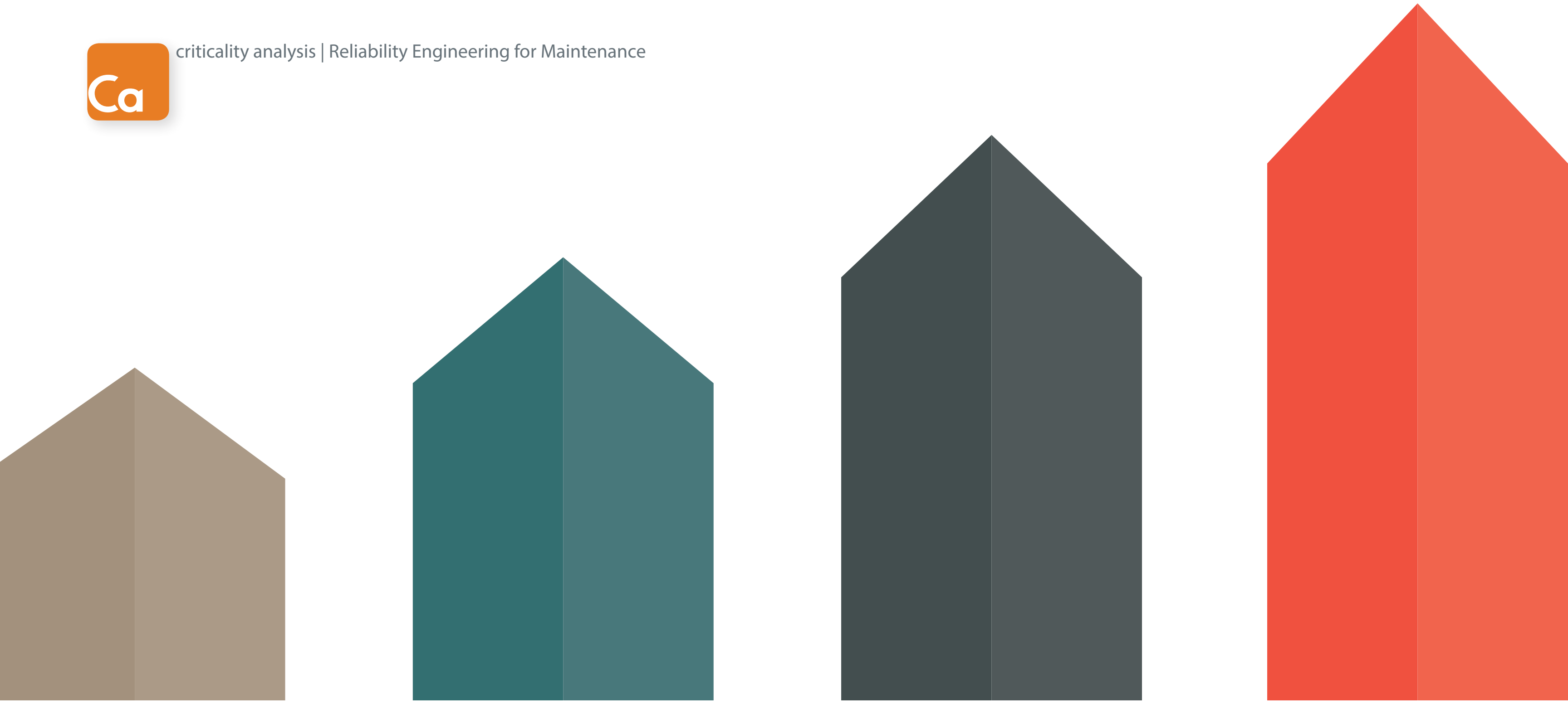
Perhaps most importantly, 2015 production is approximately 70 percent higher, with less overall maintenance spending than at the end of 2005. By helping and empowering its operators and maintenance crews to follow the chain of consequence with manufacturing problems, the plant was able to reduce bottlenecks and achieve a consistent rise in reliability across operations.

Employee morale is up because processes are running better and day-to-day operations are more predictable with less stress. Management morale is up because the plant produces far more with far fewer resources and plant reliability makes planning for the future more realistic.

The plant also had great success putting to use its manually collected highway addressable remote transducer (HART) data and is evaluating the implementation of a predictive maintenance device manager to automate the collection of essential data in the future.

These spectacular results at Blair are spreading to the company's plants around the globe, effecting positive change across the Corbion global supply chain. Blair is proud that its successes are spreading outside the organization, making the plant a reliability standard bearer and resulting in its nomination for Emerson's Reliability Program of the Year. The Blair facility is excited to face the future adding production capacity to existing infrastructure without capital investment.

