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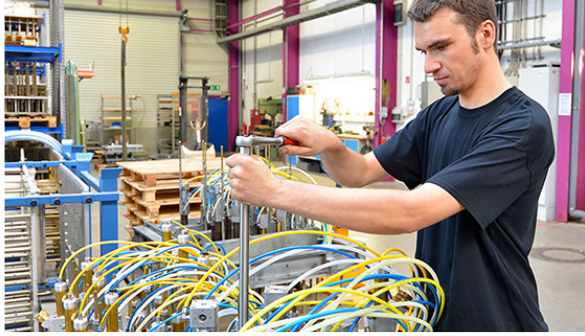

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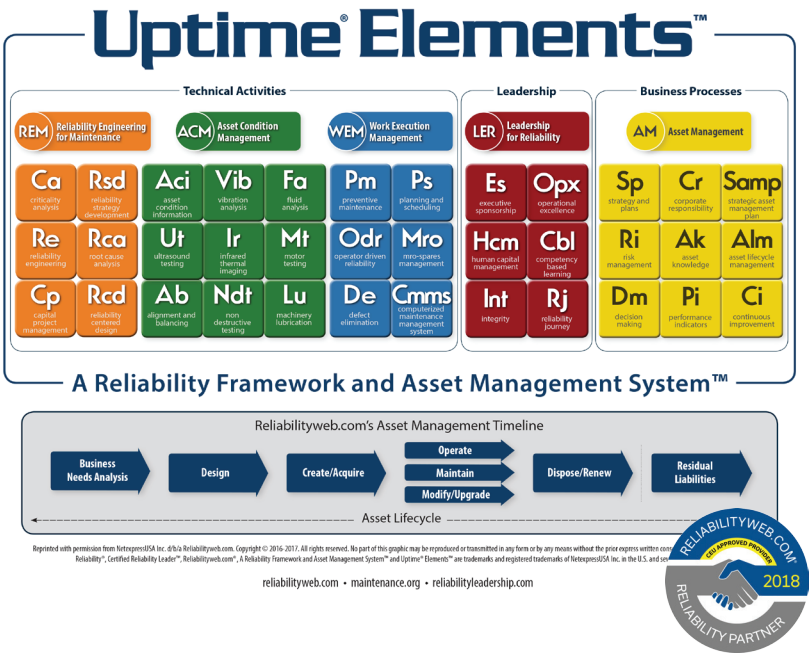

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Maintenance Planning and Scheduling	Planner/Schedulers, Maintenance Supervisors, Maintenance Managers, Operations Coordinators, Storeroom Managers and Purchasing Managers	Apply preventive and predictive maintenance practices. Calculate work measurement. Schedule and coordinate work. Handle common maintenance problems, delays and inefficiencies.	Nov 5-8, 2018 (OSU) Jan 5-7, 2019 (CHS) May 7-9, 2019 (KU) Jun 18-20, 2019 (CHS) Jul 23-25, 2019 (CHS) Aug 27-29, 2019 (CHS)	4 consecutive days 2.8 CEUs	$2,495
Materials Management	Materials Managers, Storeroom Managers, Planner/Schedulers, Maintenance Managers and Operations Managers	Apply sound storeroom operations principles. Manage inventory to optimize investment. Understand the role of purchasing. Implement effective work control processes.	Oct 23-25, 2018 (CHS) Mar 5-7, 2019 (CHS) Jan 29-31, 2019 (CU) April 16-18, 2019 (OSU)	3 consecutive days 2.1 CEUs	$1,895
Planning for Shutdowns, Turnarounds and Outages	Members of the shutdown or outage teams, planners, plant engineers, maintenance engineers	Save time and money on your next shutdown by learning how to effectively plan for and manage such large projects. Learn processes and strategies for optimal resource allocation.	August 6-8, 2019 (CHS)	3 consecutive days 2.1 CEUs	$1,895
Predictive Maintenance Strategy	Plant engineers and managers, Maintenance, Industrial and Manufacturing Engineers, Maintenance Supervisors and Managers	Collect and analyze data to assess the actual operating condition. Use vibration monitoring, thermography and tribology to optimize plant operations.	Nov 6-8, 2018 (KU) Apr 2-4, 2019 (CHS) May 21-23, 2019 (OSU) Jul 30-Aug 1, 2019 (CU)	3 consecutive days 2.1 CEUs	$1,895
Reliability Engineering Excellence	Reliability Engineers, Maintenance Managers, Reliability Technicians, Plant Managers and Reliability Personnel	Learn how to build and sustain a Reliability Engineering program, investigate reliability tools and problem-solving methods and ways to optimize your reliability program.	Oct 23-25, 2018 (OSU) Feb 26-28, 2019 (KU) Apr 30-May 2, 2019 (CU) Jun 18-20, 2019 (CHS)	3 consecutive days 2.1 CEUs	$1,895
Reliability Excellence for Managers	General Managers, Plant Managers, Design Managers, Operations Managers and Maintenance Managers	Build a business case for Reliability Excellence, learn how leadership and culture impact a change initiative and build a plan to strengthen and stabilize the change for reliability. CMRP exam following Session Four.	SESSION 1 DATES: Mar 19-21, 2019 (CHS)	12 days total (4, 3-day sessions) 8.4 CEUs	$7,495
Risk-Based Asset Management	Project Engineers, Reliability Engineers, Maintenance Managers, Operations Managers, and Engineering Technicians.	Learn to create a strategy for implementing a successful asset management program. Discover how to reduce risk and achieve the greatest asset utilization at the lowest total cost of ownership.	Oct 2-4, 2018 (CHS) Feb 12-14, 2019 (OSU) Mar 26-28, 2019 (CU) Jun 11-13, 2019 (KU)	3 consecutive days 2.1 CEUs	$1,895
Root Cause Analysis	Anyone responsible for problem solving and process improvement	Establish a culture of continuous improvement and create a proactive environment. Manage and be able to effectively use eight RCA tools to eliminate latent roots and stop recurring failures.	Oct 30-Nov 1, 2018 (CHS) Mar 19-21, 2019 (OSU) May 14-16, 2019 (CHS) Aug 20-22, 2019 (KU)	3 consecutive days 2.1 CEUs	$1,895

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Contents

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ON THE COVER
Can you find the hidden Uptime logo on the cover? uptime

WEM

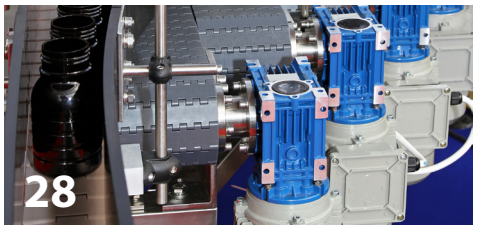
NEW YORK CITY HOUSING AUTHORITY TACKLES NEW TECHNOLOGY

Work Execution Management

Robert Marano

FEATURES

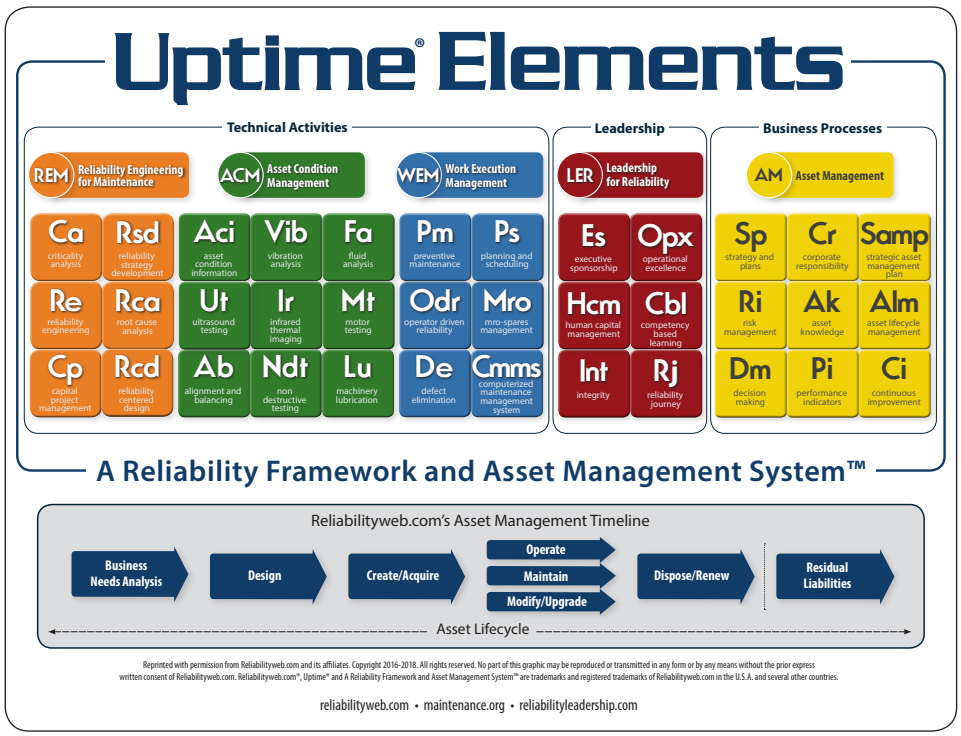
ARTICLES



Contents [Continued]

RELIABILITY PARTNERS

A powerful ecosystem of Reliability Partners who support the Uptime Elements Framework.



Uptime® Elements - A Reliability Framework and Asset Management System™ is in use at over 2,500 organizations around the work to engage and empower reliability culture.

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WHAT HAPPENS AFTER CERTIFIED RELIABILITY LEADER?

Over the past five years, the Reliabilityweb.com team has had the honor to train over 20,000 people on reliability leadership based on the Uptime® Elements – A Reliability Framework and Asset Management System™. These new conversations break from the 40-year traditional set of (mis)understandings around "maintenance AND reliability." We think it is time to free yourself and your organization from what is reactive, unwanted and, yet, persists.

We work on two parallel paths during the Certified Reliability Leader (CRL) workshop. The first is preparing participants to express confidence and competence in understanding the Uptime Elements – A Reliability Framework and Asset Management System by passing a 125-question CRL exam. For many, this is why they pursued the CRL Body of Knowledge and, once completed, they now have a holistic way to understand the many interconnected "elements" required to advance reliability and asset management. The vast majority take that knowledge and return to the path they were on prior to their participation (the default future), although this time, with added confidence and competence.

The second, more powerful opportunity is also made available and discoverable for everyone. However, this path is usually selected by a smaller group of participants who are willing to take a stand for reliability leadership and create a future that was not going to happen anyway. Taking a stand is not an easy thing to do.

These reliability leaders are tapping into a highly defined process from the domain of generation, a powerful place some people use to bring something new to existence. This is the path less taken.

Human beings have amazing capability in the domain of generation; however, many do not feel empowered; many simply do not wish to "rock the boat" and are happy to work in someone else's future. Others are not willing to be empowered or simply do not believe they have the capability to create anything related to the future. There are still others who have no understanding of what keeps them stuck in the default future.

The ability to tap into the domain of generation requires reliability leadership, a specific context and process we create with discovery opportunities during the CRL workshop. It includes effective approaches to embedding it into any existing culture. Reliability leadership meets you and your team where you are.

Imagine what your organization would be like to work in and what its performance would be like to participate in if this were the case:

- ✓ Each and every member did what they said they would do on time and in the way it was meant to be done;
- ✓ When it did not happen or was not going to happen, each member acknowledged that it was not going to happen and cleaned up the impact of it not happening, made new promises and delivered on those promises.

In addition to the above, imagine what it would look like if there was a future for the organization that inspired, touched and moved all the members in such a way that they were all pulling for it, all generating actions to make it happen, and doing so as their natural self-expression.

Often, this is what happens after the CRL workshop. This is why I dedicate much of my time to this work.

I have a sincere wish that you will take a stand to discover this for yourself at the earliest opportunity.

Please enjoy and learn from another incredible issue of *Uptime* magazine. I also invite you to join me in acknowledging the incredible Reliabilityweb.com team who supports my work and adds their own to create the best publication in the world.

I am grateful,

Terrence O'Hanlon, CMRP
About.me/reliability
CEO and Publisher
Reliabilityweb.com®
Uptime® Magazine
http://reliability.rocks

LER

RELIABILITY

IN THE NEWS

Reliabilityweb.com Celebrates 20 Years!

On a warm August day twenty years ago, in a 360-acre cornfield outside of Blair, Nebraska, there was a birth… the first Reliabilityweb.com website was created! This was the same land my great grandfather homesteaded, and the same land my 91-year-old mother was born and still lives on today. A lot has changed over the years. We moved from the cornfield to the beaches of sunny Fort Myers, Florida; we have had a few website "face-lifts;" and we have branched out to produce conferences and offer certification. But one thing has remained constant: our mission and vision.

MISSION: To discover and deliver effective approaches to making asset managers, reliability leaders and maintenance professionals safer and more successful

VISION: To be the first resource one thinks of when thinking about reliability and asset performance

Did you know:

- Reliabilityweb.com has a 10,000-sq. ft. state of the art conference center, Reliability Leadership Institute®, where we facilitate learning and networking events focused on Uptime® Elements and the Certified Reliability Leader Workshop® and Exam.
- The Reliabilityweb.com slogan, "The Culture of Reliability," refers to a shift in the context of reliability as a way of being and acting rather than a series of events or actions.
- Reliabilityweb.com publishes Uptime magazine, over 75 books, a weekly newsletter, hosts Reliability Radio and produces hundreds of videos every year through ReliabilityTV. In addition to this, we deliver three main conferences and dozens of educational workshops every year!

…And all of this is created, produced and delivered by a small, but mighty, team of twenty!

Thank you to those who support the unique work we have done, we do and we will continue to do! ~ Terrence O'Hanlon

WIRAM Keynote Speaker Shines and Focuses on the Role of Women in Technology

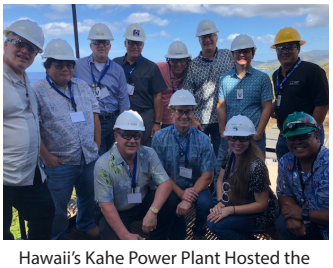
Women in Reliability and Asset Management (WIRAM) held a member meeting with over 70 attendees at MaximoWorld 2018, August 7th in Orlando, Florida. Keynote speaker, Natasha Ravinand, is the author of *Girls with Dreams;* Science, Technology, Engineering, and Mathematics (STEM) advocate; writer; and a high school student based in Southern California. Ravinand addressed the audience on the importance of women leadership and role models in STEM. She commented, "Women, and especially those of color, comprise a small fraction of workers in science, technology, engineering and mathematics-related fields. We must focus on increasing both gender and racial diversity in order to foster more innovation and more inclusion in technology. However, it's also incredibly important to make technical leadership roles more accessible for women. If more women begin excelling in positions of influence in STEM, gender biases against women in technology will begin to fade. In addition, young girls will have role models to look up to, making it more likely for them to pursue technical careers when of age."
For more information: www.maintenance.org

Seattle Hosts Two Reliability Leadership Trainings

Reliability leadership went on the road making two stops in Seattle, Washington. Reliability Leadership Road Map hosted a 1-day event, August 16th, introducing participants to the concept of reliability leadership and the Reliabilityweb.com network of partners and providers. The next visit was extended with a 5-day Certified Reliability Leader Workshop held September 17-21st. Over 65 attendees participated and learned about Uptime Elements – A Reliability Framework and Asset Management System and discovered for themselves what it is to "BE" a reliability leader. The week ended with an apocalypse…Reliability Leadership Zombie Apocalypse Game! Great fun and learning was had by all.

HIGHLIGHTS

Dave Reiber of Reliabilityweb.com Keynoted at the Congreso de Mantenimiento in Tampcio, Mexico



Hawaii's Kahe Power Plant Hosted the Asset Management Roundtable

Digital and Manufacturing Design Innovation Institute of Chicago Hosted the Reliability Leadership Institute F-2-F Meeting

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- ✓ **Best Leadership Program** Saudi Aramco Yambu
- ✓ **Best Asset Management Program** Central Arizona Project
- ✓ **Best Partnership in Reliability** BMS and JLL
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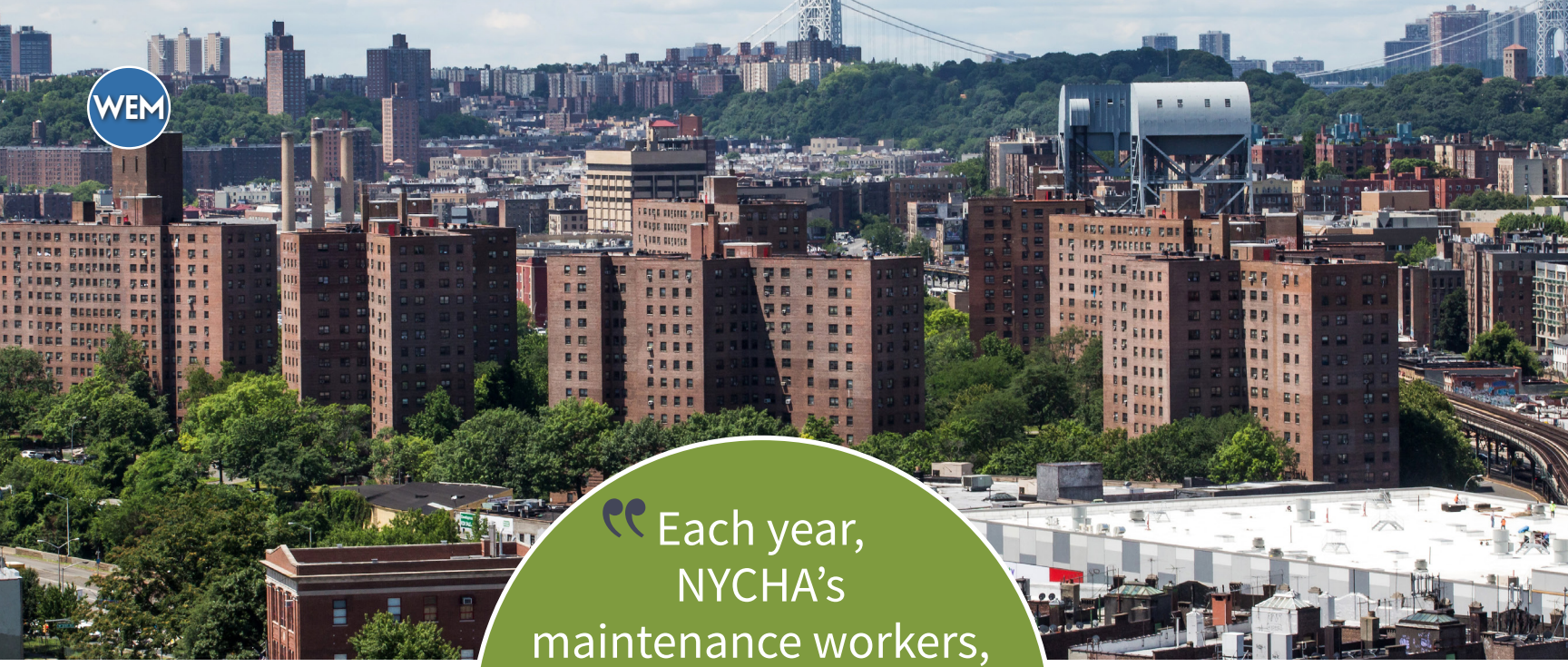


> "Each year, NYCHA's maintenance workers, skilled trades workers and supervisors close approximately two million work orders"

How does the largest public housing authority in the nation document and address its hundreds of thousands of work orders effectively and efficiently? Technology, that's how. The New York City Housing Authority (NYCHA) is utilizing cutting-edge technology to communicate with frontline staff and its residents in real time.

