Baker Hughes

The journey to plantwide Asset Health Management

Lowering costs, mitigating risk, and increasing ROI through a holistic, plantwide approach to Asset Health Management

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Plantwide – more than just the critical few:

One of a plant's most fundamental concerns is to ensure that **all** of its assets remain healthy, online, and productive. While most plants have already taken steps to address their most critical assets, the concept of "plantwide" begs a fundamental question: what about the **other** assets that might be capable of curtailing your process partially or entirely, or simply eroding reliability and incurring corresponding costs? In most industries, critical assets represent only a small fraction of the total asset population – sometimes as little as 1%. Plantwide asset health thus concerns itself with more than the critical few; it concerns itself with the entire asset population.

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Moving beyond the 1%

- A typical 250,000 barrels per day refinery has around 10,000 rotating machines, but only about **one percent** are deemed **critical**
- These “critical few” are **individually impactful** and understandably get sufficient attention
- Emphasis in the past has been on **protection for this 1%**
- Emphasis is now shifting to **condition monitoring** not only for this 1%, but the other 99% as well
- While the 99% is not composed of individually impactful assets, they are **collectively** impactful
  - Can comprise a large % of the maintenance budget, energy losses, health, safety and environment vulnerabilities, etc.
  - There are exceptions; e.g. high criticality pumps although spared can take down the entire plant

Industry 4.0 and the future of data-driven maintenance

Since the Industrial Revolution, the manufacturing industry has seen three major technological advances:

- Late 1800s — **Industry 1.0** steam engine-powered factories in the nineteenth century
- Early 1900s — **Industry 2.0** mass production powered by electrification
- 1970s — **Industry 3.0** automated machinery

We are now entering the fourth phase of technological advancement, known as Industry 4.0.

During this phase, digital transformation is occurring. Manufacturing processes are rapidly becoming digitally connected along the entire value chain via smart machines, remote sensor monitoring, and sophisticated OT/IT systems linking everything in cybersecure fashion.

But is this just a technology fad or is it revolutionizing industry to the degree that the steam engine, electricity, and automation did?

In short, yes, it is.

But there is an even more fundamental question to answer first: *why is change necessary?*

Making the case for change

why status quo maintenance techniques are insufficient

Maintenance professionals hold tremendous responsibility. As the custodians of plant equipment, they are responsible for preserving massive capital investments, preventing costly downtime, avoiding potentially catastrophic environmental hazards, and protecting the health and lives of not only the individuals who work within the plant walls, but of the surrounding communities as well.

Status quo strategies like 'run-to-failure' may indeed be appropriate for low-consequence assets, but are completely unsuitable for more consequential assets because of safety issues and the risk of catastrophic downtime.

In contrast, and contrary to popular belief, time-based preventative maintenance strategies are actually only suitable for a small fraction of assets because only a small fraction of asset failures can be shown to be a function purely of time versus other variables[1]. Indeed, a ground-breaking study released in the late 1970s showed conclusively that nearly 90% of asset failures could not be predicted based on running hours or some other time-based increment[2].

Despite this, time-based maintenance practices persist because they are both simple to implement and seem intuitively "proactive" by replacing parts before they fail.

[1] Determining which assets can be addressed by time-based maintenance alone generally involves a Failure Modes and Effects (FMEA) analysis.
[2] US Department of Defense. Report AD-A066-579 "Reliability-Centered Maintenance" Nowlan, F.S., Heap, H.F. December 1978.

There is another problem with time-based maintenance when not applied to appropriate assets. Whilst replacing parts that don't need replacing, and performing work that doesn't (yet) need to be performed is wasteful, the problems with time-based maintenance goes beyond waste, where unnecessary maintenance can create problems rather than prevent them. Problems such as infant mortality by introducing parts with manufacturing defects.

Problems such as incorrect installation that quickly affects not only the immediate part, but surrounding parts. Problems such as the false sense of security that comes from assuming freshly performed maintenance results in reliable equipment, immune from unplanned failure.

Lastly, there are the hidden costs of maintenance that may far eclipse the visible costs. Indeed, like an iceberg, the majority of these costs – as much as five times – often lies beneath the surface[3].

