RETHINKING ASSET PERFORMANCE MANAGEMENT

ARC Strategies
July 2019

Two-thirds of the 365 industry practitioners recently surveyed by ARC Advisory Group believe reliability-centered maintenance (RCM) isn't improving reliability and that operations has almost as much impact on plant asset performance as the maintenance organization does. Leaders believe that while, historically, maintenance groups have been the custodian of the reliability process, digitalization requires a rethinking of the overall asset performance strategy.

By Peter Reynolds
Principal Analyst

ARC Advisory Group

VISION, EXPERIENCE, ANSWERS FOR INDUSTRY

CONTENTS

Executive Overview

Owner-operators have long suspected that poor asset performance is hampering their overall business performance. When assets don't perform up to expectations or have the anticipated reliability, profit margins suffer, and operational excellence becomes elusive. ARC Advisory Group recently surveyed 365 industry practitioners and conducted in-depth interviews with several subject matter experts to gain a better understanding of how industry leaders are implementing asset performance management (APM) initiatives and compare the effectiveness of the different approaches.

ARC Advisory Group recently surveyed 365 industry practitioners and interviewed several experts to gain a better understanding of how industry leaders are implementing asset performance management (APM) initiatives and compare the effectiveness of the different approaches.

The objective of APM is to improve the reliability and availability of physical assets while minimizing risk and operating costs. APM tools typically include condition monitoring, predictive maintenance, and asset integrity management; and often involve technologies such as asset health monitoring and data collection, visualization, and analytics. While both maintenance and operations groups have a major impact on overall asset performance, historically, the emphasis for APM has been on maintenance-focused enterprise asset management (EAM) and inspections.

New digital technologies can augment many maintenance, reliability, and operational processes to an unprecedented degree. New commoditized computing resources in the Cloud and at the network edge and artificial intelligence (AI), digital twins, and augmented reality are changing how people work. Approaches such as the Industrial Internet of Things (IIoT) and Industry 4.0 have helped pave the way for digital transformation across a broad swath of industrial sectors. These new approaches have made their way into APM initiatives or programs to improve maintenance and reliability work processes and overall operational and business performance.

Key findings from this research include:

- Approximately two-thirds of all industry respondents surveyed either: 1. don't practice reliability centered maintenance (22 percent), 2. don't believe that RCM provides ROI or improves reliability (27 percent), or that 3. assets fail randomly despite RCM efforts (18 percent).

- Operations has as much impact on plant asset performance as the maintenance organization does.
- Leaders believe the maintenance group has been the custodian of the reliability process but are re-thinking asset performance strategy through digitalization to provide operations groups with better tools and enhance collaboration for APM.
- Successful asset performance management requires close cooperation between the maintenance, reliability, process engineering, and operations functions in an industrial facility. Operational performance as well as asset performance must be considered. New digitalization tools can help make that cooperation easier.

From Digitization to Digitalization

ARC is aware of the confusion many in industry have about the distinction (if any) between the terms "digitization" and "digitalization."

One way to look at it is that "digitization" involves creating digital versions of previously analog data such as by creating digital maintenance work orders to replace paper-based work orders. Replacing analog operational technology with digital technology, such as the transition from analog field instrumentation and control systems to digital instrumentation and control systems, would be another example. Digitization focuses on technology and infrastructure and typically impacts a relatively small number of stakeholders within a company.

Digitization focuses on technology and infrastructure and typically impacts a relatively small number of stakeholders within a company. Digitalization, on the other hand, involves making use of digital data and technologies to improve a business or work process.

Digitalization, in turn, involves making use of digital data and technologies to improve a business or work process. For example, utilizing data from a digital work order to improve maintenance work processes and execution, or using digital twins to improve asset performance. In other words, digitalization utilizes digital technologies and data to improve the way people work, collaborate, and get things done within a plant or across a company. Digital technologies and the digitalization of data and work processes offer tremendous potential to help industrial organizations improve the performance of their human and industrial assets.