NYCHA has residents or customers, stakeholders, buildings and assets located in Brooklyn, Bronx, Manhattan, Queens and Staten Island. The authority is home to almost 400,000 New Yorkers in 175,000 apartments. Striving to provide its residents with safe, clean and affordable housing is NYCHA's mission, which requires it to respond quickly and effectively to their needs. But, NYCHA was not doing this, at least not at the pace needed to truly provide its residents with the safe, clean homes they deserve.

Each year, NYCHA's maintenance workers, skilled trades workers and supervisors close approximately two million work orders. During some busy months, NYCHA can see up to 300,000 new work orders opened and closed.

Since 2009, NYCHA has used an enterprise asset management (EAM) system to capture, categorize and report on these work orders. Yet, even though the EAM system was a major improvement over the previous "green screen" work ticket system, the process of assigning and closing work orders was still paper-based. NYCHA was still printing out two million pieces of paper every year, requiring maintenance staff and residents' signatures for work orders. Also, the office staff was manually typing in data, allowing several days to go by before work orders were updated in the system. Often, some staff members inputted incorrect information. All in all, this system effectively delayed how NYCHA served its residents.

Enter NextGeneration NYCHA. Started in May 2015 by New York City Mayor Bill de Blasio along with then NYCHA Chair and CEO Shola Olatoye, NextGeneration NYCHA or NextGen NYCHA is a 10-year strategic plan to preserve and protect public housing for current and future generations. As part of this new change to make NYCHA a more modern and efficient landlord, the strategic plan sought to make NYCHA more flexible, mobile and responsive to its customers. NextGen NYCHA envisioned two complementary initiatives to streamline and improve a core business process: opening and closing work requests. One initiative would focus on the residents and the second initiative would focus on the NYCHA maintenance and skilled trades workers.

In September 2015, the MyNYCHA app went live, enabling residents to easily submit, schedule, reschedule and view their non-emergency work requests from their smartphones or home computers. It's safe to say the app has been embraced by NYCHA residents. As of September 2018, 32 percent of NYCHA's non-emergency work orders are opened by residents themselves on the MyNYCHA app.

In late 2015, the information technology (IT) department at NYCHA turned its focus on developing a mobile application to assign, update and configure work orders. In December, the handhelds project kicked off with the goal of equipping NYCHA's 3,700 maintenance and skilled trades workers with mobile devices that allowed them to view, update, address and close their assigned work orders.

The first step was to identify the right mobile solution for NYCHA. The solution needed to integrate seamlessly with the EAM system; be intuitive

> NextGen NYCHA envisioned two complementary initiatives to streamline and improve a core business process: opening and closing work requests

enough to require minimal training; conform with NYCHA's heavily regulated processes; and be flexible enough to fit the dozens of different work orders and inspection types that NYCHA and its contractors perform daily.

After analyzing the various solutions, the clear winner was a platform where all configuration and management of mobile devices and purpose-built applications are done via the mobile server application within the EAM. Working closely together, NYCHA and the mobile solutions provider's team started the implementation of the new mobile work order management system in early 2016 with a pilot at three developments. The pilot was a success and NYCHA's leadership was pleased with the results. In June, leadership requested a full rollout of the mobile solution by December 2016. This aggressive timeline relied on the project team's ability to deploy the mobile initiative to at least six developments each week. An NYCHA development consists of several apartment buildings, with some developments having over 2,000 apartments. Within the six-month period, close to 1,000 staff members were trained and provisioned with new smartphones. Field coaches were deployed throughout the five boroughs to support the newly-trained staff. A dedicated project help desk was set up and a communications campaign was launched to provide videos, quick tips and other supplementary training material.

At the same time, NYCHA worked with the provider to deploy the mobile initiative to over 10 skilled trades, including bricklayers, carpenters, electricians, exterminators, glaziers, heating technicians, painters, plasterers, plumbers and roofers, that consisted of over 2,000 staff members. Each skilled trade had its unique needs, which required a significant effort in gathering information requirements, making technical changes to the mobile solution, testing, developing training and delivering tailored training classes and deployment. By the third quarter in 2017, handhelds were deployed to all trades, completing the mobile solution's full deployment to all NYCHA's maintenance and skilled trades workers. Adoption of the new technology was swift. By the end of the project, more than 85 percent of all work orders were being closed on the mobile devices.

Much like a delivery driver can record detailed transactional data via a mobile device, NYCHA's maintenance and skilled trades staff are now able to do the same. The mobile solution allows for faster updates to system data. Additionally, transforming from a paper-based system to an electronic system has improved data accuracy and data availability. The handhelds allow for the taking of photographs, which workers can share with one another, thus facilitating their ability to truly work as a team and collaboratively plan the best course of action. Being able to share photos has helped streamline some repairs since certain NYCHA service requests may require the work of several different skilled trades.

Supervisors also benefit from the ability to assign work orders from their mobile devices, which frees them from their offices and allows them to be more hands-on at developments. On the clerical side, the staff no longer needs to manually update paper tickets and, therefore, can be assigned to other more valuable tasks. According to NYCHA estimates, the time savings on the clerical side have so far exceeded thousands of hours of data entry.

Also, an unintended benefit of the deployment of the new mobile devices was that many maintenance and skilled trades workers received an NYCHA network account for the first time. They are now able to send and receive

e-mails and have access to a suite of office productivity applications from their mobile devices, thus increasing connectivity among employees of the housing authority.

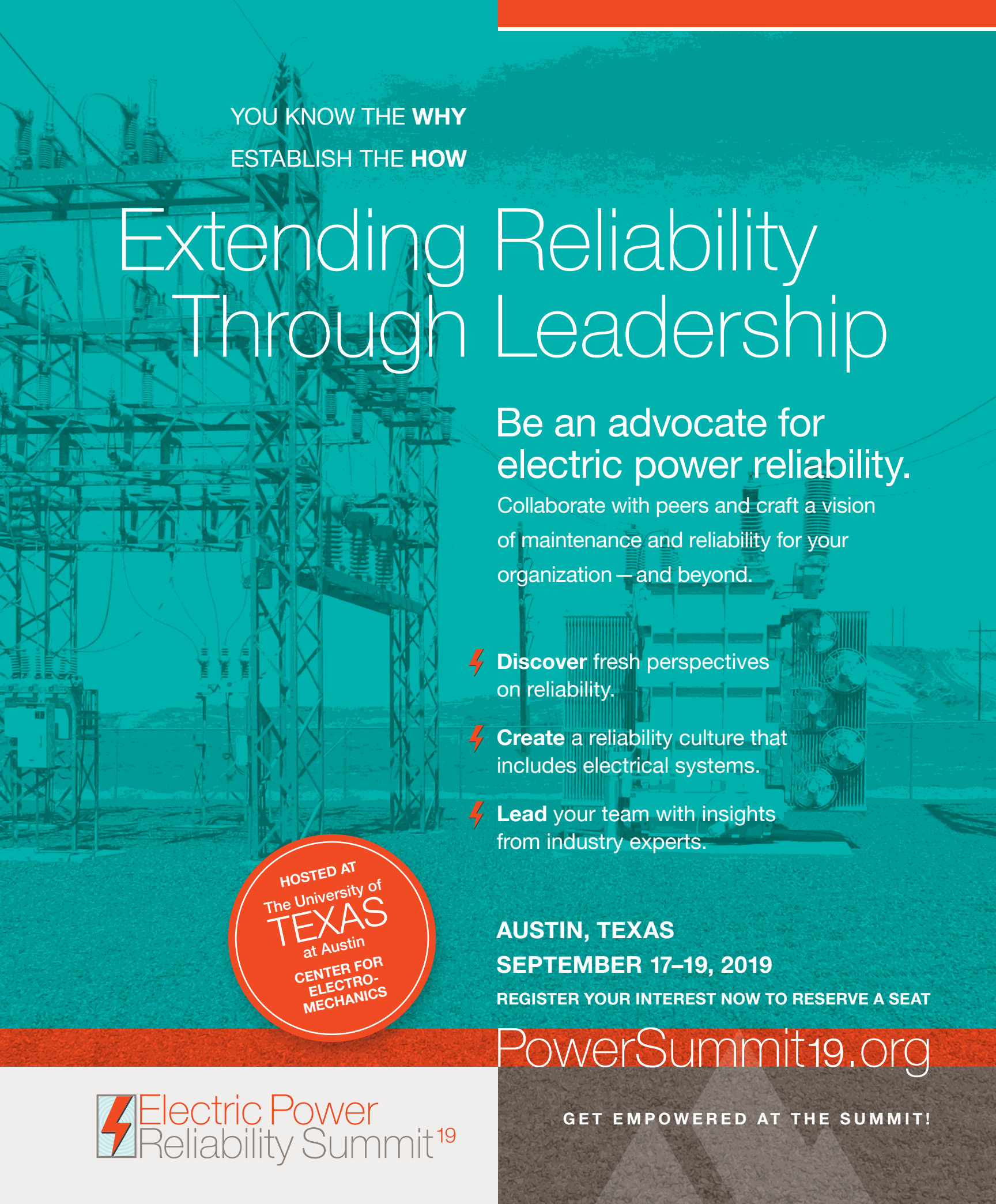
Similar to other project implementations of this size, NYCHA's implementation went far beyond technical tasks. Training 10 different types of crafts where a majority of the workforce is unionized required a significant investment and planning for the rollout. Like most mission critical city services, training had to be cognizant and reflective of the agency's need to continue to provide day-to-day services. Despite these hurdles, the NYCHA needed only 16 months to fully train the 3,700-member mobile labor force and retrain and reassign a portion of back office workers whose functions were no longer required once the mobile solution went live. The NYCHA's efforts ensured no resources were displaced from employment due to its change in asset and facilities management.

Because of this success and from using the mobile device management system, the NYCHA made plans in 2017 to expand new functionality around lead inspections, mold and mildew work orders, and other emerging needs. Also being planned are a host of new inspection types, including closed-circuit television (CCTV) cameras; monthly property inspections; apartment dust wipe assessments; fire and carbon monoxide alarms; air conditioner and window guard installations; asbestos; boilers and boiler rooms; fire extinguishers; grounds; community spaces; health and safety; injury reports; tank rooms; and fire standpipe and/or sprinkler inspection. Also, the NYCHA now maintains working inventory at each of its 144 consolidated development management locations and is looking for a mobile solution to help maintain the housing authority's expansive inventory. This will help to simplify inventory processes, such as assigning materials to work orders, cycle counting and returning unused inventory, all tasks that can be completed much faster thanks to technology.

> "By the end of the project, more than **85 percent** of all work orders were being closed on the mobile devices"

Throughout this process, everyone at NYCHA understood that technology was only part of the solution. Truly successful enterprise level implementations take into account existing and new processes and remain ever mindful of the needs of its end users. NYCHA's size, scope, the sensitivity of the data it handles, scalability, reliability and security were always key requirements. This is why intense collaboration with maintenance and skilled trades managers and interconnectivity with other areas of the organization were essential then and remain integral now.

Robert Marano is Executive Vice President and Chief Information Officer for the New York City Housing Authority (NYCHA). Robert directly oversees the IT department, sets IT direction and coordinates infrastructure and service delivery across NYCHA. He has more than 25 years of both public and private sector experience in IT project management, enterprise architecture, IT portfolio management, business process reengineering, strategic planning and IT governance.



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IN ADVANCED ASSET MANAGEMENT: THE 10 TO 1 RATIO

Jack Nicholas, with contributions from Terrence O'Hanlon, Dave Reiber and Anthony (Mac) Smith

Recently, a question was forwarded from Lhoist's National Maintenance Manager Mauricio Arroyo to Reliabilityweb.com's Global Relationship Leader and Director of Women in Reliability and Asset Management Maura Abad. The question was prompted after Mauricio read the *Asset Condition Monitoring Project Manager's Guide* (Guide) to which Maura had provided a download link. The question was:

> *"In their [the Guide's coauthors] experience across the industries, what is the average Cost Avoidance that they have found?"*

In the original query and subsequent communications, Mauricio elaborated by adding:

> *"I have always heard that the cost of no maintenance (run to failure) is "x" times higher than planning a job and or applying any of the Preventive and Predictive techniques that we have available today. That 'x' was the ratio that I am looking for. We are using at Lhoist a 3 to 1 Ratio, but based on other experiences that I have seen, it could be as high as 6 to 1."*

Maura forwarded the original question to Dave Reiber, Senior Reliability Leader at Reliabilityweb.com, Terrence O'Hanlon, CEO and Publisher of Reliabilityweb.com and Uptime Magazine, and Jack Nicholas, an independent author and consultant who, along with O'Hanlon and Reiber, is a coauthor of the Guide.

This prompted an intercontinental and transcontinental dialogue. Dave Reiber was in Budapest, Hungary, Terrence O'Hanlon was in Florida, Jack Nicholas was on a cruise touring Norway's fjords, and Jack asked Anthony M. (Mac) Smith, author of the book, *Reliability-Centered Maintenance* (1993), and coauthor of *RCM: Gateway to World Class Maintenance* (2003), then on vacation in southern California, to comment as he had frequently expressed his opinion on the value of RCM-based maintenance.

DAVE REIBER

Senior Reliability Leader, Reliabilityweb.com

20 years as a leader in Enterprise Asset Management and Asset Condition Monitoring as the former Global Training Lead for Enterprise Asset Management & Predictive Maintenance Business Lead for General Motors

I think the first thing to address here are the definitions of Cost Avoidance versus Cost Savings.

1. **Cost Avoidance** – An estimated dollar amount expected to be paid in the future if proactive events did not keep the machine, tooling, or system producing units; (e.g., Avoiding downtime by fixing something that could potentially break down)
2. **Cost Savings** – Dollars that are currently spent, but will not be spent in the future; (e.g., fixing something that causes you to use less steam, air, electrical power, etc.)

NOTE: These definitions differ from, but are not inconsistent with, those terms in *The Professional's Guide to Maintenance and Reliability Terminology* published by Reliabilityweb.com.

On page 19 of the *Asset Condition Monitoring Project Manager's Guide*, it is stated: *"Monetary benefits (i.e., cost avoidance and cost saving actions) rapidly accumulate while an organization is working through the hump period. In fact, there are usually enough, so only a portion of these benefits may need to be calculated to make program justification apparent. It is most important for the ACM team to keep track of these cost avoidance and cost saving KPIs."*

I believe you should capture all of the Cost Avoidance and Cost Savings details. It will take more of your time, but when it becomes a habit, it will be easy to do and the information will always be there to support and promote your program, even after the initial finds become further apart.

The question of Ratio is completely subjective to your particular situation. I think it is best to get the Financial Officer for your business or organization involved. A good way to do this is to get the General Ledger (GL) account information for each area of the business.

EXAMPLE: In the Automobile business, the costs on the final line (GL account) of a car or truck plant can be several hundred dollars a minute. In the same building, because of buffers and counters, the costs in the Paint or Body Shop (GL accounts) are significantly less, but still very high in relationship to downtime. Therefore, the cost avoidance is much higher on the Final Line. By using the GL account information, no one can dispute the value.

Any time you can capture Cost Savings, it should be recorded. It is indisputable.

On page 64 of the Guide, we mention **"Find-of-the-Week."** It is important to keep this information at hand to celebrate the wins.

SEND

JACK NICHOLAS

Author

45 years' international experience leading, teaching, training and consulting in the fields of maintenance and reliability in government, military, utility and commercial venues

As to ratios, the returns are highly variable and depend on too many factors to generalize. In my experience, it's better to gather overall return on investment (ROI) together and not try to segregate individual ones. What you'll find is some things work very well (i.e., give high ROI) and others not so much for many different reasons, including the enthusiasm of those upon whom the savings or cost avoidance initiative and calculations depend, the effect of applications of various strategies and technologies, etc. For example, ultrasonic analysis works better on some systems than others. Same for infrared thermography or vibration analysis. So, the effect of your investment in technologies and all attendant costs will vary and so will your returns.

As to the KPI definitions and usage, as long as your definitions and algorithms make sense, the most important thing is to follow what you come up with rigorously and consistently **all the time**, allowing no deviation without a change to what you've formally written. Any changes should be documented in follow-on KPI definitions and rationale, with reason for the change, so anyone questioning your logic can understand why you made the change. This goes to the heart of your competence and integrity in the eyes of those who try to judge your credibility and the usefulness of your KPIs.

SEND

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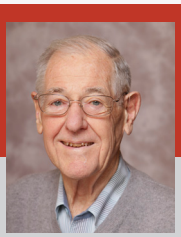

ANTHONY (MAC) SMITH

Author

55 year engineering career and is an internationally recognized expert in the application of Classical RCM providing RCM consulting and education services to more than 75 clients in the Fortune 500

Thought about the ongoing dialogue about the 10 to 1 ratio and I feel there may be a larger issue that brought this up – namely the Role of Operations and Maintenance (O&M) in Supporting (or Failing to Support) Corporate Financial Goals. So, I took off on that topic last night and the lengthy response is as follows:

Try to look at things in the simplest way possible. So, for O&M people who are concerned about how their organization affects their company's financial picture (i.e., Profit and Loss), they can control (or fail to control) only three aspects of what they do or fail to do. An example I frequently use to open most discussions that I have on the topic (Why Are We Here?) is that O&M people COST their company money to keep the production or process working as intended. Depending on how good they perform that function, they play a key role in keeping the product moving to the marketplace (PROFIT). This is why I believe the O&M organization should actually be considered a PROFIT CENTER if they do their job effectively. Now, the COST elements here are how good they PREVENT Failures (Preventive Maintenance - PM) from occurring and, if that doesn't always happen, how quickly they can CORRECT the problem (Corrective Maintenance - CM) and restore continued production. If they are good at those two things, they are a direct contributor to PROFIT but, if they are not, they are a major factor in LOSS. In other words, if they avoid DOWNTIME (DT), they become a major factor in making money. To me, that is a fairly direct and simple way to think about O&M's role in the organization.

Now, one of the things that intrigues me about RCM is that it requires you to first understand where your O&M organization gets its most pain – Which of my plant's SYSTEMS are eating my lunch (i.e., costing me the most to constantly be in a fix it (or REACTIVE) mode? Enter the Pareto chart and the 80/20 rule. Which of the above parameters could logically be such a database for a Pareto chart? Well, it could either be CM data or DT data. Which of these two is the easiest and most reliable to access? Anyone with database experience will say CM data, either Work Order (WO) counts or WO cost data. From experience, CM count data is best, although trial exercises have clearly shown that either CM or DT leads to the same Pareto chart and the same 80/20 conclusion.