[3] Wienker, M., Henderson, K., Volkerts, J. The Computerized Maintenance Management System: An Essential Tool for World Class Maintenance. Procedia Engineering. 138 (2016). pp 413-420.

The "Iceberg" model[4]

Direct (traditional) maintenance costs

Indirect (hidden) maintenance costs = up to 5x direct costs

[4] Wienker, M., Henderson, K., Volkerts, J. The Computerized Maintenance Management System: An Essential Tool for World Class Maintenance. Procedia Engineering. 138 (2016). pp 413-420.

A move towards predictive maintenance

90%
of failures
are NOT time-based

Average cost of downtime
$22K/min

+25%
Production

Machinery breakdowns
-70%

50%
Of workforce to retire in the next **5 to 10 years**. Knowledge & experience is not being transferred

Downtime
-40%

Maintenance costs
-50%

60%
Estimated increase in EHS spending among global E&P companies

6x
The cost for unplanned events vs. planned maintenance in process industries

[1] A survey of 500 plants by Keith Mobley, "Introduction to Predictive Maintenance"
[2] U.S. Department of Energy

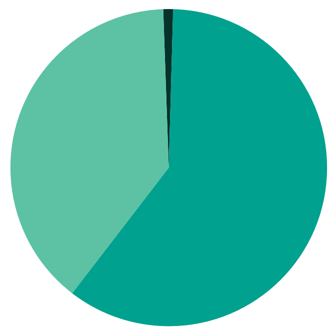
The cost hurdle

In an ideal world, cost would be no object and a plant would be able to monitor the condition of every eligible asset continuously. Indeed, continuous condition monitoring is how critical machinery is almost always addressed. But that approach has simply not been justifiable for the substantial population of assets deemed less-critical. Historically, continuous monitoring technology hasn't lent itself to the economics and needs of all asset categories. As a result, the approaches used by many plants tend to fall into three distinct categories:

Critical: full online protection systems and online condition monitoring

Less-critical: only offline condition monitoring approaches are used via route-based portable data collection, without any permanently installed systems

Non-critical: no monitoring at all



While many plants have addressed category 1 assets quite capably though modern online condition monitoring and protection technologies, and while there will always be a certain population of category 3 assets in any facility, it is the category 2 "plantwide" assets that today prove to be the most vexing and are typically where the richest opportunities for improvement can be found once category 1 has been addressed. This is precisely where technology advancements and cost-effective monitoring solutions are now making it easier for plants to address category 2 assets with more than just portable approaches.

The technology hurdle

With the introduction of the route-based portable data collector in the 1980s, predictive maintenance grew in popularity – initially on category 1 and 2 assets and then later mostly to category 2 assets as category 1 assets were fitted instead with continuous, online condition monitoring systems. But this approach is only sufficient for some category 2 assets – not all category 2 assets. When an entire program relies on portable data collection for category 2 assets, substantial gaps may still exist:

Blind spots: Monitoring intervals resulting from manual data collection strategies may not be frequent enough to match the speed at which incipient failure can appear and progress on some machines. Conversely, more frequent data collection rounds may be cost prohibitive and category 1 "continuous" solutions may likewise be cost prohibitive[5]. Something in between portable and continuous is required.

Tunnel vision: Abusive process conditions frequently lead to degradation of asset conditions, but unless process data and condition data are brought into the same environment, these correlations cannot be observed. As the saying goes, "1+1=3" and this is particularly true when machine condition data and relevant surrounding process data can be brought together. However, this is difficult or impossible when relying on manual data collection methods.

Fragmented, point solutions: Utilizing multiple condition monitoring software platforms and suppliers creates complexity and added cost. A single system is almost always superior in terms of cost, cybersecurity, support requirements, integration, simplicity, and efficiency.

[5] Customer benchmarking has shown that when data needs to be collected more frequently than once monthly, an online system will usually be capable of generating better ROI than a manual approach.

To address plantwide needs, a mix of right-sized edge device technologies is thus needed rather than relying solely on one approach, and where the various condition monitoring technologies are unified under the same software management platform. Indeed, one of industry's most pressing needs right now is for economical, right-sized solutions for category 2 assets, able to fill the gap between portable data collection methodologies and the systems designed for category 1 assets. Such solutions must be tailored to the economics of each asset, its failure modes, and its consequences of failure[6].