Vincent Mancini *is a maintenance and reliability engineer at Corbion in its Blair, Nebraska, facility. He is responsible for the continuous improvement and execution of the site's reliability-centered maintenance program. He draws on the 30 years of experience gained in the specialty chemicals, pharmaceuticals, foods, munitions and ordnance manufacturing. Mr. Mancini believes leadership makes a difference.* www.corbion.com



Asset Criticality Ranking

Value for Each Management Level

by Ralph Tileston

Asset dependent organizations need to be continually educated and diligent about the importance of classifying assets in terms of the impact of asset failure on the organization. By using a prescriptive method to identify and classify failure consequences, organizations can most effectively allocate asset care resources within their enterprise asset management (EAM) model. Within the reliability-based maintenance (RBM) asset management model, this prescriptive means is a facilitated process called asset criticality ranking (ACR).

Using a list of all assets to be managed, ACR defines the relative importance of asset failure consequences to the overall business. This is accomplished by evaluating asset failure consequences against graduated criteria within several business impact factors. Typically, the business impact factors of safety, quality, throughput and cost are used for an evaluation, but ACR is unique from other asset criticality assessment tools because it allows for a completely customizable format. ACR recognizes input from a variety of sources, but is primarily a facilitated dialogue between subject matter experts (SMEs).

Regardless of the business impact factors and criteria applied, ACR results in a numerical criticality score for each asset, which then can be put to use in a variety of ways, from daily maintenance workflow management to capital project funding decisions. The ACR numerical results can be scaled and grouped, making it possible to classify the asset groups by their functional importance to the business, such as non-essential to operations, essential to operations and critical to operations (listed in groups of least critical to most critical, respectively).

Table 1 – ACR usefulness to other areas in an organization

Department	Information	Benefits	Preparations
Engineering	Bad actors list by criticality	Candidates for replacement, reengineering or PM optimization	Detailed review from most critical to least
Finance	Bad actors list by criticality	Budget preparation	Equipment replacement schedule based on engineering recommendation
HR/Training	ACR list by area	Training requirements/upgrades	Training records review, OEM training offerings
Production/Operations	ACR list by area	Production commitment	Realistic sales and operational planning
Supply/Warehouse	ACR list by area	Spares for critical assets	Stocking practices based on criticality

By using ACR, asset management stakeholders can systematically arrive at an agreement about which assets are important to the business and why, thereby appropriately applying resources for their care.

Conducting Good ACR Sessions

Nothing takes the place of good, detailed preparation prior to conducting any ACR session. Utilizing a well prepared and organized master equipment list (MEL) or master asset list (MAL) by group and area, consider arranging each ACR session by a discrete list of assets (typically 80 to 100 assets depending on complexity) for a 90-minute duration with facilitation. Choose your SMEs for their particular knowledge of both the equipment and area of the plant or company. Since most companies are usually tight on resource availability, the facilitator should have the ability to manage time expectations, as this is not only courteous, but demonstrates a professional commitment to the EAM process. A word of caution: while it may seem convenient to distribute these lists of assets for scoring independently, the interaction between different SMEs is where the real criticality facts come out. Often, engineering will have a differing view on asset criticality than operations or maintenance, but in any case, getting to a consensus is the real goal.

> "ACR defines the relative importance of asset failure consequences to the overall business"

Preparing the Organization for the Results and Meaning of the ACR

When considering the benefits of conducting an ACR, it's important to understand why and what can be expected from this process. Keep in mind that any ACR is not the be-all and end-all of process checks. The outcome of this activity has benefits for other parts of the organization and is really much more than just a "maintenance" tool. Engineering, finance, human resources/training and production/operations all should be aware of the information that will be provided from the rigor of an ACR. For example, knowing which assets are the most critical and where investment strategies should be placed impact more than the maintenance department. Most companies are a collection of various assets that do not always work well together within their designated process. Perhaps newer equipment versions have increased functionalities or vastly improved reliability curves, or items may have just hit the end of useful life and are due for replacement. Whatever the case may be, the Table 1 chart explains the information and possible usefulness of the ACR process to different areas of the company.

Companies may choose different reports or outcome benefits, but it all comes down to this one question: Does your company utilize the ACR process in ways that benefit the total reliability program or is this just one more data set that gets posted to the computerized maintenance management system (CMMS)?

Some ACR Realities

An analysis of asset criticality rankings performed at numerous companies shows several things always seem to pop up. First, data and usage histories are usually never as good as is claimed. Also, different areas of a plant or division utilize the CMMS differently in terms of work order creation, work recording and parts usage. Furthermore, the MEL or MAL, which tells a lot about the background and organization of all the assets, typically has issues with terminology (what is and isn't an asset), units of measure and a lack of hierarchy. This can leave the ranking process with more opinions than fact. Usually, these issues cannot be completely resolved before conducting the ACR, but simply recognizing them as next step activities will add immensely to the value of the entire EAM process. Speaking the same ACR language and terminology throughout the plants or divisions eliminates many interpretive issues as one goes forward.