The second thing that intrigues me about RCM is that it now gives me a tool, the Decision Logic Tree, to further determine which Component Failure Modes in that System are the culprits behind its "bad actor" label. The criteria that identifies the culprits are those that lead directly to a Safety/Environmental, Outage and/or Economic issue when and if they occur. And, in fact, it also determines if they are Hidden. The default decision is to do nothing and fix when convenient. This is commonly referred to as Run to Failure (RTF).

So, where does the 10 to 1 ratio come from and what does it mean? Namely, if we did the right PM action in the first place, chances are very good that the Failure Mode would occur infrequently, if at all, and we would not be faced with the need to do CM. And, here is where my RCM analysis results start to show some eye-catching results. First, a large portion, typically 30 to 70 percent, of the Failure Mode population has **no** pre-RCM assigned PM task at the time of the analysis. Second, where a PM task did exist, it was frequently (10 percent or more) seen to be an action that could not have prevented the Failure Mode in the first place. So, when the analysis did define a new PM task, we became very interested in determining what the new PM would cost to prevent the Failure Mode versus what a CM action could (or did) historically cost to take it back to its originally intended functional state. A pattern emerged over time and the data reflected that the CM cost was typically eight to 12 times larger than the cost of the new PM task. So, we talk about that finding using a 10 to 1 ratio, on average. Some of the projects that provided inputs to this were paper mills, refineries, nuclear and fossil power plants, aircraft assembly lines and wastewater treatment plants, which are among my 87 RCM projects successfully completed. The absence of published data on this ratio was the resistance of Companies (i.e., lawyers) to publicly release such information. My book, *RCM: Gateway to World Class Maintenance*, contains seven fairly complete case histories, but even the release of this book was delayed over a year obtaining legal okay to publish what is there. Virtually, no hard cost data is ever seen in public books or papers.

Another startling result was the multiplier that existed when the Failure Mode led not only to the COST to restore, but also involved a significant DT and loss of product sales. Thus, the multiplier of 100 to 10,000 can occur there. If those ratios blow your mind, think about a 1200 megawatt power plant out for just one day and the cost of replacement power costing some $800,000 per day. Or, consider 20 sold 777 airplanes sitting on the tarmac that are costing the Seller a penalty of $25,000 per each day that delivery is missed all because the machines that made the pieces for the overhead bins were in a constant state of fail and fix.

I hope this helps to explain the 10 to 1 ratio.

SEND

TERRENCE O'HANLON

CEO & Publisher, Reliabilityweb.com & Uptime Magazine

Certified in Asset Management by the Institute of Asset Management, acting Executive Director of the Association for Asset Management Professionals (AMP) and co-author of the book, "10 Rights of Asset Management"

Mac,

Fabulous response – I learn more every time we speak or with every e-mail you send.

My one issue is that we should focus on the business issues that may or may not correlate to work order count, but I also agree with your (Mac's) advice to use whatever data you can easily get your hands on.

Ford Motor Company came up with a 10X rule that states that the cost difference to removing a failure mode depends on the Lifecycle phase you choose to remove it in.

Remove the failure mode in design 1X
Remove the failure mode in early build X 10
Remove the failure mode in final assembly X 100
Remove the failure mode in operations phase, could be 1,000X to 10,000X

So, a multiplier of 10:1 is reasonable.

This thread from Jack, Dave and Mac has been outstanding and I appreciate Mauricio thinking enough of us to ask. He got a real treat with better replies than most would ever have access to. Thank you.

There is such a lack of asking questions/discussion/respectful debate in our community – I really cherish these opportunities.

I hate to sound like a fuddy-duddy, but in the beginning of the Internet – for the first year when all global maintenance experts first connected – we hosted an e-mail discussion group that was basically a college education in all things maintenance, reliability and asset management. Maintenance.org still has healthy discussions, but I sure miss that e-mail group. Eventually people stopped sharing, they disagreed "disrespectfully" and then the dreaded marketing/sales messages followed. It was good while it lasted. This group and discussion reminds me of those days.

SEND

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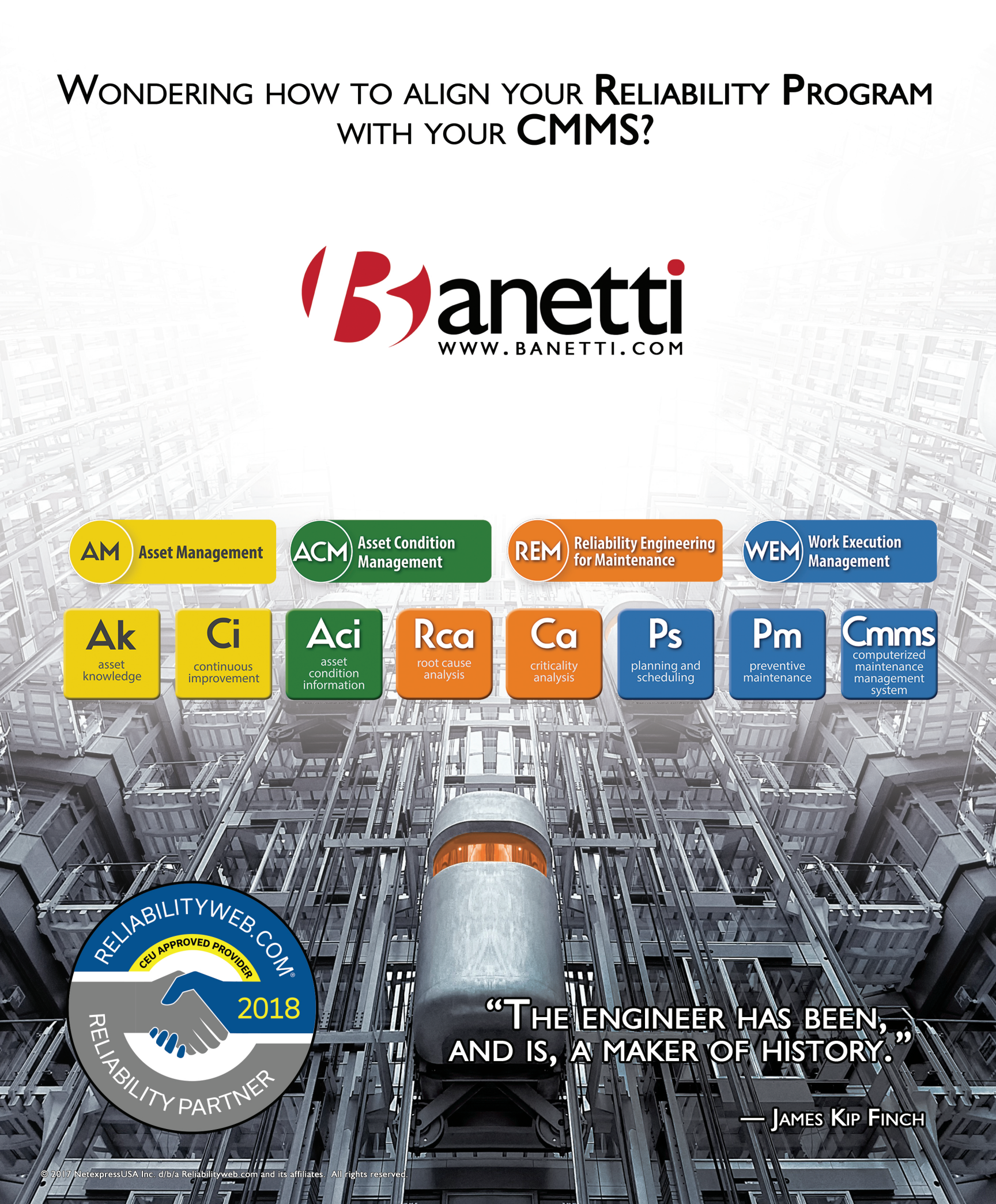

"The engineer has been, and is, a maker of history."

— James Kip Finch

Ci
continuous improvement

CONTINUOUS PREDICTIVE MAINTENANCE IS THE WAY FORWARD

Sean O'Connor

Over the last few years, the continuous improvement of maintenance strategies is taking place at an incredible pace. The rapid influx of accessible data has the industrial world living in exciting times. As the industry just begins to scratch the surface of what the Industrial Internet of Things (IIoT) can deliver, there is a tremendous opportunity to displace antiquated ways of carrying out asset management.

Continuous monitoring of critical equipment and real-time access to predictive analytics have the ability to provide consistent and reliable insights that may have been only available in limited quantities using legacy systems. Enterprises, large and small, are looking at upgrading their existing condition monitoring technologies to include continuous monitoring as a means of staying competitive within a global economy.

> "It is never a good day when critical assets fail unexpectedly"

Continuous PdM as a Foundational Element

Throughout the years, at facilities large and small, many maintenance models have been implemented, including run to failure, preventive maintenance (PM) and predictive maintenance (PdM). There has been a swift and vast evolution of technology, from transferring data on floppy disks to the advent of cloud computing. However, gaps will exist, which is where continuous PdM comes into play as a foundational element of helping businesses meet their asset management goals.

When Critical Assets Fail

It is never a good day when critical assets fail unexpectedly. A maintenance reliability strategy can be as much an art as it is science. Unfortunately, the days of relying solely on folks walking the shop floor as the primary means of work identification have passed. The advent of such tremendous technology, coupled with the current employment trends, presents a situation where you no longer have that lifelong employee who can walk into a space and just know by the sound, smell, or feel of the floor that something is wrong. You still need to know what is wrong, but now that resident tribal knowledge can be acquired through wireless sensors and feeding data from existing instrumentation into a machine learning system.

You probably have been witness to failures where continuous monitoring would have significantly increased the likelihood that a defect was caught before it resulted in a loss to the business. Take this example, for instance: One particular area, which housed temperature sensitive material, required 24/7/365 adherence to strict environmental parameters. A defect in the area's cooling system resulted in a loss of temperature control. By the time the error was noticed, it was too late to salvage the material.

Here's how continuous PdM could have been beneficial in this case: There was a high temperature alarm in place as a lagging indicator. Had there been alerts to leading indicators of the system's compromised condition, such as a deviation in the compressor's normal cycle time or a trend of motor current, it could have caused a proactive investigation of the root cause. At the

MY INDUSTRIAL JOURNEY

I have walked the maintenance and reliability path for just about 13 years now, in both the military and industrial worlds. Starting off as a United States Marine, my trade within the service was that of an avionics electrician working on helicopters and jets. At the end of my five years on active duty, I worked my way into a leadership role where 10-15 Marines and Sailors were under my direct supervision. As a maintenance-focused unit, we were charged with filling the uptime needs of flying squadrons serving all over the world, including forward operating positions in Iraq.

Transitioning into the industrial world upon my honorable discharge, my career then took me down the path of predictive maintenance and reliability engineering. This is where I logged tens of thousands of hours in the field, manually collecting and analyzing vibration data, conducting infrared thermography inspections, pulling oil samples, and running ultrasound routes on expansive compressed gas systems. Eventually, my work took me from tactical to more of a strategic role where I became more focused on client relations and consulting on reliability strategy with the industry leaders we served.

Over the years, at facilities large and small, I have helped implement many maintenance models, including run to failure, preventive and predictive. I have been fortunate to have witnessed the swift and vast evolution of technology from transferring data on floppy disks to the advent of cloud computing. Being that close to the action and understanding the gaps has absolutely convinced me that continuous PdM will become a foundational element of helping businesses meet their goals in regard to asset management.

very least, some level of warning could have triggered a temporary move of the temperature sensitive material while operational checks where preformed on the system. Unfortunately, that was not the case.

Another event where continuous monitoring would have benefited system reliability involved a supply air fan for a large, multistory building that contained critical operations for a business. One of the two fans supplying fresh air to the building experienced a catastrophic failure. The 75 HP motor driving a 5½-inch fan shaft seized, resulting in the need to completely rebuild the unit. Though the asset was included on the site's vibration monitoring program, the fault appeared to progress faster than what the inspection frequency was able to detect. Not only did the business have to absorb the emergency repairs, but the circumstances then created a single point of failure in the other fan, putting critical operations at a higher risk while repairs were completed.

> "When critical assets fail, there are enormous cost and productivity implications on the facility's overall operations"

When critical assets fail, there are enormous cost and productivity implications on the facility's overall operations. In most instances, continuous monitoring increases the detectability of occurrence by alerting personnel at the earliest point possible.

Conclusion

The rapid evolution of technology in a span of less than 10 years is fascinating. The barrier to entry in terms of cost for continuous PdM has been largely mitigated. Plants and facilities already are spending money on managing their assets in terms of reliability initiatives and predictive maintenance. The industry is going in the direction of not spending additional capital, but in reallocating on a smarter spend.

Technology drivers, like artificial intelligence and cloud computing, have expanded what is possible to unfathomable proportions. Knowing what's brewing within your key industrial assets at all times was something typically reserved for only the largest and top revenue producing locations. But not anymore! Today, there are solutions out there that deliver on-demand predictive maintenance at great price points. With quality data and actionable intelligence readily available and accessible, businesses are able to ensure world-class reliability of their critical assets.

***Sean O'Connor** is a Site Operations Manager with Bristol-Myers Squibb in New Brunswick, NJ. Sean began his career with BMS in 2015 as a contract Reliability Engineer. He got his start in maintenance and reliability while maintaining aircraft as a United States Marine. His extensive background in the predictive technologies has served as a launching pad to more strategic roles. www.bms.com*

The State of America's

Earlier this year, there appeared to be a moment when Democrats and Republicans could agree on increased infrastructure funding. In his State of the Union address in early 2018, President Trump called on the United States Congress to produce a bill that generates at least $1.5 trillion in new infrastructure development.

President Trump said, "As we rebuild our industries, it is also time to rebuild our crumbling infrastructure." Referencing the time it took to build the Empire State Building, the President asked both parties to come together to provide a "safe, fast, reliable and modern infrastructure that our economy needs and our people deserve." After much public discussion on the importance of a dramatically increased investment, in March 2018, Congress passed a spending bill with only $21 billion for infrastructure.

Noting the "disgrace" for the length of time it takes to "build a simple road," the President called on Congress to streamline the approval process to "no more than two years and perhaps even one." As a follow-up, in April 2018, 14 U.S. federal agencies agreed to reduce the time needed for environmental reviews and permitting on major infrastructure projects. Trump also called for every federal dollar to be leveraged with state and local contributions, as well as private sector participation.

Ironically, on the morning after President Trump's State of the Union speech, an Amtrak train filled with federal Republican lawmakers headed to a legislative retreat apparently hit a truck on the tracks and derailed.

It is these types of potential disasters that keep transit CEOs and their teams focused on keeping the nation's public transportation systems running safely, efficiently, reliably and with world-class customer service.

When they are not working on getting positive train control (PTC) installed in their commuter trains, renegotiating labor contracts, or working on getting more funding, they are working on improving America's aging transportation infrastructure. Lately, it seems not a month goes by without a disaster for some transit system whose subway tunnels flood or trains derail. While many systems have been adding new rail service over the last decade, too many have failed to maintain their infrastructure in a state of good repair. This is one of the reasons for the Federal Transit Administration's (FTA's) guidance in the Moving Ahead for Progress in the 21st Century (MAP-21) program, which requires better asset management.

Publicly elected officials are willing to sacrifice long-term system needs, such as mid-lifecycle overhauls of light rail vehicles or major track replacement, for a shiny new light rail extension to an airport. While they are listening to their constituents who want the system to serve new areas, this is often

Transit Infrastructure

shortsighted when done at the expense of system safety upgrades. These elected officials often argue that ridership is declining because their system does not currently serve the needs of today's commuting public, so the new rail line must be constructed.

Transit CEOs are working to educate their board members, mayors and council members on the importance of investment in state of good repair because they know that one significant safety issue can set a system back a decade in public trust. Without public trust, you can kiss increased ridership goodbye.

> While many systems have been adding new rail service over the last decade, too many have failed to maintain their infrastructure in a state of good repair

No one wants their system to have the next disaster, so transit CEOs are working to shift millions of dollars in their capital budgets to emphasize track and track exchange replacements, computer-aided dispatch and automated vehicle location (CAD/AVL) dispatch system upgrades and new or overhauled trains. They are also trying to find the balance between expanding their system and maintaining it adequately.

Paul Wiedefeld, CEO and GM of the Washington Metropolitan Area Transit Authority (WMATA) in Washington, D.C., is often described as the man with the "toughest job in Washington" as he labors to make repairs to a once glorious metro subway system that was the envy of the world.

Wiedefeld came to the job with a background in transit and aviation. He soon found that the rail infrastructure at WMATA needed significant work, which was highlighted in a series of well publicized smoke/fire incidents. Wiedefeld developed a straightforward approach to assess and repair the tracks and called it the SafeTrack work plan.

Now past that phase of the WMATA metro upgrade, Wiedefeld says that state of good repair efforts need to be "incorporated into the design of a project from day one." He continues, "Too often, it's coming in after the fact. We should not wait until it comes to a crisis to staff and budget" for continuing maintenance and state of good repair work. He also says that CEOs should plan for equipment obsolescence right from the start.

Es
executive sponsorship

WMATA had to institute restricted hours of service so formalized preventive maintenance programs could continue unabated. Wiedefeld encourages transit systems to get ahead of the curve on state of good repair issues so they can be proactive, not just reactive. He also reiterates a familiar theme that transit systems need to budget appropriately and recruit new staff to maintain new systems or rail lines as they come on line, incorporating maintenance as an ongoing expense.

Remember the old nursery rhyme when Humpty Dumpty falls and cracks and all the king's horses and all the king's men couldn't put Humpty back together again? The same is true for transit systems with significant safety failures. They lead to very bad publicity, which leads to ridership declines, which leads to lower fare revenue, which leads to less money available to maintain and/or expand the system. This vicious cycle is hard to break.

In order to keep that cycle from occurring, solid enterprise asset management tracking and scoring is a must. Additionally, transit system CEOs and their boards of directors must prioritize state of good repair capital expenses in their annual and supplemental budgets.

Safety truly needs to be the #1 priority up front at every transit system. Public transportation leadership in America's cities and the nation needs to put their money where their mouth is.