However, when it comes to asset performance management, many companies today tend to focus their efforts on the technology without considering the full organizational impact. ARC research shows that only a small percentage of industrial organizations consider themselves ready to digitalize APM. Many others are not prepared to scale up the pilot programs currently in progress. ARC research also indicates that barriers to organizational accountability, culture, and employee change management impede digitalization. These barriers are reflected in the following APM benchmarking categories discussed in this report:

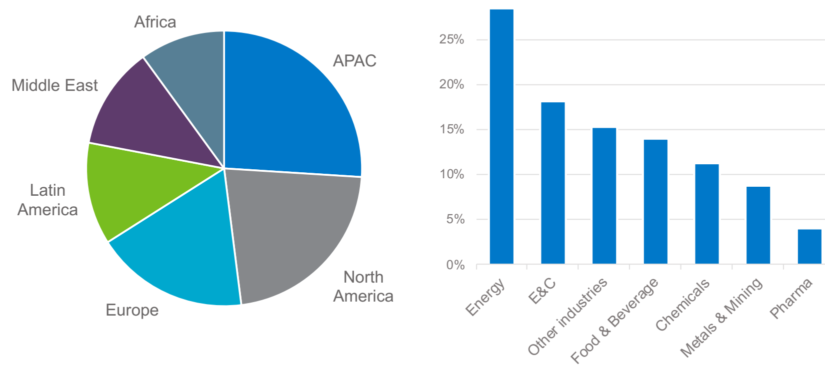
- Maintenance tools and approaches
- Benefits and value of APM
- Features of an APM system
- Advance warning systems
- Maintenance program tools

APM Benchmarking Research Survey and Methodology

The goal of this research was to gain a better understanding of how today's industry leaders are implementing asset performance management initiatives and compare the effectiveness of the different approaches. In March and April 2019, ARC Advisory Group conducted research to analyze and benchmark the current industry state and emerging best practices in APM. This research was designed to answer fundamental questions about digitalization and asset performance, APM tools, and the benefits of different maintenance and reliability strategies.

Armed with a few key questions, ARC launched a global web survey of 365 experts from North America, Europe, Latin America, Middle East, Africa, and Asia-Pacific. ARC then had in-depth discussions with a handful of subject matter experts (SMEs) across several industries. The research identified some compelling reasons for industrial organizations to rethink their current asset performance management approaches.

ARC analyzed and compared responses from 75 engineering SMEs, 124 maintenance and reliability SMEs, 52 operations leaders, and 72 technical managers or general management. Industries represented include energy, engineering & construction, food & beverage, chemicals, metals & mining, pharmaceutical, and several other industry segments.

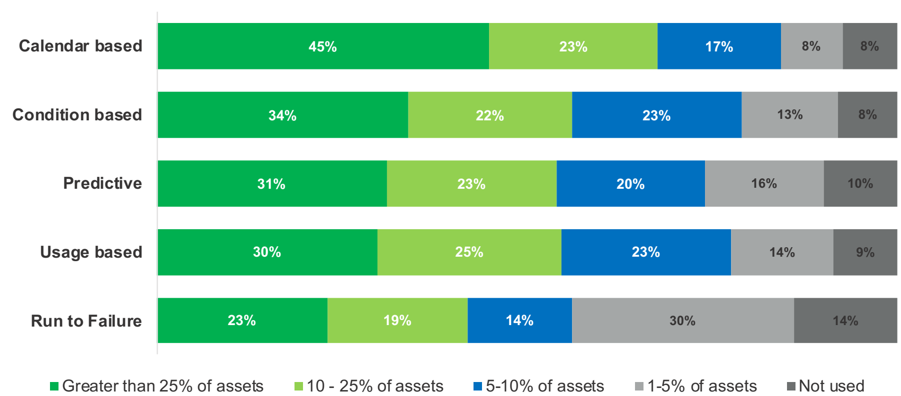


Global Survey Distribution and Industry Segmentation

Maintenance Tools and Approaches

Calendar-based Maintenance Most Utilized Approach

ARC asked survey respondents to describe their current maintenance practices. Not surprisingly, the results varied quite a bit.



How Would You Best Describe Your Current Maintenance Practices?

Calendar-based maintenance is the most utilized maintenance approach. In the (heavy process) refining and petrochemical industries, maintenance is driven by the turnaround schedule for major equipment. Most of these companies had a five-year turnaround cycle target. Most assets and related spare equipment are serviced based on the original equipment manufacturer (OEM) service schedule. (Users appear to lack the confidence needed to deviate from the OEM's recommendations).