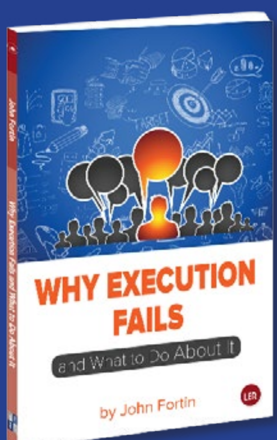
After the ACR process has been conducted, planning and scheduling activities for maintenance work orders can be guided by the rankings on a priority basis. In other words, the highest ranking criticality among the work orders would be chosen first for execution and then each lower level ranking is performed in turn until all back orders are completed.

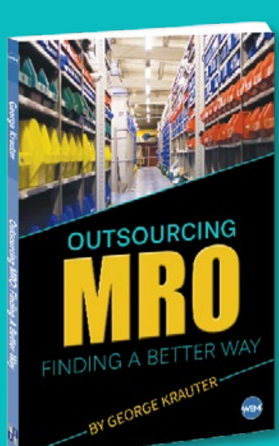
When applying criticality rankings to any work scheduling, the analysis reveals that many companies really do not plan and schedule their work in an organized way. Methods, such as supervisor selection, workforce seniority selection, or simply whatever sequence in the stack gets worked on first, second, etc., is how the work gets accomplished. These methods are subjective and do not comply with the rules of reliability or criticality and really leave no room for asset criticality ranking scores.

In addition, parts may not be available or the correct skills personnel may be off work, both of which could have been avoided with a little advanced planning guided by the ACR results.

Conclusion

Asset-intensive businesses should embrace the asset criticality ranking process and all the discovery that comes with it. Sorting out terminology and usage data, and understanding the ranking process and the implications for work order execution are but a few of the overall benefits. Removing most areas of subjectivity from capital investments, work order process and the supply chain takes the adventure out of day-to-day maintenance routines and supports the capitalization and administrative goals of effective, reliable asset management.





ACR Value: An Inside Story

Recently, a major transit company was conducting a full asset criticality ranking (ACR) on its principal facility that supported equipment maintenance. The facility operation was also critical to many other activities and was touted as a premier example of how facilities should operate. Lots of environmentally sound equipment and many precautions were built into the design. It looked quite impressive!

After the ACR was completed, a series of questions were posed to a group of engineers and maintenance people. From the list of eight critical items, they were asked:

What is the maintenance strategy for each item?

a. Preventive maintenance (PM)
b. Predictive maintenance (PdM), also referred to as condition-based
c. Run to failure (RTF)

What is the material/stocking strategy for each critical item?

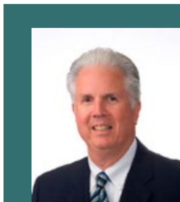
a. Spares on hand with restocking levels identified
b. Spares available at local supplier with less than four hours to deliver
c. No spares arranged, usual expedited ordering in case of failure

Following their responses, arrangements were made for the company's computerized maintenance management system (CMMS) to conduct a query by critical part number live on a screen where the group was gathered. The point was to see what the system contained. The query showed:

- Six out of eight critical items had no maintenance or PMs identified, so by default, they were deemed run to failure.
- Two of the critical items had some mention of an original equipment manufacturer (OEM) recommendation, but were not complete.
- Only one critical item had maintenance spares on hand, but without any reorder point.
- The remaining items had no spares or ordering process in place.

The moral of this ACR is this: Remember to follow up on any new equipment or facility to ensure all assets, especially critical ones, are thoroughly reviewed and vetted for documentation and PM instructions. And whenever an ACR is conducted on any equipment or facility, remember to review the CMMS for the preventive maintenance instructions and spares strategies.

Don't wait for failure to create its own discovery process.



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Thinking Sustainability?

There is an overwhelming focus on sustainability these days. Issues related to carbon emissions, global warming, exponentially growing landfills, rampant energy wastages, etc., which seemed conceptual a decade or two ago, are a reality hitting everyone harder than ever before. Most people are yearning to play a role in contributing to the world's sustainability goals, which is a very good step!

But now, the bad part. In spite of this drive, it has somehow been assumed that the world's responsibility toward sustainability starts and ends with the above stated issues. In recent years, the idea of sustainability has grown to be recognized as the connector that binds a business with the society as a whole while ensuring its profits are rolling. However, corporations these days are trying to communicate with the outer world in a language that everyone understands best, sometimes making them seem and sound redundant and making others wonder if they are really doing enough. That's not to say reducing the carbon footprint or increasing reusability are unimportant or vague topics, but hard fastening these terms every time someone speaks about sustainability somehow creates a notion that it's a mandate for some big corporations or countries to look at while relieving other important stakeholders from this responsibility. In short, generalizing these parameters is depriving one of performing enough action when it comes to implementing these practices in real sense.