The types of technologies that best-in-class operators are leveraging today include:

- low-cost, wireless sensing
- hybrid solutions with wired sensors and wireless connectivity to asset management platforms
- wearable portable data collection technology that improves labor efficiency and ergonomics
- distributed, high-reliability, high performance condition monitoring and protection systems, while providing the option to place processing at the machine (reducing sensor wiring costs) while linking distributed modules via robust, redundant, high-speed fiber optics
- embedded intelligence and AI-enhanced fault detection capabilities
- highly integrated software that can consider not just mechanical condition but process conditions, real-time economic factors, maintenance history, and risk

Fueling adoption of online approaches is the falling cost of such technology while the costs of manually collected data continue to rise, driven primarily by the rising costs of labor. As a result, the case for deploying permanent monitoring on a larger percentage of plantwide assets is becoming easier to justify and more compelling.

[6] For an extensive examination of a systematic methodology for selecting appropriate monitoring technology for different criticalities of assets based on consequences, consult Bently Nevada whitepaper 101521-WP "Using PF Curves to Tailor your Plantwide Monitoring Strategy."

Machine Health as a Service

Some industries are particularly good candidates for an entirely outsourced approach to asset health management. Although they may have dozens, hundreds, or even thousands of assets within the continuum we have referred to as category 2, their business model doesn't treat condition monitoring as a necessary or desirable core competence. As a result, they are often already outsourcing their asset health management to a third-party provider.

What is changing, however, is not so much the concept of outsourcing asset health management, but the technology used to deliver it.

The past was defined by providers using labor-intensive, manual data collection technology. The future is Machine Health as a Service, where low-cost, permanently installed wireless sensors replace manual data collection.. The sensor data is streamed to the cloud where AI-powered intelligence has taken over the task of tedious data review to detect anomalies – a task that was also previously labor-intensive.

Making the case for Machine Health as a Service

HEINEKEN

- Catastrophic machinery failures from all sources were reduced by more than 80%
- Failures caused specifically by mechanical malfunctions were eliminated entirely.

FritoLay

- Breakdowns, process interruptions, and incremental costs resulting from machinery failures were reduced to zero
- More than 1 million pounds of food were saved in the first year

100,000,000+	machine hours monitored
80,000+	machines diagnosed
3x+	average ROI and payback within months
90%+	engagement rate among reliability and maintenance users
95%+	prescriptive accuracy for rotating equipment
99%+	detection accuracy
1 day	time to insight post-deployment
7 days	average time to value

The integration hurdle

Another important need is that of integration. Many plants use multiple suppliers with one supplier addressing category 1 assets but multiple other suppliers to address the mix of category 2 assets such as one for wireless cloud-based technology, another for portable data collection technology, and another for conventional quasi-continuous wired technology. It is not uncommon for operators to have three or more edge device technology stacks and corresponding point-solution software just to do plantwide condition monitoring. This is clearly less than ideal. Instead, a single, integrated software environment from which to manage every class of asset is desirable – along with a supplier whose portfolio is broad enough to address the continuum of assets with technology that is not one-size-fits-all.

Fortunately, it is within reach of every operator today for a single enterprise-wide solution to monitor the health of critical and supporting machinery alike. For example, this aptly describes Bently Nevada's System 1 software and its portable, continuous online, quasi-continuous online, wireless, and prescriptive asset management service solutions.

The "eagle-eye view" provided by an asset health management solution:

- **enables** plant reliability managers to make informed, proactive decisions about individual machine maintenance
- **provides** a holistic view of the health of their entire asset population
- **predicts** potential downtime with much better precision
- **improves** overall plant ROI
- **decreases** risk associated with reactive, outdated, and spotty maintenance techniques