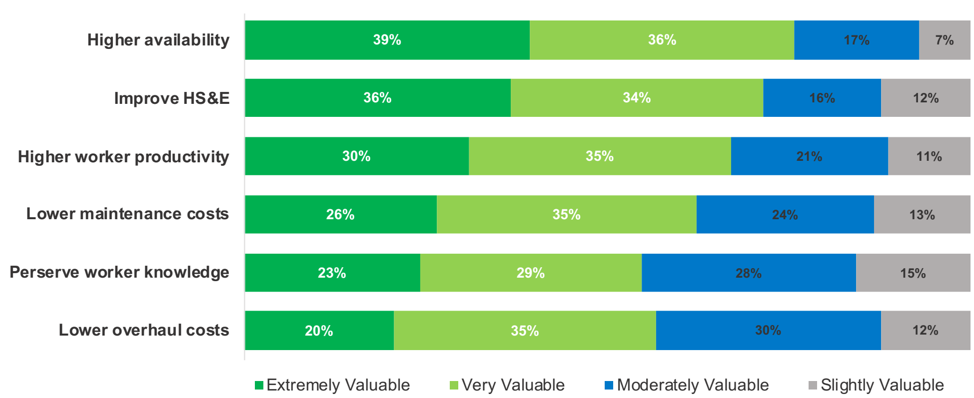
Calendar-based maintenance is the most utilized maintenance approach. Some users believe there has been a lack of confidence to deviate from the original equipment manufacturer recommendations. For many respondents, the asset-criticality analysis process drives the maintenance approach.

Condition-based maintenance (CBM) also scored quite high. This is consistent with the adoption of common tools and objectives of reliability-centered maintenance (RCM), which provides a process for determining the most effective maintenance strategy. The RCM philosophy employs preventive maintenance (PM), predictive maintenance (PdM), real-time monitoring (RTM), run-to-failure (reactive), and proactive maintenance techniques in an integrated manner to increase the probability that an asset or component will function as designed over its lifecycle with a minimum of maintenance. For many respondents, the asset-criticality analysis process drives the maintenance strategy and approach. For example, run to failure might be perfectly acceptable for a chiller that runs periodically and is not critical to production.

While the "predictive" category scored surprisingly high, we observed that a variety of strategies and technologies are used with a wide range of abilities to predict failures. These drive confidence (or lack of confidence) to change a work process.

Increasing Asset Availability Most Valued Benefit of APM

We asked users how their company values the benefits of APM. While "higher availability" scored highest, care must be taken when interpreting



How Does Your Company Value the Benefits of APM?

this metric. We also noted some differences when comparing continuous process industries to discrete and batch processing industries.

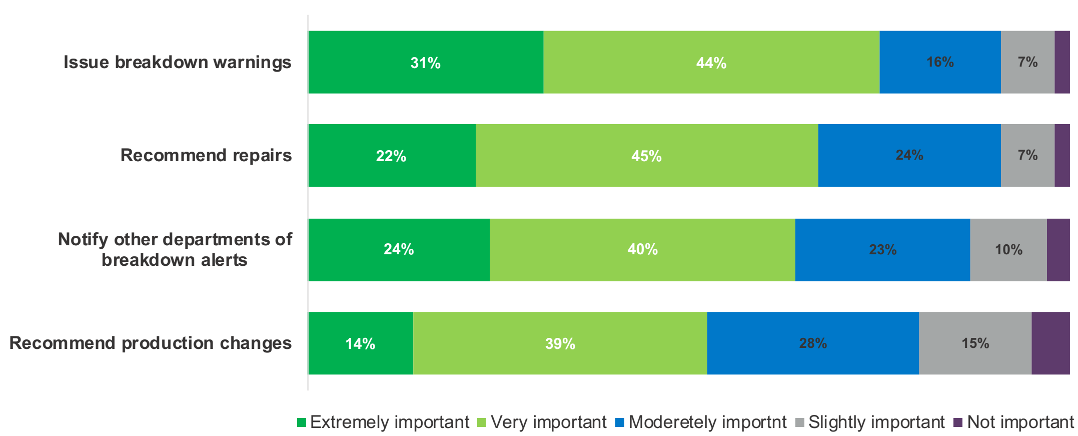
Process industry experts consider "availability to plan" to be a much more meaningful target than attempting to achieve higher availability for each asset (the objective of RCM). Availability to plan is most often used in the process industries because of built-in redundancies. Stated simply by asset owners, availability to plan means: "It needs to run when it is supposed to run."