Get Focused on Sustainability

All individuals can and should make a conscious effort to work in their own capacity to evaluate how best they can deliver back to society. Dean Kamen, an American inventor and entrepreneur, provides inspiration, not so much for his invention of the Segway, but by making a better living standard affordable. Through his invention of a system that purifies water, people in developing nations have easy and affordable access to potable water. Massimo Bottura, a famous Italian chef, did something similar in 2012 when a small city in Italy was ravaged by an earthquake and the local vendors thought they had no other choice but to dispose of millions of pounds of much valued parmesan cheese. He invented a delicacy and persuaded the government to help him make it famous around the world. Not only did his efforts ensure that vendors suffered only minimal losses, his risotto initiative also helped in clearing the inventory and preventing job losses.

So, how does this all relate to asset management practitioners? For starters, it should get you thinking about what sustainability means to you and how you can contribute. Asset management has a strong potential to implement sustainability. You may wonder how something that purely operates in the context of a specific business domain has anything to do with sustainability.

Consider these questions:

❑ YES ❑ NO Is energy important to you? In a resource constrained space that you live in, do you think energy conservation makes sense to society as a whole? Does the idea of minimal entropy excite you?

❑ YES ❑ NO Do you think an asset's reliability has anything to do with health, safety and the environment? Do you see a safer work environment as a social imperative?

❑ YES ❑ NO Do you think by maxing optimal reuse of assets that you are benefiting society?

If you answered **"yes"** to some of these questions, you are probably someone who would advocate asset management as a candidate for implementing sustainability in the true sense.

by Rejeesh Gopalan

Think Asset Management!

Sustainability's Link to Asset Management

More than half of the typical manufacturing operational expenses are incurred by the energy required to run the machineries and peripheral systems. While assets drive the operation for an organization, they consume an enormous amount of energy and often waste even higher energies than what is required. This should definitely bring a focus to sustainability, which, in principle, targets efforts to reduce energy wastage.

{ Is energy important to you? }

A U.S. Energy Information Administration report[1] finds that worldwide energy consumption by heavy industries has been rising at an alarming rate. If this finding worries you, so to should the amount of energy that gets wasted by the inefficient working of assets. Nothing in the world is perpetual, including the equipment that runs your operations. The nature of entropy ensures that nothing can virtually operate at 100 percent efficiency, with energy losses through friction, heat loss, etc., some of the contributors here. But through an optimal asset management process, you can be sure of reducing these energy losses, ensuring you are burning less energy to produce better process output. Asset management improves machine productivity and cuts wastes, from non-productive work hours to breakdowns, etc. In the process, it automatically takes care of the emission and global warming aspects of sustainability.

An article[2] emphasizing the importance of safety shows a common link of safety-related ignorance that acts as a catalyst to oil spills, reactor blasts, refinery explosions and other adversities. Asset management helps in effectively and efficiently managing safe operating conditions that may otherwise effect workplace occupants and the environment. Safety remains a fundamental aspect of asset management. Through a robust premise of guiding principles and programs, it establishes a safe limit for equipment to operate while deriving operational efficiency. Losses witnessed lately due to these adversities clearly emphasize the fact that a safe upkeep of assets makes an organization responsible toward its ecosystem more than its business output.

Research on servitization,[3] a business model that involves delivering value instead of product, reveals a sustainability link. Imagine a company opting to buy service of an asset rather than the asset itself. With changes in technologies, business needs and the temporary nature of assets, the need to pile up on asset inventory is gone. The traditional model of production and consumption is not environmentally sustainable. Wastes, overproduction and non-context based manufacturing result in customization and added maintenance costs. Servitization offers opportunities from an environmental aspect also, providing incentives for manufacturers to increase fuel efficiency that, in turn, results in less carbon dioxide emissions and reduces the cost of the service delivery. But for its effective implementation, servitization needs asset management as one of its core support systems.

Implementing Asset Management

Are you convinced about the importance of asset management in sustainability and ready to implement? First, you need to be ready to control and sustain this culture.

Knowing the importance of asset management in sustainability is just half the battle won. A strong implementation of asset management policies needs to be backed by an equally robust control mechanism. Imagine a tighter control being brought in through an accountability check to manage a safe work limit for an asset. This can potentially de-risk the environment in which assets are operating. Reporting on sustainability practices also acts as a persistent self-check and could channel the efforts of an organization in this direction without deferral. An external auditing body that keeps a tab on the sustainability mechanism and correctly reports activities in a timely manner would ensure the credibility of such reports and the actions behind them, thereby ensuring persistency. These external agencies would act as enforcement agents for the sustainability policies of the organization. It is extremely important to bring in the assurance aspect of sustainability reporting to ensure the asset management activities of an organization are reported along with other operational and strategic aspects.

Motivate Toward Sustainability

Incentivizing stakeholders plays an important role in getting a natural and voluntary support from them. It also goes a long way in ensuring the focus remains on the sustainability goals. Mechanisms, such as universally tracking adherence to safety parameters (e.g., accident history, waste disposals), equipment emissions and the willingness and ability to reuse, could enable a framework for providing incentives to participating stakeholders. Imagine gifting a "carbon credit" for adhering to the sustainability policies or providing other types of incentives that would motivate employees to do more and achieve more.