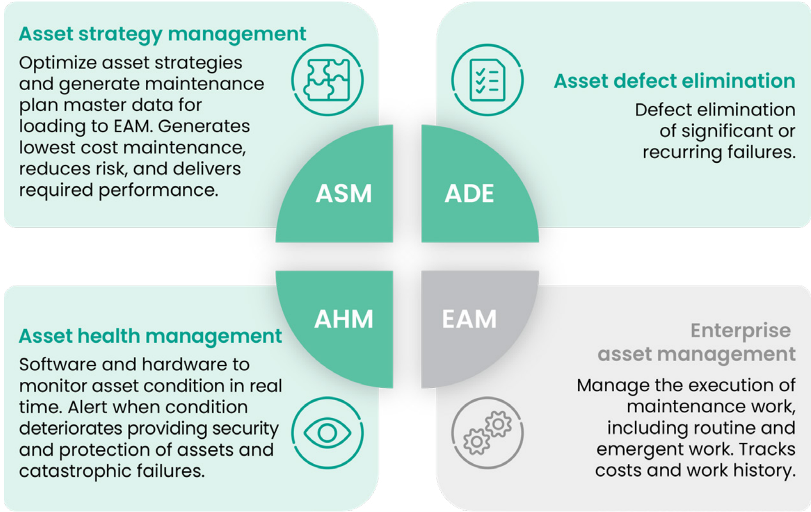
The knowledge hurdle

One look at the reliability community often tells the story: more gray hair than not. The repository of machinery and reliability knowledge gained over the last five decades is largely resident in people that have reached – or are fast approaching – retirement. When that knowledge walks, many companies will be unprepared and will have to learn the same, hard-won lessons all over again.

Modern asset health management solutions thus embody the concept of digitizing and embedding intelligence. The best of such systems do not rely strictly on AI and data science approaches, or strictly physics-based first principles approaches. Instead, they draw on both, applying each where it adds the most value without treating them as mutually exclusive approaches that cannot coexist.