In the batch and discrete manufacturing industries, overall equipment effectiveness (OEE) is the key metric. OEE identifies the percentage of manufacturing time that is truly productive. For example, an OEE score of 100 percent means you are manufacturing only good parts, as fast as possible, with no down time. In the language of OEE, that means 100 percent quality (only good parts), 100 percent performance (as fast as possible), and 100 percent availability (no stop time).

Current Systems Do Not Provide Adequate Warning

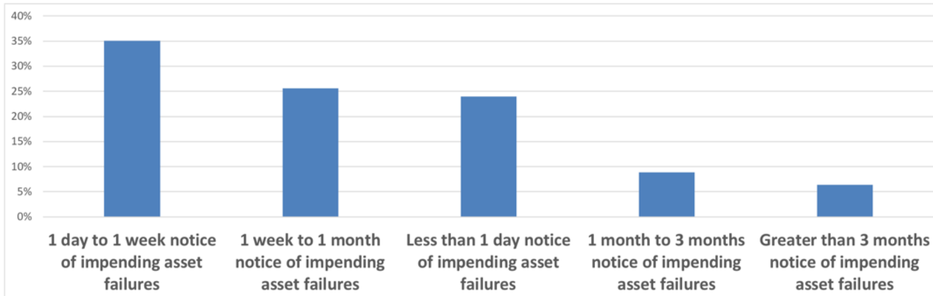
The process industry generally accepts that advance warning of impending breakdowns is the most important functionality of APM systems. Yet, when we inquired about how much advance notice they typically receive, the response was surprisingly poor. Fifty-nine percent of users on average receive less than one week notice of impending failure. While not yet fully mature, new IIoT-enabled remote monitoring and predictive analytics technologies have the potential to significantly reduce the time

For process industries "availability to plan" is a much more meaningful target then achieving higher availability for each asset.



What Are the Most Important Features of an Asset Performance Management System?

needed to identify and alert the appropriate personnel about impending failures.



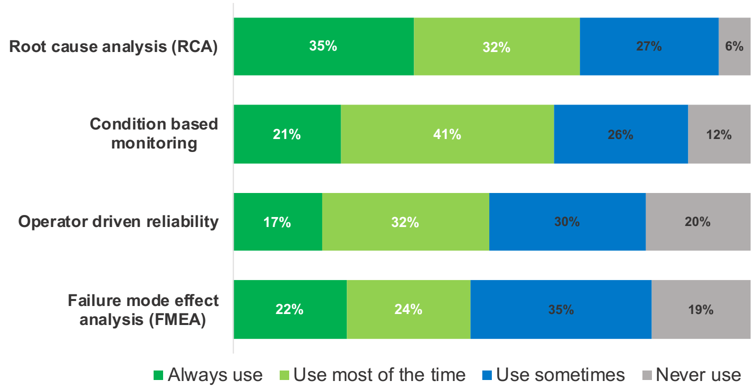
In leading plants, systems generate these warnings so that - depending on the work process - operators can first make the necessary adjustments to the process, maintenance can then (if needed) make the necessary asset repairs/replacement, or – if the best choice financially – the asset is simply left to fail.

Many consider a maintenance work order to be an appropriate mechanism to inform other departments. Leaders are moving toward digitalization and improving decision making by taking action in a time frame that can make a difference. Unfortunately, many believe that creating a work order within enterprise asset management systems (EAM) constitutes adequate notification, which is not always the case.

62 percent use condition-based monitoring (CBM) and leaders are looking to new tools, Industrial IoT, Industry 4.0, and data science to understand the problem better.

Maintenance Program Tools and Operations

Root cause analysis (RCA), the most common maintenance program tool cited, is an essential component of reliability programs. Sixty-two percent of survey participants use condition-based monitoring (CBM) and leaders are looking to new tools,