Without a doubt, asset management has a strong potential to contribute to society while aligning to the nature of business in which it operates. It is very important not to get restrained by the standards or the general notion of sustainability. Instead, expand your own horizons with a serious desire to operate in a sustainable environment, thus making sustainability a more practical term than a mandated one.

Being a representative of asset management, you have a major role to play in promoting this culture. Are you up to the task?

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10 Components of a Successful VIBRATION PROGRAM

by Alan Friedman

Right Understanding, Right Analysis and Right Reporting

In continuing the Uptime series on the 10 components of a successful vibration program, this article explores three more components: the right understanding, the right analysis and the right reporting.

Right Understanding

Right understanding is about knowing the equipment and understanding how it fails. If you do not understand how the equipment fails, then you cannot come up with an appropriate strategy to maintain it. When it comes to maintenance strategies, you generally have four options:

1. Redesign the asset to remove the failure mode;
2. Condition-based maintenance (CBM) if the machine gives you an indication that it is entering into the failure mode, you can monitor this indicator;
3. Preventive or time-based maintenance (PM) if the component fails in a known amount of time, then you can replace it before that time;
4. Run to failure maintenance (RTF) if the consequences of failure are very low, you can simply let the component fail.

Out of these four options, the first option is by far the best, but it is not always practical. It is always better to remove the root cause of the problem

Figure 1: 10 components of a condition monitoring program

1. Right Goals	Having clearly defined and achievable goals that may evolve over time.
2. Right People	Having the right people in the right roles with the right training.
3. Right Leadership	Inspiring continuous improvement.
4. Right Tools	Having the right tools and technology to help reach the goal.
5. Right Understanding	Equipment audits, reliability and criticality audits, FMECA, maintenance strategies, etc.
6. Right Data Collection	Collecting the right data at the right time to detect anomalies, defects or impending failures.
7. Right Analysis	Turning data into defect or fault diagnoses.
8. Right Reporting	Turning data into actionable information and getting that information to those who need it at the right time and in the right format.
9. Right Follow-up and Review	Acting on reports, reviewing and verifying results, benchmarking, auditing and improving, etc.
10. Right Processes and Procedures	Tying together: people, technology, information, decision-making and review.

than to continuously fight the symptoms. Just think of the airline industry. Every time a plane crashes, the root cause is determined and steps taken to ensure it never happens again. But as creatures of habit, people are more inclined to keep tripping over the same crease in the carpet then to bend down and straighten it out.

For condition-based maintenance, one needs to consider the different failure modes and how they present themselves. Condition monitoring (CM) is based on the idea that machines tell you when they begin to fail. They can tell you this in a variety of ways, such as by vibrating differently, making different sounds, changing temperature, changing how electricity flows through them, changing pressure, etc. These are called indicators of a change in condition. It is necessary to understand the variety of indicators a machine presents for different failure modes in addition to understanding the failure modes themselves. The monitoring technology you choose (right tools) and the tests you perform (right data collection) are based on the indicator(s) you wish to measure.

> "It is always better to remove the root cause of the problem than to continuously fight the symptoms"

You need to know how quickly the failure modes progress in order to know how frequently to take measurements. For example, a turbine with a large journal bearing can go from perfect operation to catastrophic failure in a matter of seconds, therefore, a continuous monitoring protection system is required. A centrifugal pump operating in a clean environment will give the first signs of bearing wear up to a year or more before the bearing actually fails, so monthly or quarterly tests are adequate.

Different indicators will appear at different times. For instance, a bearing will emit high frequency vibration at its earlier stages of failure and lower frequency vibration later. When it's much closer to failure, it might make audible sounds or get hot. This also needs to be considered when choosing a monitoring technology.

Different machine fault conditions generate different patterns and frequencies of vibration and can appear at different test points and in different axes. Therefore, before taking a vibration test, it is important to understand the machine, its internal components and the faults it is likely to experience. This helps ensure you are testing the machine in the correct way. In order to do this, you need to know shaft rotation rates and the number of gear teeth, pump vanes, fan blades, etc. Because this information might not be readily available, you need to document the information you have and remember to track down the information you need.

Right Analysis

Right analysis boils down to creating baselines and looking for changes in these indicators over time. Most people seem to do all of this in reverse. They start with a tool or monitoring technology, then they look for things to test and then they look at the data as if it was tea leaves trying to figure out what it means. A better way to begin is with the asset and its failure modes. Determine the indicators that the machine produces when it begins to fail, select the appropriate technology and test configurations to monitor for those indicators, and then analyze the data to look for changes. If you have good software and take the time to set alarm limits on these specific indictors, your software can do the majority of the analysis work for you.