Paul Comfort is an expert on transportation infrastructure and transit trend. Paul was the former Administrator and CEO of the Maryland Transit Administration (MTA) and led a revolutionary change from a 50-year-old antiquated transit system to the world-class BaltimoreLink, an efficient, high-frequency, high-tech bus line. He is currently the Vice President of Business Development for the Trapeze Group. www.trapezegroup.com

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John Natarelli

3 TECHNIQUES FOR OPTIMIZING PREVENTIVE MAINTENANCE

When Benjamin Franklin wrote, "An ounce of prevention is worth a pound of cure," he was referring to fire safety. But, as you may know from experience, this saying holds true with regard to preventive maintenance (PM). Simply stated, preventive maintenance is an activity performed at a set interval to maintain an asset, regardless of its current condition. It's a properly planned activity, where materials and parts are on hand and labor is scheduled ahead of time. The goal of any PM program is not only to extend the life of an asset or maintain it to its existing capabilities, but to also identify potential failures that could cause an unexpected event in the future. Properly planned corrective maintenance is typically several times less expensive than performing unplanned work. But, are the typical frequencies that PMs occur actually correct?

> "An ounce of prevention is worth a pound of cure."
> *~ Benjamin Franklin*

The Society for Maintenance and Reliability Professionals (SMRP) Best Practices Committee recommends approximately 15 percent of total maintenance labor hours be associated with PM work. This, of course, could fluctuate depending on the type of plant, its location, age and complexity, among other things. However, having a line in the sand can provide a starting point to begin the preventive maintenance optimization (PMO) process.

TECHNIQUE #1:

Evaluating PM Labor Hours vs Emergency Work Labor Hours

Though there are many potential starting points, one option is to begin by evaluating the amount of emergency work that occurs on equipment that regularly gets PM performed on it. Start by identifying a critical plant pro-

cess and its associated assets. Once these assets are identified, choose one piece of equipment that gets a regular PM. Do not pick the most complex PM, as you may be immediately overwhelmed with the amount of information available. Instead, choose something basic. Begin by tallying the amount of PM labor hours and emergency labor hours charged to this specific piece of equipment over a period of time, for example, three to five years to start with. If the site has properly utilized a computerized maintenance management system (CMMS), this task should be relatively easy, as all maintenance work performed should be available. If a CMMS has not been adequately utilized, this task may be more time consuming.

> "An engaged maintenance workforce can be a tremendous help in the PMO process"

Once this information has been gathered, compare the amount of labor hours charged to PM work versus the amount charged for emergency work. If the emergency labor value is greater than that spent on completing PMs, something is probably wrong. It could be that the work within the PM is focused on the wrong item and missing something that's having a frequent impact to production. Root cause analysis on failures must be performed to completely understand this. Generally speaking, if the numbers are adverse and emergency labor is consistently minimal or nonexistent, the frequency of PMs might be adequate.

TECHNIQUE #2:
Day's Theory

There is also the possibility that PMs are being performed at the wrong interval even though hours are aligned as previously explained. John Day, Jr., manager of engineering and maintenance at South Carolina's Alumax, the first organization in the world to be certified compliant with world-class standards, developed another method to evaluate PM effectiveness. Day's theory assumes that for every six PMs performed, one corrective work order that cannot be completed within the required PM time frame should be written. If the ratio is greater than 6:1, say 10:1, then it's likely the PM is being completed too frequently. If the ratio is less, at 2:1 for instance, then the interval between PMs is likely too great, resulting in corrective work orders being written once for every two times the PM is performed. Again, utilizing a CMMS will make gathering and evaluating this information a much easier task.

Considering every corrective work order could eventually lead to unplanned downtime, should the frequency of the PM in the last example be increased? Maybe, but not without some additional research. It is important to understand the work that was identified, the threat it poses and the asset that it's on. If the corrective work poses a higher risk, the frequency should be increased. However, a conservative approach should be used to begin with. Also consider instead of every year, changing the frequency to every nine months. However, if the work poses no threat to safety or production loss, it is quite possible it's an acceptable risk that can be addressed as it is identified. The bottom line is that without a consistent evaluation process, the optimal frequency cannot be accurately determined. And, as mentioned earlier, variations in plant operating conditions also can impact the decision.

TECHNIQUE #3:
Engage the Maintenance Workforce

A third way to begin the PMO process is perhaps the easiest and the most overlooked. It's that of the human factor – the craftspeople performing the work. As plants, and the workforce itself, are aging, it is highly likely that the PMs being performed were established many years ago and never revalidated. It's also likely that the same people perform the same PM every time it's scheduled. An engaged maintenance workforce can be a tremendous help in the PMO process. They're the ones who can provide input on its quality and contents. Since they routinely perform the work, they can help identify process improvements and validate that the PM includes all relevant work. They can make suggestions on items that should be added to or removed from the PM and could even provide input as to the right frequency.

Each of these three techniques provide a starting point to PM optimization. Additional methods, such as utilizing metrics like mean time between failures and mean time between maintenance, also can provide benefits. Whichever path you choose, remember that PM optimization is a facet of the continuous improvement process. The SMRP's 15 percent guideline and Day's 6:1 ratio may not be a perfect fit for every plant or asset, but they'll provide a starting point for a PMO initiative.

A vision and a long-term commitment from every level of the organization are required for PMO to succeed. Achieving small gains early on can provide momentum and increase buy in to the process over the long haul. And although the process may initially seem costly, PM optimization can reap benefits for years to come.

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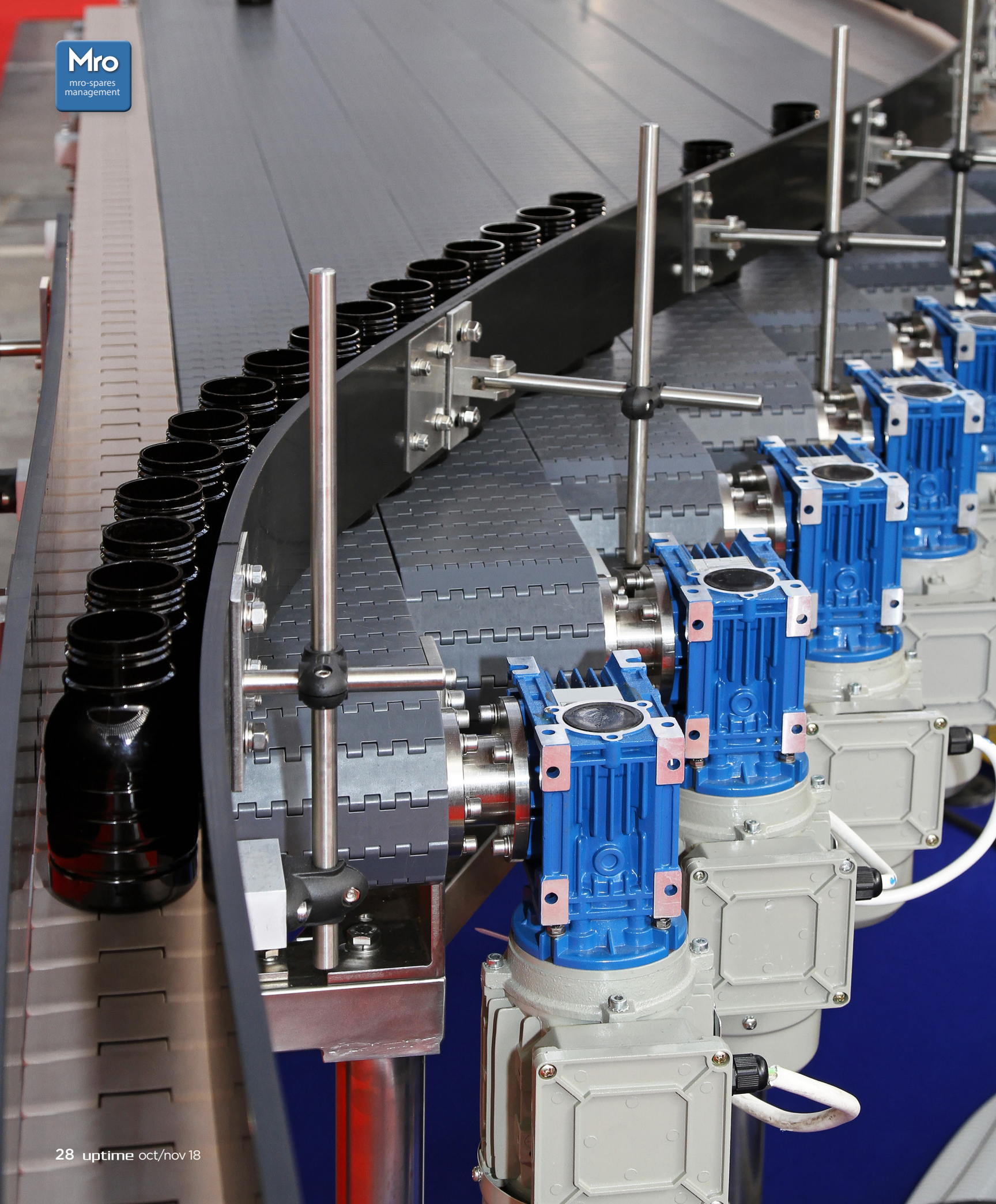

HOW SERVICE PARTS PLANNING IMPACTS MACHINE UPTIME

Carl Fransman

Predictive maintenance (PdM) is a very hot topic, and rightly so. Holding the promise of cutting down costly unplanned maintenance events, it's one of those areas where the hopes of saving a lot of money are very real.

Many domains influence the ultimate performance of any PdM exercise. Some are very hot, such as the Internet of Things (IoT), also denominated as machine to machine (M2M) or Industry 4.0, which allows for the gathering of system data. But, be careful not to confine system data to data pertaining to the machine you're trying to monitor. Rather, be sure to include the "extended machine," which could hold data as to the environment (e.g., weather, but in the case of moving equipment also geographic information), driver, origin of fuel, etc. In general, the more circumstantial data you can gather, the greater the chance of being able to put together a meaningful PdM setup.

Obviously, successful PdM is largely dependent on the availability of good predictive analytics (PA). A lot has been written on PA, but generally, there are two schools to deploying PA for PdM. One approach tries to analyze the mechanics of what one tries to predict and from there deduct an algorithm that will lead to determining the chance of something failing. The other approach essentially gathers all the data and allows for automated systems to look for elements that allows one to come up with appropriate algorithms. When well designed and deployed, the latter approach has the advantage because it typically yields many more and often better results than the former. The drawbacks are that it requires a lot of computing power and the results are hard to interpret.

> "...Successful PdM is largely dependent on the availability of **good predictive analytics**"

If the resulting forecast is difficult to interpret, it means you can't determine from the prediction why exactly the event is being predicted. This doesn't mean the prediction is bad. However, there have been instances where, even in situations where predictions were more accurate than 90 percent, operational issues occurred. What's happening in the field is that when the computer churns out a prediction, it leads to a machine having to be taken down and a part or several parts end up being replaced. After a few interventions, mechanics start asking questions about why they have to replace parts, which may look perfect, even upon a very thorough inspection. Such is the essence of PA: to catch a part with a high risk of causing a failure before the part is actually faulty. In fact, said part may be able to operate quite well on a different machine; it's just that on this particular piece of equipment, in these circumstances, etc., this part holds a high risk of failure. It's difficult enough to explain this to scientists, imagine dealing with mechanics in the field who build upon years of practice. It's hard to change old habits.

Another domain impacted by PdM, but more down to earth and the focus of this article, is parts planning (PP). The importance of PP excellence can't be understated. When it comes to improving machine uptime, this still may be the domain where most progress is within easy reach. These solutions for optimizing service parts inventories have been around for some time now, but companies keep making some common mistakes. Many believe it's an inventory and supply chain problem and, therefore, can be solved by regular supply chain approaches. However, service parts supply chains are very different from production or distribution supply chains. Demand is very erratic, hard to foresee, often urgent and includes a reverse supply chain in case of repairs. These are just a few elements that set service parts supply chains apart. Thankfully, in recent years, corporate strategists and consultants have started to realize there's money up for grabs and PP projects typically generate double figure returns very quickly.

All these elements impact machine uptime, so how does PP fit into the grand scheme of things? Figure 1 illustrates the typical breakdown of the timescale associated with machine failure.

In reality, only a small part of the total downtime is actual repair time. Depending on the industry, the chunk of time spent waiting for mechanics and parts can take up to 90 percent of the total machine downtime. Does this

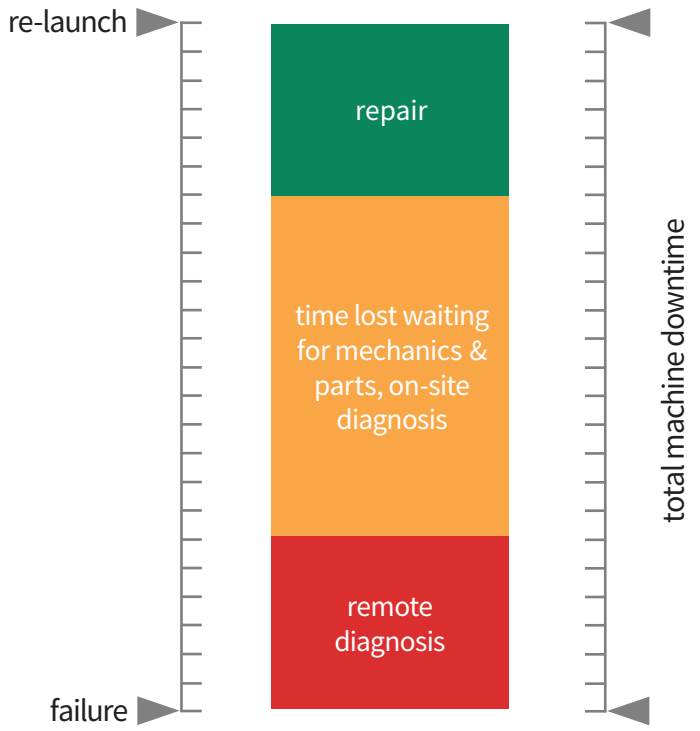

Figure 1: Total machine downtime breakdown

Table 1: Time to Fix		
Repair 1	10 hours	1 hour
Repair 2	10 hours	1 hour
Repair 3	10 hours	1 hour
Repair 4	10 hours	1 hour
Repair 5	10 hours	1 hour
Repair 6	10 hours	1 hour
Repair 7	10 hours	1 hour
Repair 8	10 hours	1 hour
Repair 9	10 hours	1 hour
Repair 10	10 hours	91 hours
Average Total Downtime	**10 hours**	**10 hours**

mean you shouldn't invest in optimizing the repair activity and/or remote diagnostics? Not at all! Actually, better remote diagnostics will avoid having to send out for mechanics more than once (i.e., when the mechanic doesn't have the required part on hand) and better repair processes should lead to better first-time fix metrics.

> "The **challenge** for good consignment stock management is determining the optimal parts mix"

However, what Figure 1 really illustrates is that the biggest room for improvement is in the middle section. The simplest solution or Utopia, if you will, would be to have mechanics and parts on-site. It's not really achievable for all situations, but at least in some cases (e.g., large customer sites, platinum support contracts, etc.), consignment stock is a step in the right direction. The challenge for good consignment stock management is determining the optimal parts mix. Gone are the days of number of machines multiplied by standard parts inventory per machine; one can do much better now.

After consignment stock, van stock is the next closest inventory to the client and, therefore, can have a big impact on the middle section in Figure 1. Ideally, van stock should be managed individually within the network of vans. Each mechanic/van typically serves a geographic area, a set of clients, a type of equipment, etc. However, it's important to make sure the van stock reflects the addressable installed base. While this may seem trivial, it can be quite a daunting task when overseeing a network of hundreds, let alone thousands, of vans. Below a certain number of vans, the capability to differentiate is often not present, but beyond that threshold, the task becomes too complex and it is often left to the mechanics to partly determine how they stock their vans. This can lead to hidden inefficiencies and capital tied up in inventory that more often than not goes overlooked or is deemed a necessary evil in order to perform. If van stock is part of a company's daily life, it's one of those areas that typically can be greatly improved, leading to both positive financial impact and improved repair metrics. It's not uncommon to see service executives scratching their heads, not knowing what goes wrong, but knowing something does go wrong. Often, van stock is the answer.

Next are those cases where the part is not on hand, neither on-site nor as part of the van stock. Believe it or not, it's these cases that separate bad, good and excellent service organizations. Imagine 10 interventions with an average total machine downtime of 10 hours. Taking the two extremes, as shown in Table 1, this could be the result of 10 interventions of 10 hours each (if that's the time a repair of this sort takes, excellent) or nine repairs of one hour each and one repair of 91 hours.

While this may be an extreme illustration (although ask your service organization, it's much more common than you may think), it highlights two important points of interest. First, handle metrics with extreme care, especially when looking at averages, as they may hide or disguise situations as something they're not. Second, in the second case, there's a clear opportunity for avoiding a potentially very upset client, as well as all the stress this one case will undoubtedly have brought to the service organization. If the repair took so long due to a missing part, chasing the part, expediting it, etc., it is not only stressful, but also often extra expensive.

For this reason, the design, management and deployment of a well performing and adaptive service parts network are crucial elements. This means that, for optimal planning purposes, what's on hand at the client's site, van stock, forward stocking locations, distribution centers, repair centers, supplier lead times, etc., should ideally be visible/known at all times. A good PP solution and organization will be able to use all this information to determine the optimal part/location mixes.

