

Condition-Based Maintenance Bolsters the Bottom Line in Transportation



Condition-Based Maintenance Reduces Maintenance Costs and Increases
Availability in Transportation Assets



Overview

Digital technologies like IoT, cloud services and advanced analytics are disrupting the design and management of transportation assets. Yet, many organizations still struggle to harness transportation data to improve operations of mobile assets. For industrial, municipal and transit organizations, the pressure to ensure safety while maintaining high quality service and reducing costs are forcing managers to consider how to capitalize on digital strategies.

One way owner-operators, fleet and asset managers are responding is to focus on more efficient, data-driven maintenance programs. It is estimated that more than \$1 trillion is spent each year replacing perfectly good equipment in the US alone*. A growing number of operators are considering adopting condition-based maintenance (CBM) and other proactive strategies that are driven by actual asset conditions rather than calendar- or use-based maintenance schedules. CBM has already been proven to lower costs by eliminating unnecessary maintenance, reducing unexpected failures and reducing downtime.

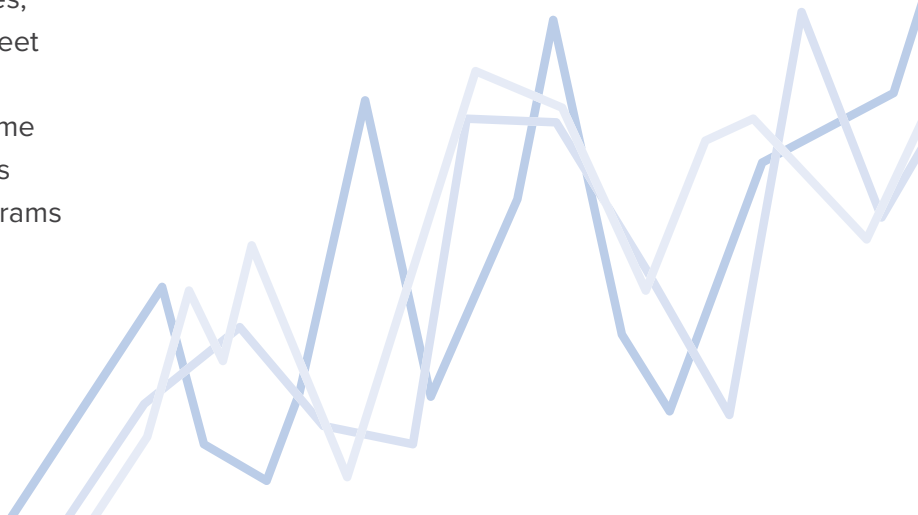
The advantages of creating a digital infrastructure to implement CBM run far beyond lowering maintenance costs. By tracking asset health in real-time and avoiding unexpected equipment failures, CBM can play a critical role in ensuring overall fleet availability, reducing the cost of downtime and meeting regulatory requirements. Linking real-time equipment conditions with popular EAM systems such as SAP® PM and IBM® Maximo®, CBM programs

can also help extend the value of operational data by integrating it with business environments, for example, to manage parts inventory, equipment lifecycle and inform capital investment strategies.

\$1 Trillion spent annually replacing working equipment

This white paper will look at the forces that are driving demand for more proactive maintenance strategies of transportation assets and infrastructure. Next, it will examine how CBM works, and how it offers a more efficient and effective alternative to planned maintenance methodologies. Finally, this paper will look at how industries are benefiting from CBM enabled by OSIsoft's PI System™, an infrastructure for collecting and managing historical and real-time data from both fixed and mobile assets, to create a comprehensive, environment for the collection, management, analysis and presentation of data essential to supporting CBM for transportation assets.