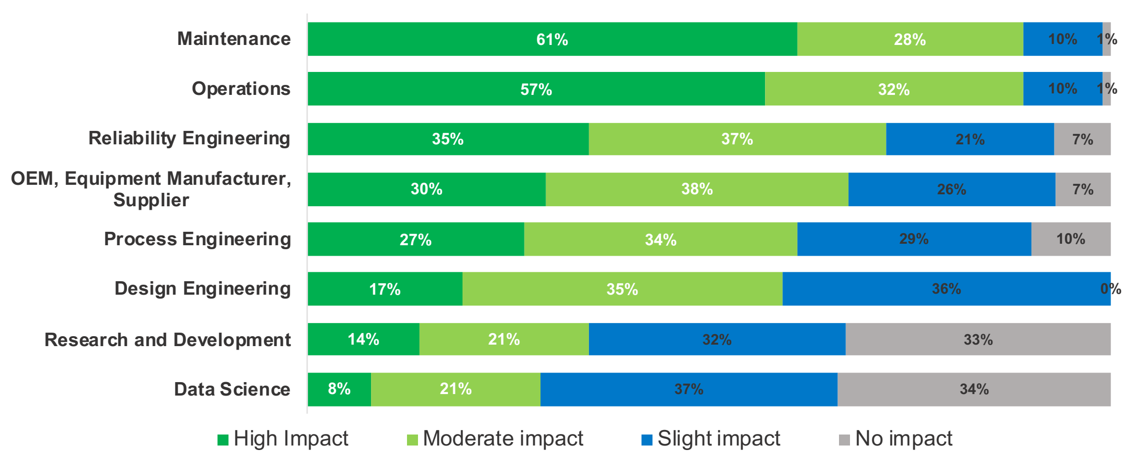


What Other Maintenance Program Tools Does Your Organization Use?

Industrial IoT, Industry 4.0, and data science to understand the problem better. However, many do not appear to be using the right techniques to determine failures or considering the potential effectiveness of current technology. According to one oil industry executive, "We use condition based-monitoring, but I am not sure this is proactive or provides ample early detection. We have tools that tell us the damage and degradation, however; we can only observe the effect, and not the ability to predict the failure. Newer tools and software have a much better analytical presence."

Less than half of the respondents use operator-driven reliability (ODR). Many believe the low adoption of ODR has been because these programs have been subjugated by reliability engineering. ODR is seen as an extension of RCM practices into the operator work process, leaving operators without a clear view of its purpose. Many believe this approach has its limitations. These have impacted industry adoption. Some expressed concern that companies have not been using the right tools to improve asset performance. Many tools have been handed down or thrown at the problem without regard to how to make it better or understanding how ODR can improve the situation. ODR's limited adoption reflects the conflict of opinion over which function in the organization has the biggest impact on asset performance.

Survey data suggests that operations have as much impact on asset performance as maintenance does. Some leaders further assert that the process engineers will play a greater role with the accelerated adoption of emerging advanced tools. A good APM program toolset should provide a clear understanding of the data patterns combining process and asset and assign these to the role with the accountability and the extensive knowledge of the process.



Which Function in Your Organization Has the Biggest Impact on Asset Performance?

Most analytical software tools help asset experts better understand the asset-related problem. But these solutions don't address the operator work process and how this can be improved in a meaningful way.

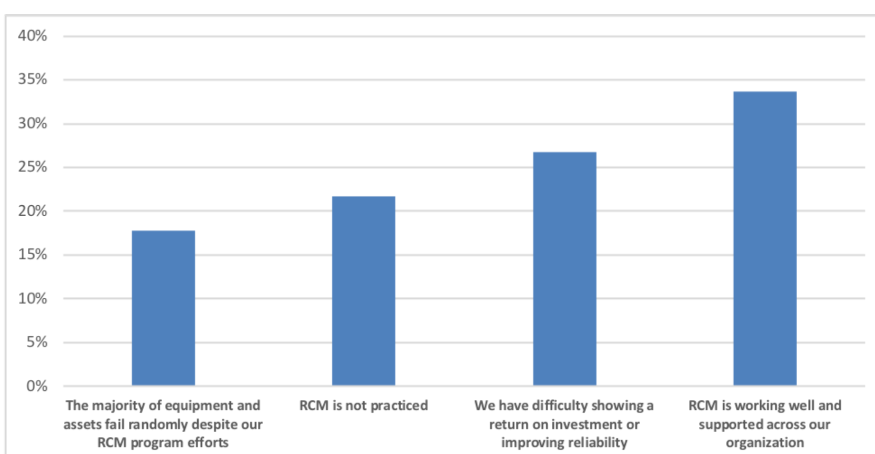
How Effective Is Reliability-centered Maintenance?

Only one-third of survey respondents believe reliability-centered maintenance is working well. A staggering 65 percent claim that most equipment and assets fail randomly despite RCM efforts, do not practice RCM at all, or have difficulty showing a return on investment or improving reliability.