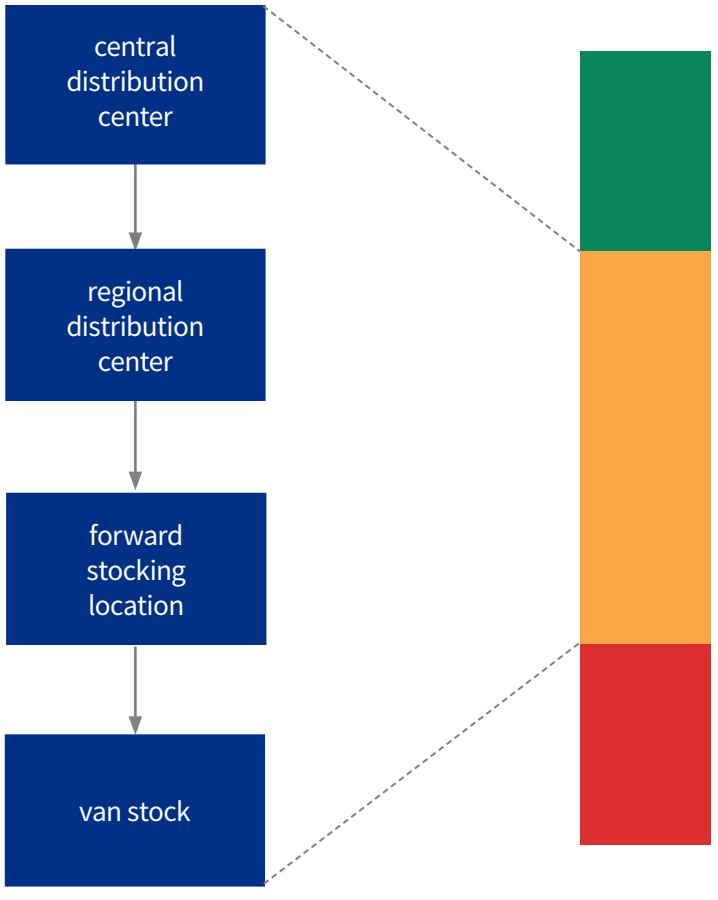

Figure 2: Simplified parts flow

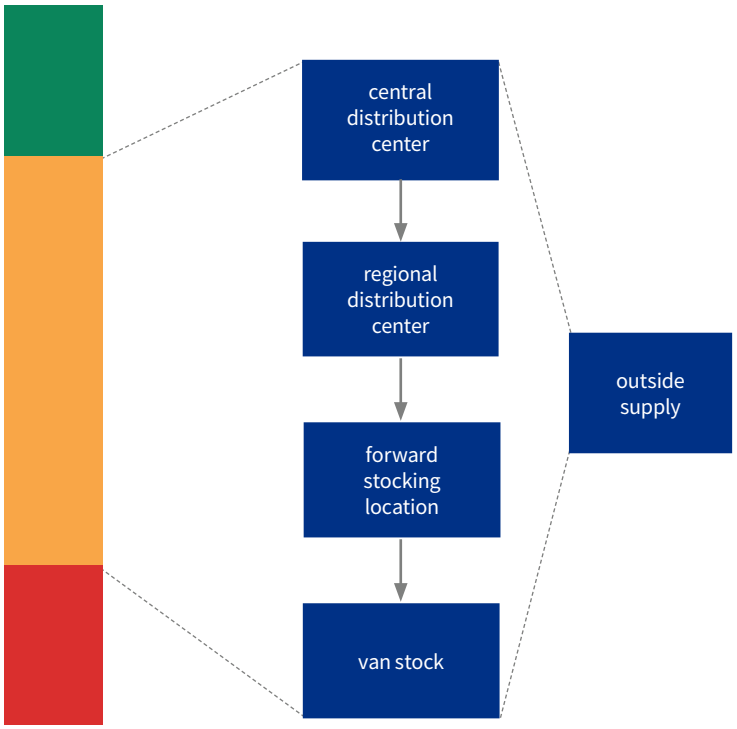

Figure 3: Simplified parts flow with outside supply

As the market moves more toward PdM, the importance of PP can't be understated either. There have been PA projects in the area of PdM where predictions were made within a time frame that couldn't even cover the lead time for parts. What PP can do is either highlight the limitations of the system, thus requiring a longer time frame for the predictions, which is not always possible, or determine what is required from the service parts network in order to be able to address the predictions made by the PA system. This poses some ethical questions, as well. Imagine PA determines a 50 percent risk of failure of a critical part on a machine, which may potentially result in bodily harm, and the part is not available. Is the machine taken out of service until the part has been provided or does the manager go for the other 50 percent?

> "...The design, management and deployment of a well performing and adaptive service parts network are **crucial elements**"

Planning service parts is about handling risk, forecasting whether or not a part may be required is only a small part of the task. What do you do if the forecast for a part's failure for next month is 90 percent? The failure could happen on the first or the last day of the month, or not at all. The part could be critical or not, expensive or cheap, available at fallback locations or not, etc. PP is about managing and orchestrating all these risks in order to minimize exposure at the lowest possible or set budget. Regular supply chain solutions or spreadsheets can't cope with this level of sophistication, which is why specific PP software has such a big and almost immediate impact.

The importance of good planning is further underlined by the fact that it's economically unsustainable to hold inventory for every possible spare part. PP, therefore, is an exercise of choosing which part to hold where. Some parts will be held back at the distribution center or central stock, whereas other parts, such as high volume, critical, etc., will be stored at forward stocking locations. Each decision has an impact on the budget and on achieved service levels. For those parts not stocked within the company's network, ideally, the lead times for obtaining them should be known. Keep in mind there may be a world of difference between promised and actual lead times. Some suppliers may promise lead times of two weeks, which regularly vary up to two months! Lead time variability should be monitored and decisions made as to which lead time will be applied for planning purposes. Longer lead times typically, but not always, command higher internal inventories. Important questions can be then asked, such as: Would you be willing to pay more for shorter and more dependable lead times? If you're willing to consider the option, do you have the tools that allow you to calculate the global impact of either option?

Quite worryingly, most company executives lack the tools to evaluate the risks they're facing, such as what it would cost them to cover those risks up to a certain level and what it would cost them in case they're not covered. When a part is not available, a whole different process is put in motion in order to get the part on-site. For example, people may have to call colleagues handling other stocking locations in order to find out whether they have the part on hand. Regardless of where the part is coming from, it still needs to get shipped or transshipped, or even procured externally. Often, because of the urgency (e.g., a client's machine is down), the part has to be expedited. More often than not, all these extra costs are not taken into account for PP. This is a huge mistake and one of the main reasons why the annual budget is missed by so much. Having the capability to take into account all these factors can lead to a huge competitive advantage.

Supported by PA predictions or not, maintenance (predictive or corrective) performance or machine downtime is impacted by parts planning. When a part is stored, a linear and, hopefully, organized flow is set in motion. This

results in efficiency and predictability. (Horizontal shipments are possible, as well, for example, between forward stocking locations (FSLs.)

Not accounting for horizontal flows, Figure 2 (page 30) also ignores repair flows, but one easily gets the point. Now, look at the scenario where the part is not internally available.

While it is not intended to depict an exact parts flow, Figure 3 (page 31) illustrates what happens in reality when a part is not available. Depending on the situation and part, it may be procured or inserted at any point in the supply chain. Even when procurement happens centrally, a drop shipment to the FSL or even to the client's site may be organized. All these possibilities add complexity, unpredictability and length to the whole cycle. Therefore, having the part available in the network has a huge impact on service performance. This also means choosing which parts not to hold is equally crucial, because remember, you can't have them all. Criticality and the likelihood of needing the part obviously play a key role, but so also does the predictability of the supplier, the ease in which a part can be delivered anywhere in the network, etc. Life is about making choices. If anything, good tools will allow parts planners to present the executive team with several scenarios from which to choose. They can then make a choice based on solid calculations and foresight into cost versus service performance.

Ultimately, increasing machine uptime is the goal: happy customers are faithful and repeat customers.

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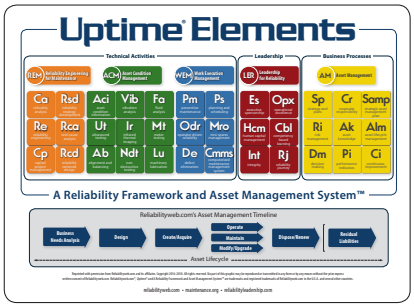

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Fa
fluid analysis

ON-SITE FLUID INTELLIGENCE:

A REVOLUTION TO ADVANCE MACHINERY RELIABILITY

Yuegang Zhao, John Morgan
and Daniel Walsh

Figure 3: Portable oil analyzers provide field service professionals with comprehensive lubricant assessment for condition monitoring and maintenance decisions

Using in-service oil analysis to improve machinery reliability has a long history. The first oil analysis was performed over half a century ago on a locomotive engine. Just as a human blood test provides important information about your health, the information provided by in-service oil analysis about machinery health, especially for a piece of complex machinery with many moving parts, such as a diesel engine, is unmatched by any other technologies on the market.

On-site fluid analysis had been adopted for a while by a few mission critical industries, such as military aerospace and F1 racing, as a tool to protect their most critical assets – engines. In the case of Formula One racing, Pat Henning, chief technology officer of a Massachusetts-based global supplier of oil, fuel, and processed-water analysis instrumentation and software, once worked with a trackside support team in an F1 racing event in Bahrain. According to Henning, "The team was literally testing engine oil samples live. They ran to the car, quickly took a few milliliters of oil, rushed back to the analyzer and waited for the results to be ready in 30 seconds. They were looking for just one ppm change in some wear metals, such as iron or silver, because after a few laps, a one ppm change in wear metals could mean a major issue with the engine and cost a win."

Figures 1-2: Fleet maintainers using on-site oil analyzer

In military aerospace, oil analyzers have to be ready and provide the first go-no-go reports within a few hours of a fly order being issued. Sometimes, pilots wait next to the analyzer for the report to give a green light.

These are two great examples of how oil analysis can be critical to the success of a mission. Oil analyzers are not just used on-site, but the oil analysis results are fully integrated in the workflow and used for decision-making. Is it safe for this aircraft to fly this mission? Is the car engine healthy enough to compete in tomorrow's race or should we swap it out?

> "…On-site fluid intelligence is leading the revolution"

Just as point-of-care medical results allow a doctor to make timely decisions, rapid analysis of machine health allows maintenance professionals to make informed, confident decisions on the maintenance actions of their valuable assets. With on-site fluid intelligence, which includes fluid analysis, diagnostics and recommended actions, engine or gearbox wear and oil condition information is immediate and easy to decipher. Just-in-time reports, combined with service recommendations from an expert system, are revolutionizing how people develop, test, produce and maintain their oil lubricated machines.

Yet today, most people collect oil samples on-site and send them to an off-site lab. Each year, tens to hundreds of million oil samples are sent to thousands of oil analysis labs around the world to be analyzed. Most of the time, oil reports arrive days or weeks later, too late for just-in-time decision-making, so they are not fully utilized.

Point-of-care oil analysis is not yet a widely adopted practice. There are several reasons why:

- One major reason is the misperception that on-site fluid intelligence requires implementation of an oil analysis lab on-site with all the expertise and costs associated with it. In actuality, building a complete commercial oil analysis laboratory on-site is neither necessary nor advisable.
- In-service oil analysis can be confusing and intimidating to beginners. The importance of oil analysis is generally well accepted. The difficult part

is deciding what to test, how to test it and how to interpret the results in order to decide on the best course of action. An engine oil analysis report, for example, can consist of over 30 parameters, including engine wear metals, corrosion, contamination (such as the presence of water), coolant, or fuel, and oil condition. Compared to other predictive maintenance technologies, such as vibration analysis and thermal imaging,

Figure 4: Small, integrated and cost-effective systems are available for industrial on-site oil analysis

there is a lot more information provided by oil analysis. This can be good and bad. It's good to get such a complete picture of machinery health, but the complexity of oil analysis can scare away many potential users. A commercial oil analysis laboratory has many different instruments to measure all these parameters, such as optical emission spectrometers, gas chromatography, particle counters, PQ index, Karl Fischer analysis, titrators, viscometers, FTIR, ferrography, and more. For a person not in the oil analysis business, it can be a scary thought to even think of doing oil analysis on-site.

- Aside from the capital expense involved in purchasing the necessary analytical instruments, there are three main categories of additional capital and operating expenses associated with setting up an on-site oil analysis laboratory:
  - Facility and IT expenses – facility, utility, networking, computers, security, software;
  - Staffing – chemist, administration, technicians;
  - Safety - environment, health and safety (EHS), chemical storage, disposal, safety training, recycling, fume hoods, acid sinks.
- Even if all these challenges are resolved and an on-site oil lab is established, an oil sample in the lab travels from instrument to instrument with a batch of many other samples for maximum throughput. While the throughput for a lab can be as high as hundreds to thousands of samples per day, it could still take hours to finish one sample because the workflow might not be optimized for a single sample. Reliability engineers in power plants sometime wait impatiently outside the lab for the report, while the lab staff works hard to run the sample through all the instruments to get a final report. This is still not point-of-care oil analysis as the report is not "just in time" for decision-making. To fully unleash the power of oil analysis, the report needs to be produced whenever it is needed so that a decision can be made right away.

The situation has changed and on-site fluid intelligence is leading the revolution. Just as medical testing has moved from the laboratory to the point of care with the advent of tests, like blood glucose or home pregnancy tests, oil analysis is similarly moving from the labs to where the assets are maintained.

Technology has advanced so much over the past 10 years that small, integrated and cost-effective oil analysis tools are now available, providing the same or similar information that an oil analysis lab provides. Tabletop oil analysis systems are only a fraction of the cost of setting up an oil lab on-site, without the need of large lab space, the handling of hazardous materials, IT infrastructure, special skills and additional staffing. Built-in rules and diagnostics can be applied to the raw data automatically, based on the equipment information and oil information, so diagnostics and recommendations are available right after the test. The whole process only takes a few minutes for a sample to complete and the instruments can be installed right inside a factory or a repair depot.

Pioneers in every industry are taking notice and are starting to integrate on-site fluid intelligence in their workflow. They are now enjoying the benefits of huge cost savings and performance and productivity gains. Here are some examples:

- A trackside oil lab was introduced by a high performance motor oils company to support its sponsored Dakar racing teams and all the competing teams, giving them confidence that they can cross the finish line without mechanical problems in their engines.
- A major oil drilling company in North America has been using on-site oil analysis for many years for its global drilling fleets, enjoying over $1 million per month in oil savings.
- A large municipal transportation fleet in the U.S. with over 3,000 pieces of heavy equipment, including 800 police cars and 500 heavy-duty trucks, used on-site oil analysis in 2016 and reported savings of over $2 million

> …Rapid analysis of machine health allows maintenance professionals to make informed, confident decisions on the maintenance actions of their valuable assets

> "Just as medical testing has moved from the laboratory to the point of care with the advent of tests…oil analysis is similarly moving from the labs to where the assets are maintained"

by extending oil drain intervals, in addition to the cost savings in reduced repairs.

- A midsize, seven-bay garage owner in the Midwest U.S. used an on-site oil analyzer to check engines and transmissions of customers' vehicles before making major repair decisions. The point-of-care oil analysis became the owner's competitive advantage and generated good revenue, as well.

The list goes on and on. It includes companies in power generation, oil and gas, mining, chemical processing, food and beverage, pharmaceutical, transportation, aerospace, lubricant suppliers and heavy equipment original equipment manufacturers. They are taking advantage of the just-in-time information provided by oil analysis and incorporating it into their workflows for better decision-making. On-site fluid intelligence is starting to revolutionize how people design, test, produce and maintain their most precious machinery assets for better productivity and lower cost. The time has finally come!

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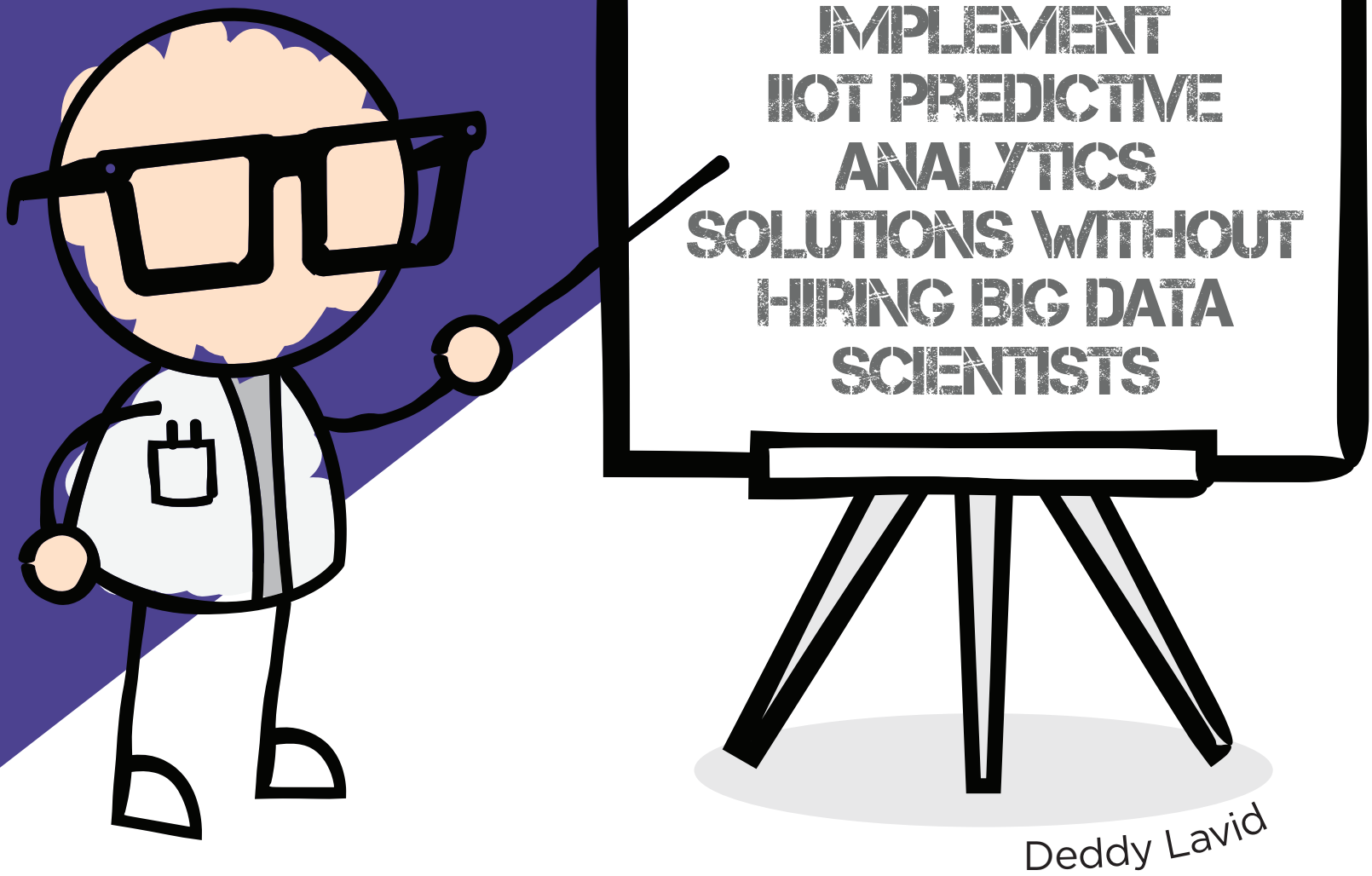
Dm
decision making

HOW TO



IMPLEMENT IIOT PREDICTIVE ANALYTICS SOLUTIONS WITH-OUT HIRING BIG DATA SCIENTISTS

Deddy Lavid

Industrial Internet of Things (IIoT) predictive maintenance is firmly on the radar of most executives. At the same time, there are serious concerns about the lack of internal resources to analyze, visualize and interpret the big data generated by industrial machines. This article proposes an alternative: Implementing a big data predictive analytics solution without hiring a big data scientist.

Background: Lots of Interest, Little Bandwidth

IIoT predictive maintenance is one of the hottest topics today. A comparison of Internet searches for "Industry 4.0" and "predictive maintenance" finds a spike in interest over the last couple of years (see Figure 1).

This increasing demand for IIoT predictive maintenance solutions has been addressed by numerous publications and analysts, among them Harvard Business Review[1] and PwC[2].

IIoT predictive maintenance is rapidly moving from strategy to execution. Senior executives are embracing the economic potential of increased uptime and higher production yield rates. At the same time, concerns are being raised about the availability of big data professionals.

In the Emory University *The Future of IIoT Predictive Maintenance Research Study*[3], maintenance reliability professionals were asked to rate their attitudes regarding predictive maintenance deployment. The statement that generated the highest rate of agreement (5.8 on a 9-point scale) was "senior executives recognize the potential of predictive analytics." At the other end of the spectrum, the statement that generated the lowest level of agreement (3.2 on a 9-point scale) was "we have sufficient staff of data scientists to deploy predictive analytics. Summary data from the study is shown in Figure 2.