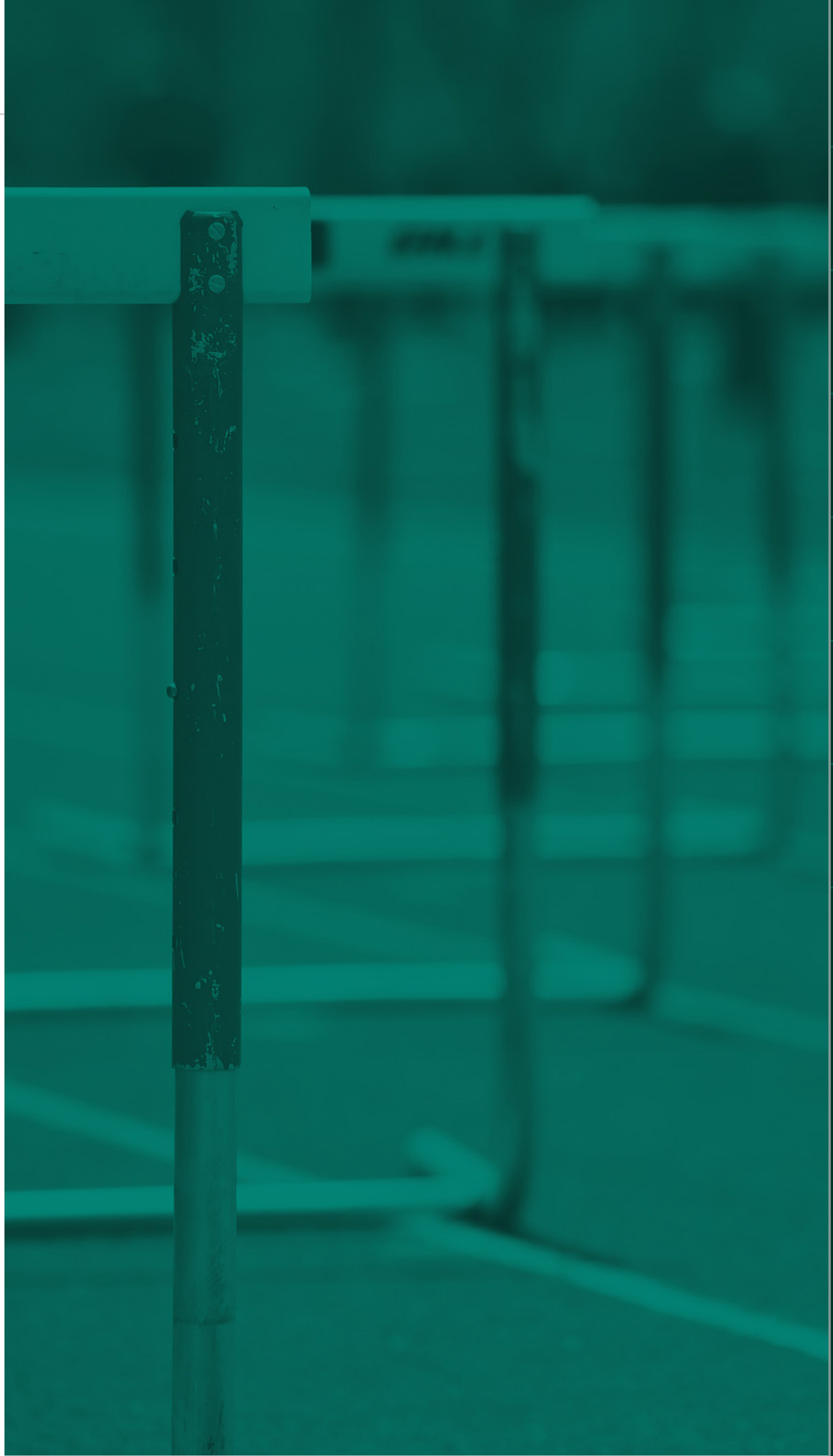
The synergy hurdle

To improve reliability and asset health management on a plantwide basis is necessary, but it isn't sufficient. For optimal results, you need all four core asset management functions working together:



The problem today is that these functions typically exist as silos, performed by different people, using different systems, and with different metrics. So, while addressing the asset health management piece to provide a plantwide view is an important part of the equation, linking these four disparate functions together is key so that asset-related reliability decisions are no longer made in functional silos, isolated from one another.

Unlocking this potential synergy comes from connecting these four functions through a common digital thread and results in an integrated approach to Asset Performance Management (APM). It's an emergent solution that draws on the lessons learned from best-in-class performers and unifies the data within each of these four areas to allow decisions based on more than just asset condition. As a result, decisions can be based on the risk that an asset's condition poses as well as the economic implications of when and how to address degrading conditions relative to competing priorities posed by other assets.



How to get started

Embrace the future of predictive maintenance.

Transitioning from current maintenance strategy to a holistic, plantwide approach will not happen overnight. The journey starts with an unshakeable belief that the future of industrial maintenance lies with interconnected, digitized, predictive solutions.

Continuous improvement

A true plantwide asset health management solution requires investment – not just in technology, but in a transformative culture that includes people and processes. Many organizations find they need help with this step, and a reliability consultant can be indispensable in helping you understand how to address each of your assets, how to prioritize your improvement initiatives, and in quantifying the short- and long-term ROI associated with each one.

Predictable performance

Reliability improvements seldom occur through technology alone. The right partner will also be able to address the people and process parts of the equation. But the right technology also plays a vital role – and as has been shown, the diversity of technology needed for plantwide success requires a partner with a broad portfolio of right-sized solutions, knit together with a unifying software infrastructure. While there are hundreds of point-solution technology providers out there, only a handful have the required portfolio breadth to truly deliver a plantwide solution. And when you add in the necessary services and reliability consulting component, the list narrows even more.

In conclusion

Plantwide asset health management is a journey and as such, numerous hurdles will be encountered along the way. Some will be cultural, some will be technological, and some will be economic. However, all are surmountable and the results make it a journey worth taking.

You can think of the journey in terms of these six major steps.

When you partner with the right provider of technology and services, you'll help to assure success.

1

Focus on all your assets – not just the critical few

2

Recognize that preventive maintenance can address only 11% of failures – predictive approaches are required instead

3

Leverage the falling costs and increasing capabilities of online technologies to address a larger percentage of category 2 assets

4

Adopt a data driven approach to to select the right maintenance approach for each asset

5

Blend right-sized edge device with unifying software to deliver plantwide asset health management

6

Go beyond asset health management to include asset strategy, defect elimination, and work execution for an integrated APM approach

Want to learn more?

For more information, contact your Baker Hughes representative or visit us at bakerhughes.com

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