65 percent claim that most equipment and assets fail randomly despite RCM efforts, do not practice RCM at all, or have difficulty showing a return on investment or improving reliability.

Unfortunately, most companies take a technology view of RCM, without considering the human element. Most RCM strategies usually include non-destructive ultrasound testing, fluid analysis, vibration analysis, motor testing, or infrared imaging. But none of these addresses the root cause of the process variability that can cause assets to fail.

A few energy executives we interviewed fully support RCM, but also state that more needs to be done to improve support for RCM across their company. Many believe culture and leadership are both key elements of a successful RCM program. Some even believe that while, until now, the maintenance department has been the custodian of these processes, it is time to give ownership and accountability to operations so the operators can improve outcomes.



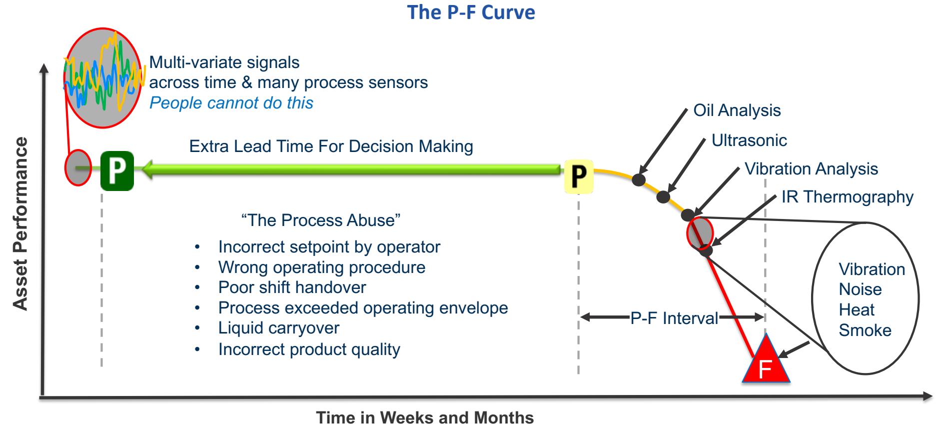
How Well is Your Current RCM Program Working?

Key Finding: The Process Impact Must Be Understood

The P-F Curve and the P-F Interval

The P-F (potential failure) curve shown in the following figure is commonly used to represent the behavior of an asset or component before actual functional failure has occurred. The vertical (Y) axis represents some measure of performance or condition. The curve shows that the performance or health of an asset or component declines over time, leading to functional failure, or loss of function for which it was intended. The horizontal (X) axis of the P-F curve represents time-in-service for an asset, or asset component. The curve may take various shapes, linear or exponential, but is generally exponential as shown. The yellow point, P, is the "potential failure point," which occurs just before a condition exhibiting vibration, noise, heat, or smoke. The point in time where we determine an asset is failing followed to the right of the curve with the functional failure (the point where the asset has failed), indicated by the red F.

The P-F Curve



Understanding the P-F interval and the various failure modes are vital to improving asset performance. Early detection of point P is essential. Failure may be detected days, weeks, or months in advance; but whatever the time interval, it must be sufficient to prevent a functional failure. Once potential failure is determined, maintenance activities are ramped up to lengthen the P-F interval or time before the failure. Six Sigma practices will tend to apply more inspections and push the P-F internal to the left. However, this is not without significant maintenance cost.

The longer the P-F interval, the better asset performance will be. Reliability-centered maintenance activities want to maximize the P-F interval using condition-based maintenance activities. CBM practices attempt to move the point P to the earliest time possible and maximize the P-F interval. Some of these activities are:

- Lubricant sampling and analysis
- Corrosion monitoring
- Motor current analysis
- Acoustic emissions detection (e.g., ultrasound)
- Vibration measurement and analysis
- IR thermography

Many maintenance organizations tend to focus on prioritizing, planning, and executing maintenance activities while ignoring or unable to address failures caused by production operations. In reality, a number of conditions can occur in any given process that are outside the scope of maintenance. We often hear about the disconnect between operations and maintenance. Root cause analysis conducted post-asset failure often reveal causes such as "operator error-related" process-induced failure. Root cause conditions such as liquid carryover, process perturbations, incorrect set point, process performance, and poor product quality all create potentially damaging asset conditions. While maintenance and reliability groups have ramped up CBM and other RCM efforts, the only option for operations has been to use its process instrumentation to monitor and trend process parameters such as flowrates, pressures, and temperatures; observe the assets physically through visual, audible, and tactile (look, hear, feel) inspection; and then perform a heuristic analysis based on those trends and observations.