> "The person who receives the report should understand what the problem is and what to do about it"

Right Reporting

Alarms are different than reports. For a report to be useful, it should contain what is referred to as actionable information. In other words, the person who receives the report should understand what the problem is and what to do about it. Just saying a machine is in alarm does not provide this information. It does not describe what the problem is or how it should be resolved. A typical format for a report might include a diagnosis, such as *moderate motor bearing wear*, and a recommendation, such as *monitor for changes*.

Because vibration and other CM technologies aim to diagnose problems very far in advance, it is not always necessary to act on the diagnosis right away. Reports, therefore, should contain priority or severity levels. Definitions of the severity levels should be agreed upon by all parties so the people receiving the reports know what action to take. Here is a typical severity scheme:

Level 1: Slight fault: No recommendation;

Level 2: Moderate fault: Monitor for changes; Consider risks of failure, availability of spare parts, upcoming shutdowns, etc.; Begin to plan the repair;

Level 3: Serious fault: Plan repair for the near future;

Level 4: Extreme fault: Shut down machine.

Many analysts prefer to wait until a problem is really bad before they report it. This is because they want to be absolutely sure the problem exists and be certain the machine is not repaired earlier than necessary. This behavior is contrary to the goal of providing an early warning to planners so they can plan better. On the other hand, some planners will receive a report with a low priority and schedule the repair right away because they have not been trained to understand the meaning of the severity levels. Optimally, everyone should have access to the same information and everyone should understand how to interpret the severity levels. In other words, report early with a low severity and train the people receiving the reports on how to interpret them.

The amount of detail in the report will depend on who is receiving it. If an outside service provider is providing reports to the maintenance department, the report might not only have a diagnosis, such as *moderate bearing wear*, but also the evidence that suggested the fault. This might include appropriate plots or trends and a description of why the conclusion was made. However, you don't want to give too much detail to people who are not interested in it or who cannot understand it. The thicker the report or the harder it is to find the important information, the more likely it is to be ignored. One problem facing everyone in this information age is information overload, so make sure the reports contain only what is absolutely necessary to the person receiving it and understand that you might need to create different reports for different individuals.

It is also important to consider the *how* and *when* of reporting. How is the report transmitted to the person? When does the person receive it and how does this align with the goals of the program? When it comes to the *how*, it is important to ask if the report is passive or active. Dropping a paper report on someone's desk is passive because the person may or may not get around to reading it. If the report arrives by way of e-mail or a software package that requires an acknowledgment, then you will know your message has been received. As for the *when*, it depends somewhat on the severity of the problem and the rate at which it can progress. A very serious problem cannot wait for an end of the month review. On the other hand, it makes sense to coordinate reporting or review with other planning activities.

Reports are also helpful to the analyst. In most cases, you are trending faults as they progress over time, so don't look at your data every month like it is the first time you have seen it. Instead, start your analysis by looking at your last report. Your software should have a convenient method for displaying the prior report alongside the new data.

Report procedures should be audited. It is a good idea to occasionally sit down with all the stakeholders and make sure everyone is on the same page regarding the issues raised. It is also important to find out whether or not the reports are valued. Too often, people in a plant do things because it is their job and that job might be presenting vibration reports to managers or planners. But if the people receiving the reports do not actually act on them or find them valuable, then resources are being wasted. Either the reports need to be presented differently or the people receiving them need to be educated about their usefulness.

Lastly, reports should be audited for accuracy. What types of problems are being reported? How much misalignment versus unbalance versus bearing wear? What are the severities of the problems being reported? Are defects being discovered at an early enough stage? What percent of the diagnoses are correct? How many failures were missed entirely? All of these are important questions that should be answered in a formal way and as part of an ongoing process. The right follow-up and review also needs to be an integral part of the program.

Right understanding, right analysis and right reporting are only three parts of the puzzle. In order to have a successful program, one needs to have all 10 components in place: Right goals, right people, right leadership, right tools, right data collection, right follow-up and review, and right processes and procedures.

***Alan Friedman** is the founder and CEO of Zenco, a provider of vibration monitoring program audits and training. Alan has more than 24 years' experience in helping people set up and manage vibration monitoring programs. Alan is the author of the book, "Audit it. Improve it! Getting The Most from Your Vibration Monitoring Program." (www.reliabilityweb.com/bookstore).*
www.zencovibrations.com

Q&A

With Claire Gowson

Claire Gowson is an experienced asset management professional with eight years' experience managing multi-disciplinary teams to deliver asset management business change projects in the UK and overseas. She was an active member of the UK Mirror Committee for ISO55000 and contributed to writing and coordinating risk management guidance for the standard. Claire has experience implementing all aspects of asset management change in the public sector as well as private sector delivery partners, and has an internationally recognized understanding of asset management challenges, particularly those facing the highways and port sectors.

Q: What has been your career path to where you are today?