Research from the Massachusetts Institute of Technology (MIT) conducted in 2012 is still relevant today and provides more context about the underlying concerns. The researchers note that data has become cheaper and there are new technologies to analyze data. However, tools "require a skill set that is new to most IT departments, which will need to work hard to integrate all the relevant internal and external sources of data."

The weak link is data science talent. There is an abundance of unstructured data that requires deep expertise in machine learning and artificial intelligence (AI) if it is to be turned into valuable and actionable information. The dearth of trained data scientists has been well-documented. According to the report, *The Quant Crunch: How the Demand for Data Science Skills Is Disrupting the Job Market*, the demand for data scientists and data engineers will grow by 39 percent by 2020 in the U.S.

> There is an abundance of unstructured data that requires deep expertise in machine learning and artificial intelligence (AI) if it is to be turned into valuable and actionable information

With the surge in demand for data scientists, it is difficult for industrial plants to compete with compensation packages provided by Wall Street and Silicon Valley.

Big Data Analytics Without Big Data Scientists

The lack of qualified data scientists is not a new issue. Part of the problem stems from a lack of education, with fewer than one third[4] of global universities offering a degree in data science.

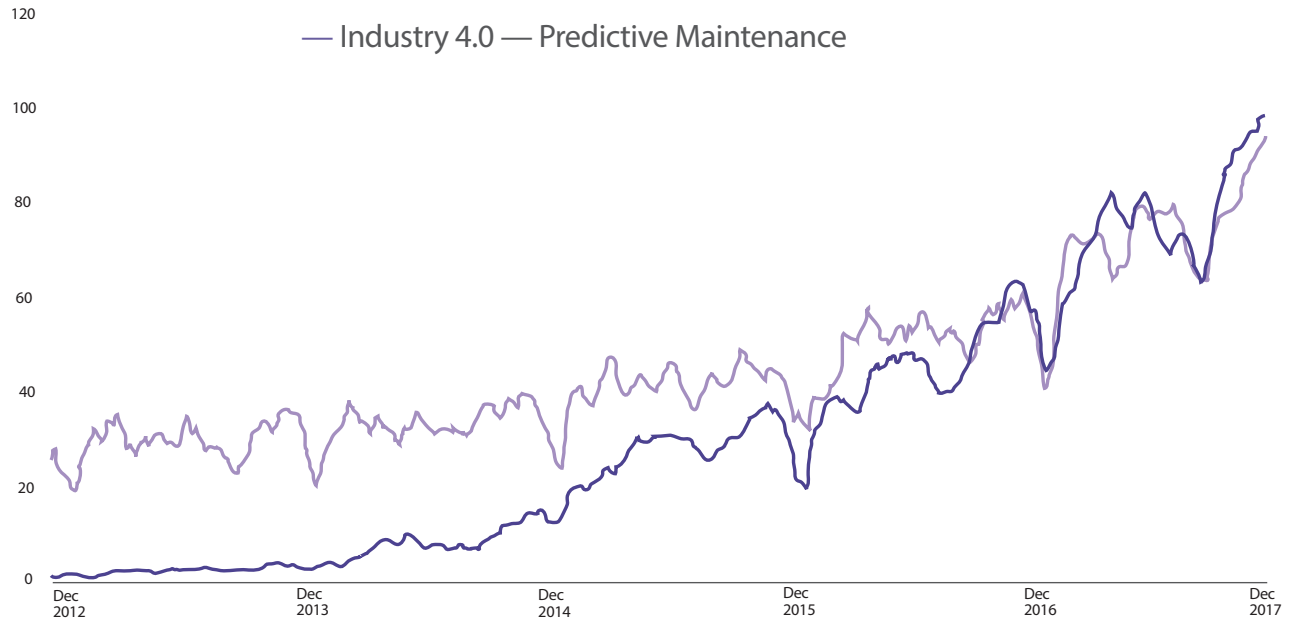
Let's start by reviewing some of the current solutions. Global research firm Gartner has presented its approach in an article titled, *How to do Machine Learning Without Hiring Data Scientists*[5]. It provides four strategies:

1. Turn existing staff into data technicians

A couple of years ago, Gartner came up with the term, citizen data scientist (CDS). It refers to a technician with mathematical capabilities who can be trained to perform data science roles.

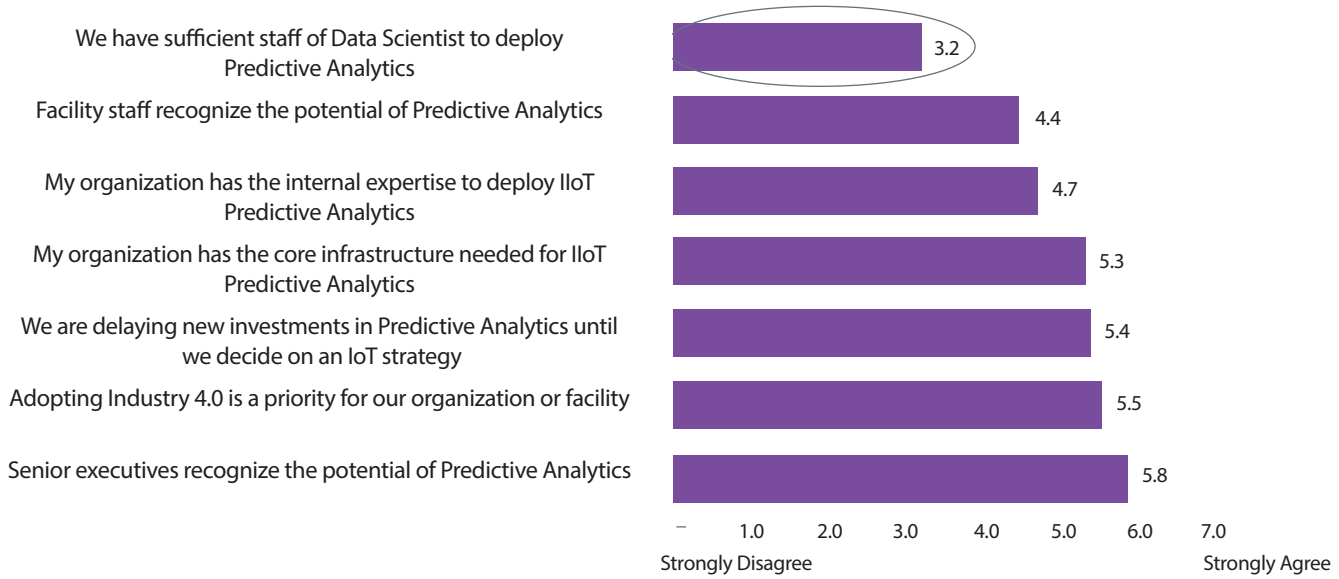
Does this work? The answer depends on the expectations for the CDS. For example, a company that recruits and hires many data scientists and engineers may see few areas where someone lacking formal training can fill those roles.

Figure 1: Monthly Search Volume: Industry 4.0 and Predictive Maintenance (2012-2017)



Source: Google Trends and Presenso Analysis based on 4 week moving averages.

Figure 2: Attitudes of Reliability and Maintenance Professionals on Predictive Analytics (9-Point Scale)



Source: Emory University Future of IIoT Research Study and Presenso.

2. Form alliances with academic institutions

Gartner suggests working with academic institutions that provide advanced degrees in data science. Some ideas include class projects, internships and hackathons.

Although companies can utilize exceptional students to work on correlation benchmarking and data labeling to run supervised algorithms, keep in mind that this requires significant mentorship and is more the exception than the rule.

An internship program can provide great value to a company and a learning experience for students. However, it is a band-aid solution to a severe skill set shortage.

3. Use third-party consultants

It is no secret that with enough budget, companies can hire highly paid consultants to do the work of their employees. However, this is not a scalable solution and it merely camouflages a company's inability to address its own needs internally. Shifting the burden from full-time employees to external vendor simply kicks the can down the road.

4. Purchase software applications

The idea that an off-the-shelf or even high-end software application can alleviate the need for big data scientists is wishful thinking. A plethora of software solutions exists, ranging from open source to custom applications. What do they all have in common? The need for skilled professionals to operate.

The Other Alternative: IIoT Predictive Maintenance as a Service

There is good news on the horizon. According to a Gartner report, in excess of 40 percent of data scientist tasks will be automated by 2020. Instead of band-aid solutions, industrial plants need to recognize that they are unable to change the long-term labor market or address weaknesses in the education system. The alternative is to build and acquire solutions that require almost no human intervention in the development and maintenance of the solution. Maintenance reliability technicians and engineers will not gain competencies in big data or machine learning and this reality needs to be accepted.

What is the alternative? Automated systems that use AI algorithms to analyze industrial plant sensor data and provide alerts of evolving asset degradation and failure. IIoT predictive maintenance surpasses traditional supervisory control and data acquisition (SCADA) monitoring because algorithms detect anomalous data patterns or patterns of anomalous behavior. With the traditional SCADA approach, only breaches of manually set controls are monitored and, in many cases, alerts happen too late.

Specifically, IIoT must be based on automated machine learning, whereby the specific algorithm applied to the data set is automatically selected. In reality, citizen data scientists and college interns lack the skill set for meta learning, artificial intelligence, etc.

More and more companies are turning to cloud-based solutions, and with good reason. If you cannot bring the data scientist to your industrial

> According to a Gartner report, in excess of 40 percent of data scientist tasks will be automated by 2020

plant, then you can bring your industrial plant data to the machine learning experts.

Conclusion

IIoT predictive maintenance impacts production yield rates, revenue and bottom line profitability. It requires the adoption of new solutions and new ways of doing business. The shift from Industry 3.0 to Industry 4.0 is based on applying machine learning and big data to operations. Existing people, processes and technologies will not suffice.

As C-level executives prioritize IIoT and focus on uptime, it will require industrial plants to embrace solutions that incorporate the real-time analysis of operational data without adding to one's workforce and disrupting ongoing production.

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Deddy Lavid *is CTO of Presenso. He is a recognized expert in the field of machine learning and big data architecture. Deddy's work spans the full spectrum, from researching isolated data problems to building complex production systems.* *www.presenso.com*

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WORTHINGTON INDUSTRIES' JOURNEY FROM FIREFIGHTING TO FIRST-CLASS MAINTENANCE

George Miconi

Worthington Industries, a global diversified metals manufacturer, recently finished a complete transformation of the maintenance department at its Columbus, Ohio, steel processing facility. In 2012, with maintenance accounting for the highest percentage of facility downtime at 7.2 percent and a growing open order backlog topping 280, the team decided it was time for change.

In just over five years, the maintenance department has gone from firefighting and reactive maintenance to a first-class operation focused on planned and preventive maintenance. Through the implemented changes, the department cut maintenance downtime 82 percent and open work orders by 96 percent.

To achieve these results, the maintenance team employed what the company calls its "Transformation 2.0" methodology. It's about using lean principles to accelerate change through rapid improvement events. The team started by identifying gaps or areas for improvement. Next, they pinpointed activities to experiment new ways to perform work. Experiments or methods that result in improved metrics or reduced waste are implemented as standard work.

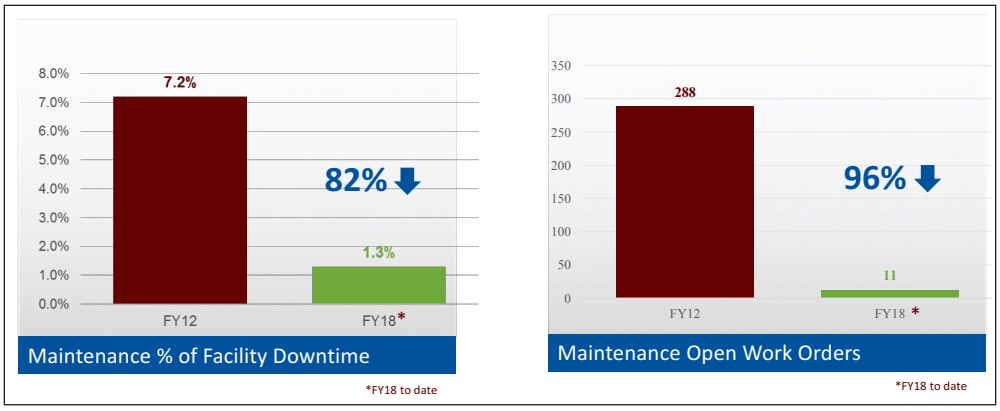

Figure 1: Percentage reduced for downtime and open work orders

Using the Transformation 2.0 framework, the maintenance department identified opportunities in three areas that were driving up their metrics and contributing to firefighting drills. They were: communication, staffing and technology/

Figure 2: Route checklists with photos were developed for each machine so operators could complete regular machine health checks

Figure 4: Three new hires with Maintenance Manager and Trainer Don McDaniel, second from left

equipment. Here's a look at the practices the team implemented to deliver significant performance gains.

It Starts with Communication

In 2012, when a work order came in, a maintenance manager assigned it to a technician. This process occurred for every work order submitted. There was little communication happening between maintenance and operations. Through a gap analysis, the team realized this was not the most efficient process. To avoid the firefighting mentality, they needed to be more integrated and aligned with operations.

To reach that goal, maintenance assigned a technician to each individual line or machine. This not only allows the maintenance technician to become an expert on that machine, but it has given the technician an opportunity to be part of that operations team. Attending daily operator meetings, maintenance technicians get to hear pain points firsthand. Hearing about issues early on has paved the way for more preventive maintenance efforts.

As relationships and teamwork strengthened, another positive result occurred. Operators began volunteering to take on more basic machine maintenance. Using standard work, maintenance technicians trained operators on these tasks. This freed up the technicians to take on other jobs and work down their order backlog.

In addition to facilitating more communications with operations, the maintenance team established weekly meetings of their own. This has been a game changer. Having these regular touch base meetings allows the group to plan ahead. Each week, they prioritize their workload for the next week. They also solicit feedback from operations when prioritizing the schedule.

Increased visual communication also has been a key to maintenance's success. The team built a maintenance communication board, which has become the central hub for sharing and tracking information. On the board, maintenance team members can see a list of all open work orders, what's been completed, or what is ready for the taking. Scheduled machine downtime is also tracked, along with updates from each shift, allowing those who've been off a shift to quickly get up to speed. The board has been a great tool for standardizing work and providing accountability.

Figure 3: Worthington Industries' maintenance communication board

Resources for Success

As members of the maintenance department set their sights on pushing the needle from reactive to preventive maintenance, they decided it wasn't enough to get everyone moving in the same direction. They needed a leader whose job was dedicated to planning, tracking and guiding these efforts. In 2012, the Columbus facility hired a maintenance planner. This addition has been instrumental in driving these initiatives.

To get out of the reactive maintenance cycle, staffing was also critical. As tenured maintenance technicians near retirement, the department realized it needed to be ready by planning ahead. However, finding skilled maintenance talent is often easier said than done. The maintenance

Figure 5: New transportation carts to reduce response times for tool requests

team decided to take action and help develop new talent.

Worthington's maintenance team started a training program with five local trade schools and colleges. The department's maintenance manager teaches classes, providing students with hands-on experience of the skills needed. To date, Worthington has hired three of these students. Out on the manufacturing floor, new technicians are paired with senior technicians for continued learning. They're also rotated through different machines to build their experience. Today, the Columbus maintenance department is fully staffed and set up for success, with a pipeline of future talent.

Tools of the Trade

To drive all these changes and, more importantly, to know if they're working, it's all about metrics. In 2015, maintenance implemented a new computerized maintenance management system (CMMS). Through the CMMS, they create and track a full year's downtime schedule for all plant machinery. They also run weekly and monthly reports to view performance on downtime and open work orders. Everyone on the team can see these dashboard reports, which provide accountability and a challenge to beat last month's metrics.

Recently, maintenance also added some new equipment in the form of transportation carts. These carts help reduce response times by giving technicians access to the tools they need right where they need them. In looking for every opportunity to eliminate waste, minutes and seconds count.

> "The only way to get better is by not staying the same"

Overall, the performance gains achieved through focused efforts around communications, staffing resources and equipment didn't happen overnight. It's been a continuous process of incremental year-over-year improvements. The reason it works is because employees are driving the ideas and the company has created an environment where it's okay to try new things and fail. The only way to get better is by not staying the same. That mind-set has allowed the team to achieve 80 and 90 percent improvements, cutting maintenance downtime to just 1.3 percent and the number of open work orders to 11.

And, they're not finished yet. The maintenance department has a list of action items they're always working to improve, along with a wish list. Once one action item gets completed, an item from the wish list gets moved over.

You know you have a successful, sustainable process in place when you've already achieved 80 to 90 percent reductions and employees are saying, "We can do better than that. We can cut this metric in half again."

Current		Change from FY2012
Downtime:	1.3%	↓ 82%
Open Work Orders:	11	↓ 96%

***George Miconi** has been with Worthington Industries for six years as a Maintenance Planner. In that role, he helps lead plant-wide maintenance strategy and continuous improvement initiatives. He's proud of all the team has accomplished, but will tell you, "we've only scratched the surface – there is so much more we can do." www.worthingtonindustries.com*

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Luis Fabian Villacres

A TRUE STORY

As a reliability engineer in an oil and gas facility, one of the main goals is to minimize reactive work, as well as increase reliability and availability of the physical assets. But another important task is to get the reliability growth noticed by all the people, including leaders and managers. A problem solved is a great chance for a "sales" presentation.

THE PROBLEM

A bad actor was identified in the water disposal injection system (see Figure 1). The three 6x4x13 pre-booster pumps had a long list of chronic failures, like broken shafts, damaged seals, etc. On average, they had one failure per week. Normally, just one of them is running, but all of them showed the same behavior.

A troubleshooting process was developed, which included gathering information about failure modes and operational context of the entire water disposal system.

The broken shafts showed two kinds of failures: a bending failure (see Figure 2) and a torsional failure (see Figure 3).

The first type of failure could be caused by operating a centrifugal pump far from the best efficiency point (BEP). By using a portable flowmeter, a measurement of 320 gpm (10,000 barrels per day) is obtained, which is 30 percent of BEP, clearly out of acceptable operational range (see Figure 4).

In addition, a failed check valve allowed the flow to return, which was probably the cause of the torsional failures since this event was present just when each pump was shut down for service.

THE SOLUTION

At this point, the causes of the chronic failures are known, but what needs to be done for solving them? Because of low oil prices, there is no budget to perform a big modification. However, having solid knowledge about the pumping system helped to find an effective and low-cost solution. By connecting both water disposal wells with a 300-foot long pipeline, the system was able to pump an additional 10,000 barrels per day. As a consequence, the pre-booster pump that was running changed its operational point to 600 gpm, which is 20,000 barrels per day or 60 percent BEP. Even though it is not an ideal situation, it is better than no action and the centrifugal pumps have not failed again since then (see Figure 5).