Leaders today are extending the P-F interval far to the left to improve lead time and detection. By employing multi-variate machine learning (ML) technologies, computers can now analyze more than 50 dimensions over time, accomplishing a level of deep learning that humans cannot achieve in reasonable time. ML is a form of artificial intelligence in which computers can learn without explicit programming. ML data used to extend the failure detection considers static and rotating assets and the process and the correlation between the two. This improves lead times needed to detect when failures might occur and provides operators with a tool to determine whether it would be better to adjust the process to avoid imminent, process-induced failures, or – if economically viable – simply let the asset fail.

APM vs. OPM

The relatively unfavorable positioning of reliability-centered maintenance from this research does not mean the RCM processes are entirely broken. In fact, many aspects of RCM are valued highly across an organization. This includes using root cause analysis following an asset failure to generate useful information. For years, master data (EAM failure codes) have not been maintained rigorously and have been subject to poorly defined work processes. RCM, combined with emerging tools and practices, helps address these shortcomings.

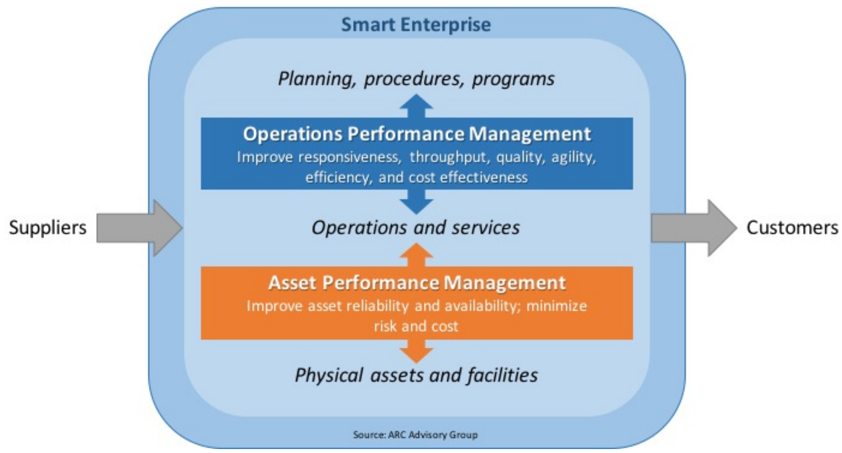
Many maintenance organizations tend to focus on prioritizing, planning, and executing maintenance activities while ignoring or unable to address failures caused by production operations.

APM requires an understanding of the process behavior and its contribution to asset degradation. This understanding overlaps the domains of process engineer, operator, and reliability engineer. New advanced approaches, such as of machine learning and artificial intelligence, bring some renewed interest in re-tuning the maintenance and reliability processes. An effective APM strategy requires multiple roles and multiple competencies, so any efforts require a harmonized maintenance and operations work process.

The emergence of advanced analytics, machine learning, deep learning and other computing technologies have changed this game and caused leaders to rethink APM. By employing multi-variate machine learning technologies, computers can now analyze more than 50 dimensions over time, accomplishing a level of deep learning that is not possible for humans to accomplish in a reasonable time. A failure signature is unique, belonging to an individual failure mode exclusive to a specific asset and under variable process conditions. ML knows nothing about root cause. It only knows about an event in time. Thus, ML must be directed by an expert or system to identify the root cause to be able to improve asset performance.

Although the process industries are among the most instrumented and connected, the next wave of asset-intensive improvements will be led by innovations to operational and process optimization. These will be provided by domain experts from operations with deep knowledge of the process, assets, and systemic interaction between the two. ARC defines this new dimension of APM as operations performance management (OPM). OPM complements APM, but has its own strategies, stakeholders, and technologies. Ideally, APM and OPM strategies should be harmonized.

APM operates in the operations space related to physical assets and facilities and seeks to improve asset reliability and availability while minimizing risk and cost. OPM, in turn, operates in the operations space related to plant operations and its interaction with business operations. These include process optimization, planning, procedures, and analytics. OPM seeks to improve responsiveness, throughput, quality, agility, efficiency, and cost effectiveness. APM and OPM complement and depend upon each other.