I have a law degree and before joining eAsset Management have been working in the United Kingdom with the public sector, specializing in highways as part of the Highways Agency (now Highways England). My background is a little different, not being from engineering, but it provides diversity when working with the range of people involved in asset management. I am currently part of a team involved in the troubleshooting of an asset data management system implementation with our client's maintenance supply chain.

I have also worked with strategic highway and roads, helping to set up data and data standards. While we practice asset management in the public sector, it is not necessarily a well-known discipline across all the parts of organizations that need to be involved in it.

I participated in ISO55000 development as part of the U.K. mirror committee and helped deliver key aspects of the 55002 guidance document. I am still involved with the ongoing ISO55000 standard efforts and keep up with reports from the various committees.

Q: In your opinion, how has Brexit been perceived by the average British citizen?

Brexit, to the average British citizen, is very divisive. Many people were completely surprised the way the vote turned out even if they were on the "vote leave" side themselves! In retrospect, London-based politicians needed engage with working people across the country who feel disconnected from politics. Some people feel Britain will be better off separate and are saying they're getting their country back from distant bureaucrats. But most people feel the country is on hold until the impacts of Brexit are understood. There are concerns about job prospects and the broader economy. People may not have the ability to move freely between the U.K. and Europe for work. In summary, most people are just uncertain.

Q: After reflecting on your knowledge of the asset management marketplace, how will Brexit affect companies and their asset management strategies?

Brexit is a prime example of when to use asset management principles. For example, engaging with stakeholders to confirm and re-state objectives will help to steady an organization. Asset management offers guidance that can be used to stabilize and communicate in a time of uncertainty. Applying some of the principles of asset management allows organizations to make long-term decisions that people can clearly understand, above the noise of political argument.

In the short term, there may be no immediate effects of Brexit on actual asset management strategies, which should be long-term rather than reactive. But in the medium term, there are many possible changes to the way businesses achieve their asset management objectives. For example, employment. Must we hire from only in Britain or will we be able to recruit from Europe? Depending on the answer to that question, the way key po-

With the recent referendum by British voters to exit the European Union, many have wondered its effect not only on the global market but businesses, asset management and industry's standards. *Uptime* Magazine had a chance to discuss Brexit and it's potential effect with experienced asset management consultant, Claire Gowson.

What is 'Brexit'?
Brexit is an abbreviation of "British exit", which refers to the June 23, 2016 referendum by British voters to exit the European Union.

sitions are filled may change. Should we invest in new assets in the next year, or wait until the full effects of leaving the EU are known?

I think businesses will adopt a kind of "active inertia," and avoid making big decisions until the situation is much clearer.

Q: What are some things asset management professionals can do to help their companies weather the Brexit storm?

There are at least four areas where asset management professionals can help their organizations. They are:

1. Align business objectives – Asset management leaders can use this opportunity to talk with stakeholders and refine or firmly restate their business objectives. Currencies will shift, labor markets may change and raw material costs might alter, but being clear about what your business is there to do and how asset management objectives need to collectively support the business will help your teams know where they're going, in spite of any broader upheaval.
2. Articulate a long-term strategic approach – We're told that realistically, Brexit will take at least two years to enact. Many assets, along with the businesses that own and operate them, will be around for much longer than that. Now is the time to ensure your policies and strategies set out what companies need out of their assets in the long term, rather than reacting to any short-term constraints. The way long-term strategies are achieved will clearly need to adjust to a changing economic climate, but in most cases, business purpose should not be dictated by it.
3. Enforce risk-based decision-making – Start evaluating what the changing political world could mean for your business objectives and asset management plans. Document those risks, both positive and negative, and review them regularly. Ensure risk analysis can feed directly into investment decisions, rather than existing on the side-lines in a spreadsheet. It may be a good time to consider whether your organization's risk evaluation process and criteria effectively handle all the potential consequences.
4. Make transparent and consistent decisions – The restatement of objectives and evaluation of risks to them need to be explained to stakeholders. Any changed business priorities or investments resulting from your risk analysis should be made clear. This communication covers all stakeholders, including staff and colleagues, as well as customers and shareholders. There's no point in adding to scaremongering, but there is value in honestly sharing well considered analysis, otherwise people will fill in the gaps with their own guesswork.

Q: What is your vision of where Brexit will ultimately lead asset management?

I'm not sure Brexit should lead asset management anywhere – rather asset management is a framework for managing the impacts of this change.

However, there are a couple of items around Brexit and businesses. First, we need to develop existing British employees' skills since we may not be able to get those skills from Europe as easily.

Second, businesses need to engage with their young people. Many were disappointed with the vote, since a high proportion wanted to remain in the EU. We must ensure a dialogue with young people to keep them in the country and ensure the open values associated with the "remain" vote have a place in Britain. We also need to find new ways to get students interested in the skilled trades.

Third, Brexit is causing a political storm. Asset management provides guidance on a decision-making framework based on risk. Businesses using asset management principles need to apply the guidance they know to the uncertainty posed by Brexit.