Figure 2: Bending failure

DON'T TELL ME, SHOW ME

Reliability initiatives need to get noticed, but the right language is key. The Crow-AMSAA (C-A) plot is an excellent method to demonstrate reliability improvements and the savings obtained, which everyone in the organization is able to understand.

The main reasons to use C-A plots are:

- The equation, $N(t) = \lambda t^{\beta}$, provides line slope, β and Y-axis intercept at t=1, λ. β<1 means failures are decreasing, β>1 means failures are increasing and β≈1 means neither increasing nor decreasing.
- To make a reasonable forecast of when the next failure occurs. Mixed failure modes are acceptable and C-A plots can tolerate an arbitrary starting point for accumulation of time.

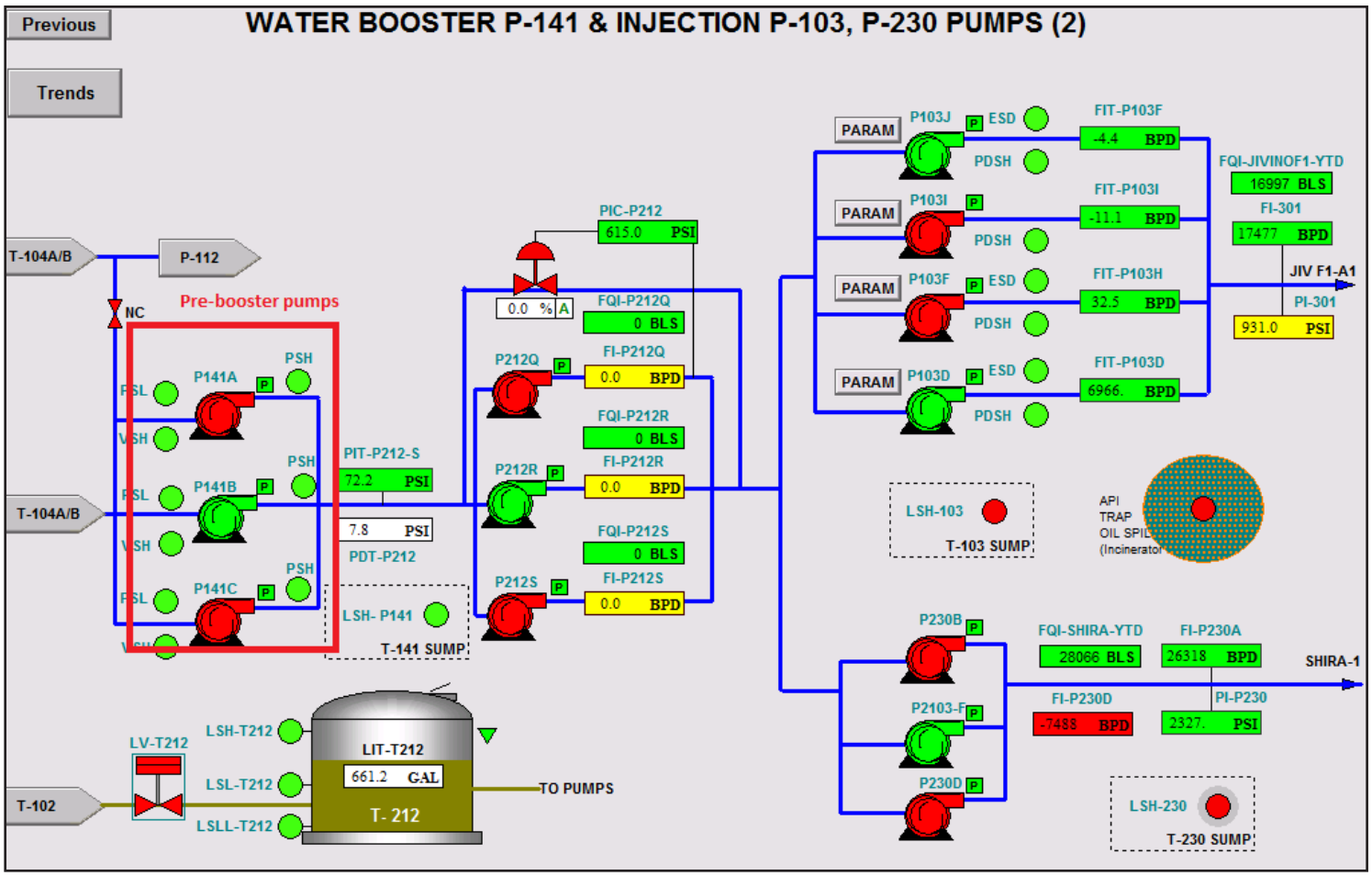

Figure 1: Water disposal injection system

Figure 3: Torsional failure

> "Reliability initiatives need to get noticed, but the right language is key"

Table 1 – Failure Records			
#Failures	Date	Cumulative Days	Cumulative Failures
0	18-Jun-15	0	0
1	19-Dec-15	184	1
2	3-Apr-16	290	2
3	21-May-16	338	3
4	30-Jun-16	378	4
5	4-Jul-16	382	5
6	23-Aug-16	432	6
7	1-Sep-16	441	7
8	8-Sep-16	448	8
9	22-Oct-16	492	9
10	24-Oct-16	494	10
11	28-Nov-16	529	11
12	26-Jan-17	588	12
13	27-Jan-17	589	13
14	10-Mar-17	631	14
15	1-Apr-17	653	15
16	7-Apr-17	659	16
17	9-Apr-17	661	17
18	15-Apr-17	667	18
19	05-Jan-18	932	19

The failure dates of the system, cumulative days and cumulative number of failures are shown in Table 1. Figure 6 is a plot of each point on logarithmic axes, with the cumulative number of days between failures on the x-axis and the cumulative number of failures on the y-axis. The blue dots represent failures when the pump was operating at 30 percent of BEP and the power curve fitted shows β=2.3, meaning failures are increasing rapidly until April 15, 2017.

Assuming a failure on January 5, 2018, a new power curve can be fitted by using the last real failure and the assumed one (red dots). β=0.16 means a good improvement because failures are decreasing.

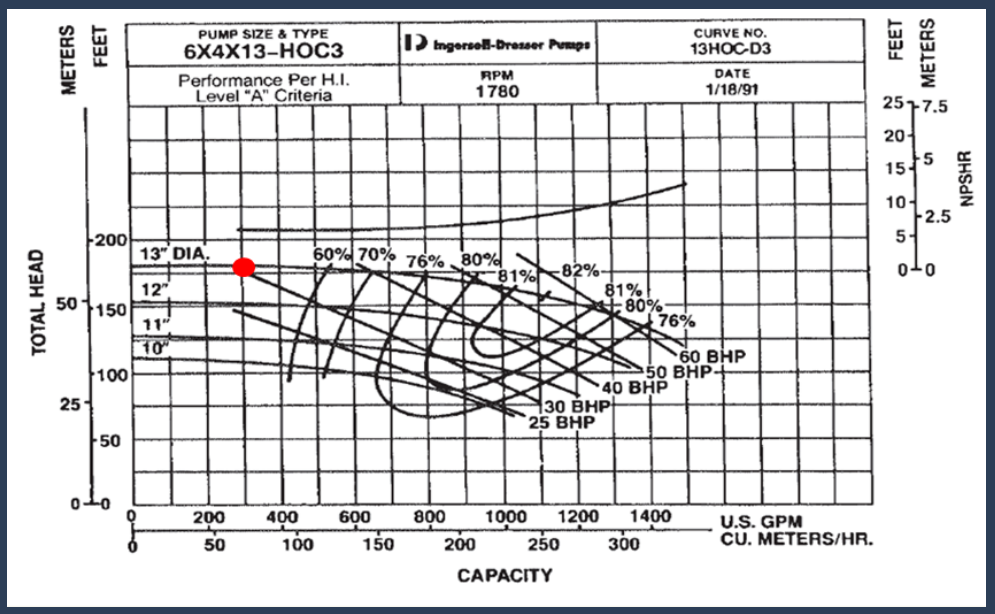

Figure 4: Pre-booster operational point (red dot)

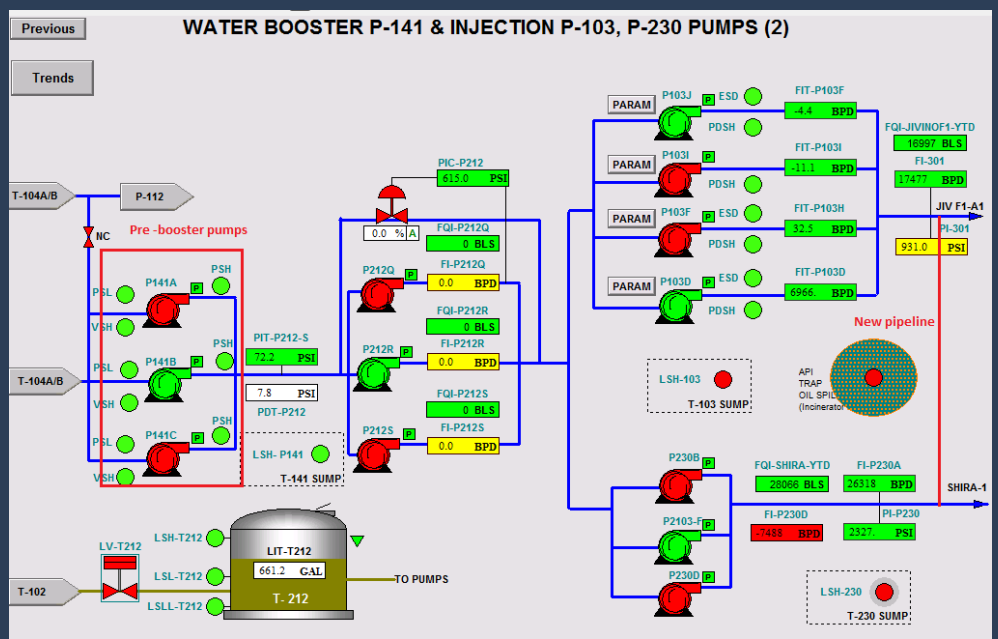

Figure 5: Recommended solution

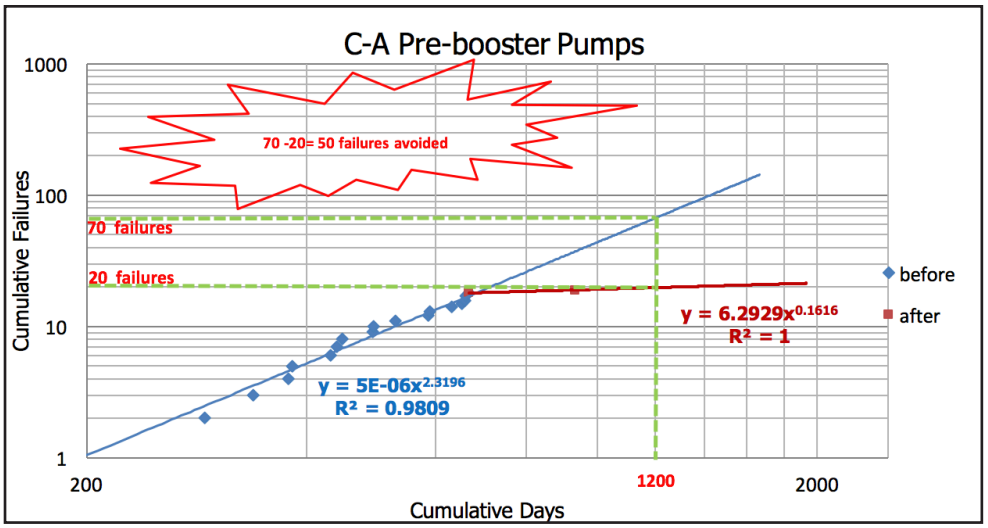

Figure 6: C-A plot pre-booster pumps

By extrapolating both curves, one is able to forecast future failures for the next 1,200 cumulative days, for example.

At the 30 percent of BEP situation, there would be 70 cumulative failures, while at the 60 percent of BEP, there would be 20 cumulative failures. That means 50 failures were avoided in that period. An average cost per failure is $10,000. The savings can be calculated as:

Savings = #failures avoided x average cost per failure
Savings = 50 x 10,000= $500,000

This is a great result, taking into account the very low budget used in the implementation of the new pipeline connecting both water disposal wells.

These kinds of plots are easy to understand and also show how the reliability improvements support the business objectives.

Reliability expert Paul Barringer once said about the C-A model: "Please recognize that many equations describing physical phenomena have simplistic equations: $F = ma$, $E = mC^2$, $S = F/A$, etc. Since most of you cannot derive or explain the theory behind these well-known equations, why would you doubt that also describes important physical relationships in the field of reliability."

Luis Fabian Villacres, *CMRP, is the founder and CEO of Ingenieria CBM, a provider of condition-based maintenance and reliability services, including training. Luis Fabian has more than 16 years of experience in the Ecuadorian oil & gas industry as a reliability engineer, predictive maintenance engineer and RCM facilitator. He is ISO18436-2 Category IV certified. www.ingenieriacbm.com*

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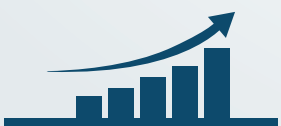

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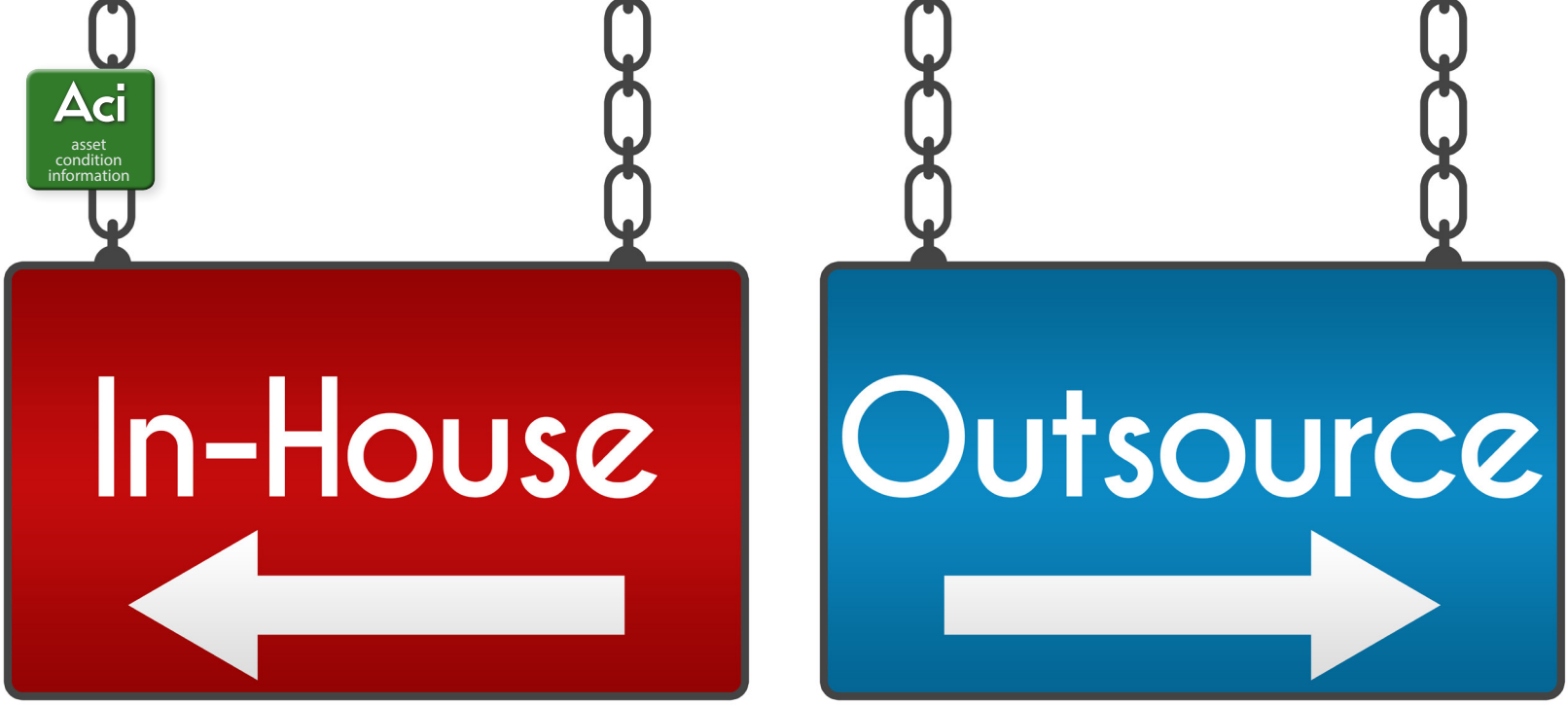


Do You Trust Your In-Plant or Outsourced Rebuild Facility?

Dillon Gully

Let's face it, people make mistakes – and some mistakes can be quite expensive. Mistakes made in a gearbox rebuild, for example, can cost a plant hundreds of thousands of dollars due to unplanned downtime and even workplace injuries resulting from a bad rebuild. Have you ever taken the time to audit your in-plant or outsourced rebuild facility? Do you require acceptance testing of the components that have been rebuilt to verify they are service ready?

Many rebuild facilities claim they have skilled technicians, quality programs and testing capabilities. But do they really? Realistically, you should not have to just take someone's word that the rebuild of the equipment was done to the original equipment manufacturer's specifications. There should be data from a performance test to prove this. If you are not getting such data, then you should be asking why.

Some things to consider with gearbox rebuilds are:

- What are gearboxes and how can they stop production;
- How do gearboxes fail;
- How to prevent these failures;
- How to test for failures and understand the data.

What Gearboxes Do and How They Can Stop Production

Gearboxes are used to decrease the speed produced from a motor, increase speed from a motor, translate mechanical horsepower to torque {t (lb.-in) = (HPX63025)/RPM} and increase torque {output torque= input torque X gear ratio}. Think of a diesel engine running at 900 rpm and coupled to a speed increaser gearbox with a 1:2 ratio. Now, you have an output speed of 1,800 rpm to run your electric generator.

Gearboxes are used in tandem with electric and hydraulic motors to reach speed and torque requirements. Let's say you have a gearbox turning a fan that ventilates the restrooms at your office. The gearbox stops working, so the fan stops working. That may be unpleasant and you may not win a workplace popularity contest, but it will not really cost your facility much in production loss. Now, let's imagine that gearbox is on a conveyor that moves your finished product to the shipping area. That failed gearbox not only causes you to miss your quota, but also delays shipment, resulting in customers losing faith in your ability to deliver a quality product.

> "A failed gear reducer on a paper machine can result in production losses costing $70,000 per hour"

A gearbox failure also could be costly in downtime. A failed gear reducer on a paper machine can result in production losses costing $70,000 per hour. This can add up quickly, but knowing how this could happen is important in avoiding such catastrophic events.