Relationship Between OPM and APM

Case Study: Digitalization Helps Saras Refinery Improve Asset Performance

A technologist at the Saras refinery in Europe offered ARC Advisory Group some insights into how to improve asset performance proactively by improving failure detection systems. According to Alessandro Zucca, Digital Platform Manager, Operations and Assets at Saras, the refinery improved its asset reliability, positively impacting a wide range of issues. These include:

- Reducing current maintenance costs
- Planning for abnormal process conditions
- Avoiding emergency or unplanned shutdowns
- Managing unpredictable feed and demands

Saras expects to achieve savings from this initiative, which is part of an important digitalization project. Aspen Mtell executed this project within weeks. According to Mr. Zucca, this speed of deployment and the solution's ability to accurately detect asset failures early and avoid false alarms are impressive. Significantly, the solution can also be scaled system-wide.

The Saras refinery, with a capacity 300,000 barrels per day, is the most complex refinery in the Mediterranean region. As part of its digitalization program, the company evaluated ways to drive greater reliability across its capital- and asset-intensive refinery operations. Saras selected Aspen Mtell based on a competitive pilot project selection process. This focused initially on critical refinery equipment such as large compressors and pumps. Aspen Mtell mines historical and real-time operational and maintenance data to discover the precise failure signatures that precede asset degradation and breakdowns, predict future failures, and prescribe detailed actions to mitigate or solve problems.

Saras plans to use its sister engineering company, industrial automation specialist Sartec, to roll out Aspen Mtell refinery-wide.

The desired outcomes of the pilot project were to implement a solution that:

- Accurately detects precise patterns of normal behavior, failures, and anomalies
- Provides early warning, with significant lead time from point of detection to actual failure
- Provides the ability to capture a failure signature and use it to detect failures in unseen data on the same assets and/or similar assets

The data used for the Aspen Mtell agents consisted of 52 million process sensor values, including both condition data and process variables. The project team reviewed 163 data quality issues (such as bad values and missing values) and cross-referenced the work order history for the four assets, including 340 prior work orders. The maintenance history spanned 17 problem classification codes. According to the refinery, the project achieved all objectives and the agents were able to predict failures with significant lead times. These include:

- High valve temperature - 36 days
- Oil seal replacement - 45 days
- Pump seal replacement - 33 days
- Gas seal replacement - 24 days

The agents accurately identified the specific failure mode — and did so without false positives. Saras expects these capabilities to reduce unplanned shutdowns by up to 10 days, increase revenue by 1 to 3 percent, reduce refinery maintenance costs and cut operating expenses by 1 to 5 percent.

Recommendations

Based on this and related research, ARC has the following recommendations for industrial organizations seeking to optimize the performance of their industrial and human assets:

- Owner-operators or asset owners should re-evaluate the effectiveness of current reliability centered maintenance programs and consider who is driving the strategy from an organizational perspective. The role of the operator and operations must be front-and-center for an asset performance strategy to succeed.

- While RCM and related approaches have not always been successful in improving reliability, these should be fully embraced and incorporated into broader APM processes, which encompasses operations and process engineering as well as maintenance groups.

- Consider the human element before taking a technology view and look to organizational capability best practices to improve APM culture.

- Digital transformation initiatives should evaluate advanced analytics solutions designed to address the interaction between the process and static and rotating assets to address the key issue of "process abuse."

Analyst: Peter Reynolds
Editor: Paul Miller
Distribution: MAS and EAS Clients

Acronym Reference:

AI	Artificial Intelligence
APM	Asset Performance Management
CBM	Computer-based Maintenance
EAM	Enterprise Asset Management
IIoT	Industrial Internet of Things
IoT	Internet of Things
IT	Information Technology
ML	Machine Learning
OEE	Overall Equipment Effectiveness
OEM	Original Equipment Manufacturer
ODR	Operator-driven Reliability
OPM	Operations Performance Management
OT	Operational Technology
PdM	Predictive Maintenance
P-F	Potential Failure
PM	Preventive Maintenance
RCA	Root Cause Analysis
RCM	Reliability-centered Maintenance
ROI	Return on Interest
RTM	Real-time Monitoring
SME	Small-to-medium Enterprise

ARC
arcweb.com

3 ALLIED DRIVE DEDHAM, MA 02026 USA 781-471-1000