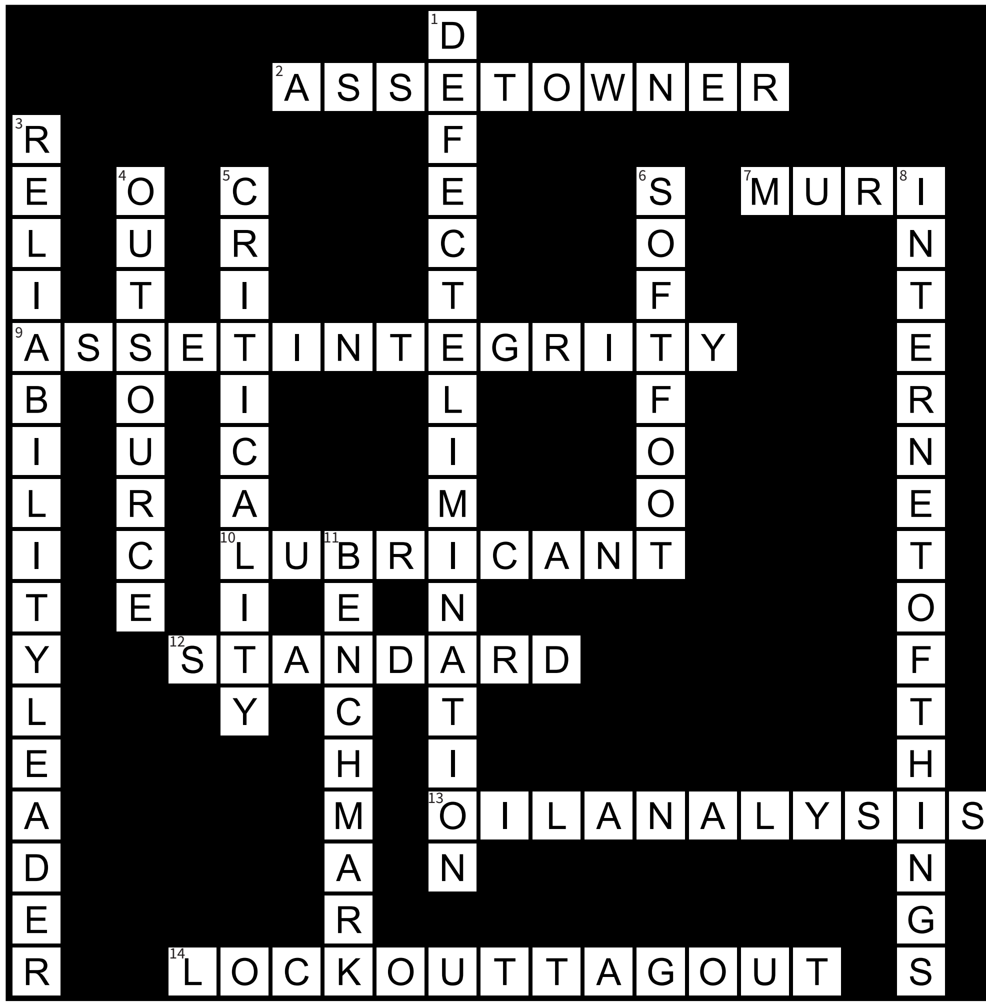
Ultimately, British organizations will need to find a way to keep trading and communicating across European boundaries. Britain is likely to need to meet the same standards as European nations to do business, so maybe changes won't be as significant as people think.

Claire, thank you for spending some time with our readers and sharing your insights concerning Brexit and asset management.

uptime® Elements™ ANSWERS

Crossword Puzzle

Created by Ramesh Gulati



ACROSS

2. A person or group of people who have the total responsibility for the operation and maintenance of asset(s), including capital improvements
7. A Japanese lean word for overburden or unreasonable work
9. The fitness of an asset to perform its intended function effectively and efficiently without being degraded while protecting health, safety and the environment
10. Any substance interposed between two surfaces for the purpose of reducing friction and/or wear between them
12. An established norm or requirement generally presented in a formal document that establishes uniform technical criteria, methods, processes or practices
13. A predictive maintenance technology used to determine the quality of the lubricant oil and/or condition of equipment being lubricated
14. A safety practice to ensure an asset is inoperable, safe and properly tagged when it's down for inspection or being repaired

DOWN

1. The identification of a defect - nonconformance and its removal
3. Anyone who helps another person, a machine or a gadget to do a better job to improve reliability
4. An arrangement where an external organization performs part of an organization's function or process
5. A ranking of assets according to potential operational impact
6. A condition in which one of the feet on a machine does not sit flat on the base - the foot or base may have been damaged causing misalignment and initiating vibration when tightened
8. Network of physical objects, such as devices, components or machines, using embedded technology to communicate with each other with minimal human intervention
11. A standard measurement or reference that forms the basis for comparison

Answers from page 7.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