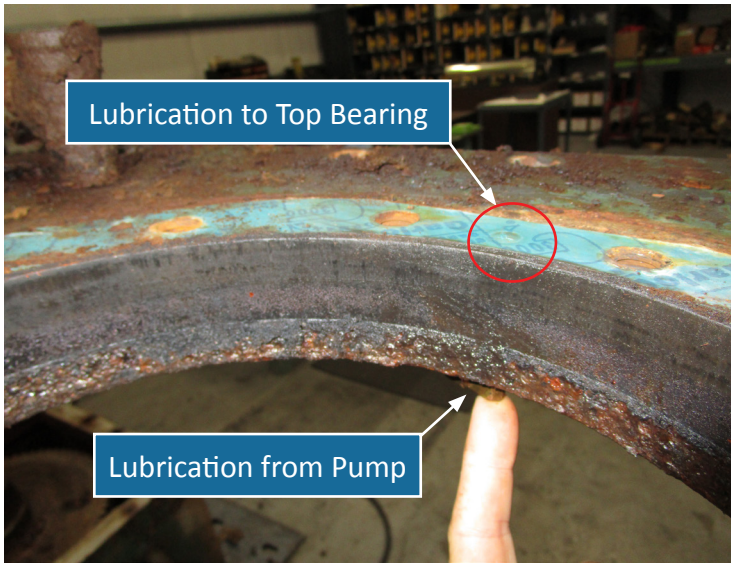


Figure 1: Gasket material blocking lubrication port to top bearing
(All images and tables courtesy of Motion Industries)

How Gearboxes Fail

Numerous forces can cause gearboxes to fail. Failure mode and effects analysis (FMEA) is beyond the scope of this article, but here are some basics for those not familiar with gearboxes. Gearbox parts include the housing, bearings, seals and gears. If any of these parts are not handled properly, stored properly, or assembled properly, they can cause the gearbox to fail prematurely.

Bearings are typically the weakest part of a gearbox and can cause a gearbox to fail very quickly. The list of ways a bearing can fail is quite long and always indicates human or latent failure as the root cause of failure. In most gearbox failures, lubrication failure is the result of human error, whether the lubricant is insufficient, inadequate, or unable to perform. Figure 1 shows a lubrication passage that is blocked by a gasket. This failure is the result of human error during the manufacturing of the gasket and assembly of the gearbox.

With so many chances for gearboxes to fail, what can you do? Auditing a rebuild facility is your first line of defense against gearbox failure. Whether your gearboxes are rebuilt at your own site or off-site at a rebuild facility, you can and should audit the facility to ensure you are getting the quality service you require to have a reliable operation.

As previously mentioned, failures are often caused by human error. Even the greatest and most experienced gearbox mechanic will eventually make a mistake. These human errors can be the result of inexperience, lack of training, improper tools, uncalibrated tools, stress at home, stress at work, etc. Your audit should attempt to include all areas where failures can occur. This is to ensure that shop management covers the potential of gearbox failure with a consistent and unbiased operation that includes fail-safes to ensure a quality rebuild and prevent latent failures.

> "Auditing a rebuild facility is your first line of defense against gearbox failure"

Preventing Gearbox Failure

Anyone who provides a service will always claim to provide a quality product. Policies and procedures are most vital in preventing latent failures, which is the first step in the failure process. It is latent failures that allow human error to occur or go unchecked. Auditing that process will determine if quality can be achieved consistently. General audit items include:

- Storage;
- Handling tools;
- Teardown;
- Inspection area;
- Cleaning area;
- Assembly process;
- Policies and procedures;
- Certifications and authorizations.

How can you ensure the rebuild facility follows these policies and procedures in a way that you can track and measure? The most basic quality assurance documentation is a quality control document. This document contains all the steps that should be performed during the rebuild process. It should be signed by two technicians involved in the rebuild process, with one of them a member of management. The purpose of the two signatures is to ensure the work was double-checked.

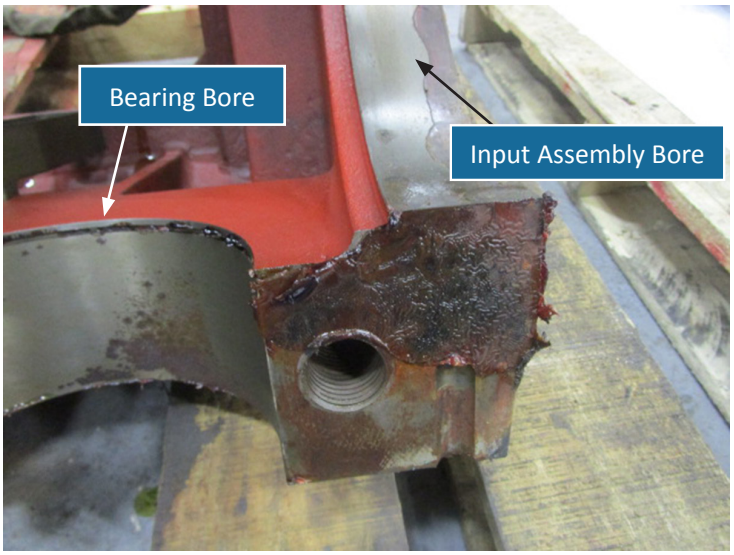


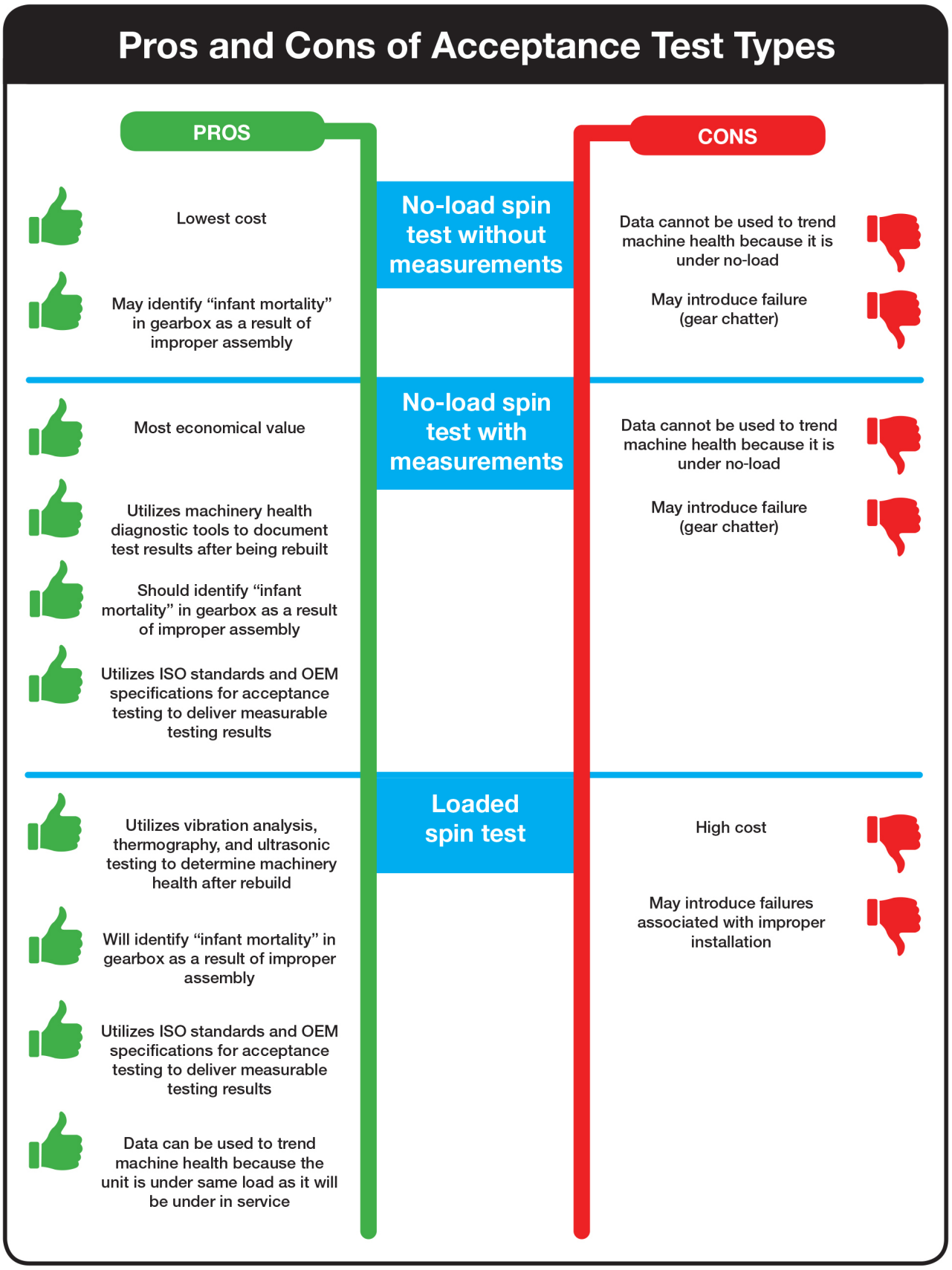
Figure 2: Housing fasteners improperly torqued, indicated by a .026" thick flange sealant that caused the bearing bore and input assembly to be out of tolerance

Figure 2 shows a flange sealant that is .026 inches thick. This is caused by the housing's fasteners being improperly torqued, putting the bearing bores and input assembly out of tolerance. A two-person inspection procedure is more likely to catch such costly mistakes.

Gearbox Acceptance Testing

The next level of quality assurance is acceptance testing. As the name implies, acceptance testing is any test that measures the performance of an

Table 1 – Pros and Cons of Acceptance Test Types



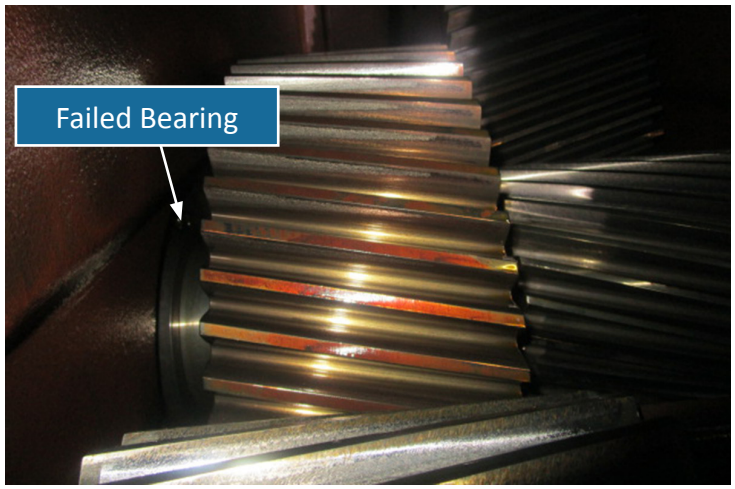


Figure 3: Gearbox had misalignment wear on gear teeth as a result of an improper bearing fit - the bore was out of tolerance

asset, tool, or machine before it is put into service. The obvious question is: Why not test every single gearbox? An acceptance test costs money, including the labor to set up and tear down the motors, sheaves and bolster plate, and the required training and expertise to perform the test.

Acceptance tests are performed at various levels to achieve different results, as shown in Table 1.

If no acceptance test is performed, then any failure that would otherwise be found and addressed in the shop will not be identified until the gearbox is placed in service. Asset managers should review acceptance test results before the gearbox ever leaves the rebuild facility. If the gearbox is not performing to the proper standards, it can be addressed without any additional delays.

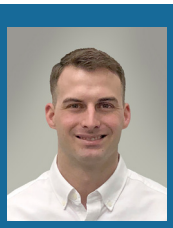
The gear wear in Figure 3 is the result of a bearing failure. The bearing, which had an improper fit to the shaft and in the housing, is likely to be the root cause. Acceptance testing with thermal imagery and vibration analysis would catch this failure.

Bolstering Your Uptime

Auditing rebuild facilities is your opportunity to ensure all latent failures are covered by appropriate policies and procedures. Those policies and procedures should prevent or identify any failures caused by human error. Requiring an acceptance test on a rebuilt gearbox verifies policy and procedure adherence.

Acceptance testing may add to the cost of the rebuild, so it should be the responsibility of the asset manager to determine if it is required or not.

Implementing a program to audit your rebuild facility and test the finished product will help identify failures before service and reduce unplanned downtime.



Dillon Gully *worked as a Service Technician for three years at Motion Industries' Gearbox Rebuild Facility in Pensacola, Florida. His roles included vibration analysis, failure analysis, thermography, and video scoping of stored and dynamic assets. www.motionindustries.com*

10 THINGS YOUR MANAGEMENT NEEDS TO KNOW NOW

Joel Levitt

Ignorance Is Contagious and You Are the Only One to Save the Day

1. There is a widespread misunderstanding of what preventive maintenance (PM) does and does not do. PM does not put iron into an inadequate machine. PM does not work on junk. Initiating a PM program rarely effects your breakdown rate for a year or more unless you commit to this one thing. PM and predictive maintenance (PdM) inspection detect deterioration, damage and defects that will lead to failures, but does not stop them! You stop these incipient failures by doing the corrective tasks, which include correcting the damage, deterioration, or defect in a timely way before the failure.

2. All the Industrial Internet of Things (IIoT) sensors, the Cloud, analytics and artificial intelligence (AI) won't make you world-class or change the need for basic maintenance. Fortunately, or unfortunately, all the tech you can buy will not change the engineering, physics, or chemistry of your equipment. Bearings overheat, bolts loosen and dirt gets where it shouldn't. Your cool sensors with up-to-the-minute analytics might tell you when or how bad, but they have no impact on the mechanism of failure. The only activity that has an impact on the mechanism of failure is basic maintenance, like greasing, tightening bolts and cleaning.

3. Maintenance instruments are about as accurate as medical instruments. False positives (e.g., the doctor sees something on an X-ray and says you may have a disease and orders more tests and it turns out to be nothing) and false negatives (e.g., people drop dead right after seeing a doctor) happen every day and are widely known and studied. If your vibration tech says a bearing is going to fail, there is a nine out of 10 chance the finding is accurate. That means you must give the PdM crew some space to be wrong. Medicine realized that if there are no false positives, then the test might not be sensitive enough. They increased the sensitivity of the test until they got a few false positives. Then, they knew they had the right sensitivity.

4. The single, biggest cause of your breakdowns are random acts of carelessness. Research into failures done as far back as 50 years ago showed conclusively that the leading causes of breakdowns are random. According to Winston P. Ledet et al., 63 percent of breakdowns are due to misoperation. Random breakdowns in careful operations or careful maintenance are at the source. Some of them can be addressed through training, poka-yoke (i.e., mistake proofing), precision standards and a shift in emphasis to intentional precision operation and maintenance.

5. Logically, then, most of your breakdowns have nothing to do with maintenance! Blaming breakdowns on inadequate PM or generally bad maintenance efforts is just like blaming doctors for the epidemic of obesity. Of course, doctors must deal with the sickness that results, but they are no more responsible for the epidemic than the maintenance department is for most breakdowns. Likewise, an obese person visiting the doctor more often (i.e., increasing the PM frequency) will not fix the problem, although it might detect an issue earlier, which is a good thing.

6. For better or worse, your maintenance department can only impact a small part of the overall reliability of your equipment. Reliability is complex! There are inputs, decisions and opportunities during every lifecycle. If you want reliability, you must start at the business case or conception of the asset and make good decisions and continue to make good decisions until the asset's end (i.e., when it no longer contributes adequate value to the organization). If reliability in your company is for maintenance to figure out and be accountable for, you will miss the boat.

7. Most of the lifecycle costs of a motor purchased today is electricity, yet the incentive for purchasing is on price. Electric usage is practically ignored. You might argue that the present value of the future savings doesn't justify it. But, do the math, it does. Lower electricity also means lower heat and usually longer life.

8. You deliberately choose equipment with high maintenance costs. It's the same logic as buying inefficient motors. Let's face it, buying cheap equipment is easier than figuring out the best equipment for the application. And, by the way, you have created a monster. By buying on price alone, you bankrupt any original equipment manufacturer (OEM) with the temerity to build quality. Most of them turn to the dark side and

make up lost profits with margins on parts and services. Of course, there are still good ones out there, so figure out who they are and buy from them before they, too, turn to the dark side.

9. New plants, lines and facilities are designed, built, commissioned and operated intentionally with excessive maintenance costs for the next 25 years. The cause is short-term thinking, using incentives for on budget and on time performance to the exclusion of lowest lifecycle cost, maintainability and successful start-up. There is a basic reluctance on management's part, living deep in silos, to share the information and experiences of brother and sister disciplines. Sharing and communicating are the antidotes.

10. Spare parts are the life blood of maintenance once something does go wrong. Their reason for storage is not to make it convenient for maintenance. The real reason is simple: You stock parts to reduce the risk of downtime from having to wait for parts. Attempts to cut spare parts inventory generally increase the cost of producing your product due to downtime while waiting for parts. This is because you got rid of the wrong parts. By the way, you still wasted a ton of money and now you don't even have the downtime buffer that the parts represent.

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MAINTENANCE STOREROOMS AND MRO MADE SIMPLE

BY DANIEL DEWALD
REVIEW BY GEORGE KRAUTER

The stated purpose of *Maintenance Storerooms and MRO Made Simple* is to "share the secrets" of running an excellent storeroom. Author Daniel DeWald achieves this purpose.

In the introduction, DeWald correctly outlines real-life situations existing in many storerooms that are the cause of an unreliable MRO storeroom operation. He states that a proactive storeroom revolves around change – change in attitude, beliefs and expectations – and presents the steps necessary to achieve excellence in stores and MRO management.

Many profitable ideas and concepts can be learned from reading this book. For me, three stand out significantly:

- A crisis in lost production (i.e., downtime) caused by MRO mismanagement resulted in plant management entering into an MRO change program to solve the problem. Once the crisis was over, the storeroom returned to the old unreliable mismanagement. Change must be sustained.
- DeWald points to silos that exist in plants where different departments have different ideas and goals regarding MRO. He states that in order for change to be effective, all departments must be in agreement.
- The book states that MRO storerooms that are expensed are a cost center; they should be converted to a profit center. All should be in agreement that any profit drain function in the plant should be changed to achieve a profitable environment; this should include MRO.

In Chapter 6, Inventory Management, DeWald dedicates three pages to vendor managed inventory (VMI), defined as "an outside source brought into the plant to manage your inventory." Later, he states that other activities can be added to that outside source, such as a third-party logistics (3PL) company. He lists the advantages of contracting with a 3PL provider.

In any plant function where changes occur for the better and are sustained, there are always investigations into how to achieve greater improvements and cost reductions. Except for the three pages on 3PLs, the processes presented in the book still leave the company in the MRO business…not the plant's core competency. The company produces the products it sells to its markets; it is not in the hardware business, also known as the company's MRO storeroom. In my opinion, there are far more costs and efficiencies to be had by getting out of the MRO business entirely.

This book is a fine reference for those companies that cannot or will not outsource the entire MRO supply chain from the MRO manufacturer through to the mechanic on the shop floor.

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