* McLean, C. and Wolfe, D. (2002), "Intelligent wireless condition based maintenance", Sensors Magazine, Vol. 19 No. 6, June



ADDRESSING NEW CHALLENGES

Industry experts predict that transportation, including off-road trucks, rail networks, maritime assets and public transit systems, will undergo more change in the next ten years than they have in the past hundred. That's hardly news to infrastructure, asset and fleet managers already focusing on digital management strategies. While asset health does not attract the public's attention, a growing number of managers realize that updating maintenance strategies can play a key role in making mobile assets more available, cost-efficient, ultimately

supporting more profitable operations and supply chains.

The following three major trends demonstrate that the value of these new maintenance strategies lies not just in lower maintenance expenses, but extends to overall asset availability, reliability and effectiveness. Moreover, these new approaches promise to have a considerable impact far beyond simple equipment maintenance.

Growing Demand

It is estimated that over 1 million people a day move into urban areas globally. At the same time, more and more goods are shipped by rail and truck to those people, further stressing current transportation infrastructures. Many organizations simply do not have the time, resources or physical space to expand existing infrastructure. As increased use constrains infrastructure capacity, asset, infrastructure and fleet managers in transportation organizations are working to develop new strategies to keep pace with growing demand.

Safety and Asset Performance

In capacity-constrained systems, time lost to mechanical failures cannot be recovered, jeopardizing commercial commitments, network reliability and even safety. Yet, total cost of ownership over a relatively long life cycle is several times the initial purchase price for high value mobile assets. Although the cost of unexpected failures can be catastrophic, asset managers must constantly balance costs with risk and performance, even when they have little hard data on actual asset condition and wear.

Doing more with less

As organizations strive to offer cost-effective services, it can be easier to deprioritize maintenance rather than bear the spotlight of increasing costs. In the absence of hard data, managers often are reacting to the crisis of the day, jeopardizing system reliability. As assets near end-of-life, maintenance costs using best practice models for lifespan calculations are often out of line with fiscal depreciation, which may create crisis near end-of-life. Compounding these issues, most industries have either reduced maintenance staff and are seeing a decline in knowledge workers in maintenance areas.

Impact on Maintenance

Driven by these trends, asset, fleet and infrastructure managers are altering maintenance practices by:

- Migrating from reactive and preventive maintenance to proactive and predictive maintenance based on real-time conditions
- Moving from static, periodic equipment condition assessments to dynamic real-time online asset health monitoring
- Developing predictive information from asset data to push leading indicators further back in time, giving plant operators more time to plan, increase uptime and reduce spare parts inventory
- Combining many disparate data systems into a single system to provide additional context for asset health solutions
- Embracing new IoT technologies that can fill information gaps or replace inefficient manual data collection techniques, improving information and freeing SMEs and other staff for higher level work.
- Establishing data-driven partnerships with SME's at OEMs, universities and vendors/suppliers to provide recommendations or analysis as a service.
- Combining operational data with advanced analytics or machine learning applications to accelerate confidence in predictive information.

MORE EFFICIENT MAINTENANCE STRATEGIES

Most industries today use a variety of maintenance strategies. Studies show that the average facility spends over half its maintenance budget on highly expensive reactive, “run-to-failure” maintenance strategies where maintenance only occurs after a piece of equipment fails. Alternative proactive maintenance strategies include preventive approaches that are calendar- or runtime-based, and condition-based strategies that use different combinations of either manual or automatic data collection and analysis, and predictive maintenance strategies that use model-based learning systems to more accurately estimate asset lifecycles and give operators more time to plan capital expenditures and maximize availability.

Proactive maintenance strategies use corrective, preventive and predictive processes to complement one another and have clear monetary benefits. Industry studies indicate that using predictive and proactive maintenance practices reduces costs of reactive maintenance by 45%, not including associated down time.

CBM is generally defined as a set of maintenance processes guided by the collection of asset data to ensure maintenance is performed only when needed. Unlike calendar-based maintenance strategies, CBM leverages asset data to reconcile maintenance schedules with actual asset conditions, organizational priorities and changes in the operating environment. Today, leading industries continue to expand adoption of CBM practices based on real-time and historical data to drive down the high cost of reactive maintenance strategies (Figure 1).

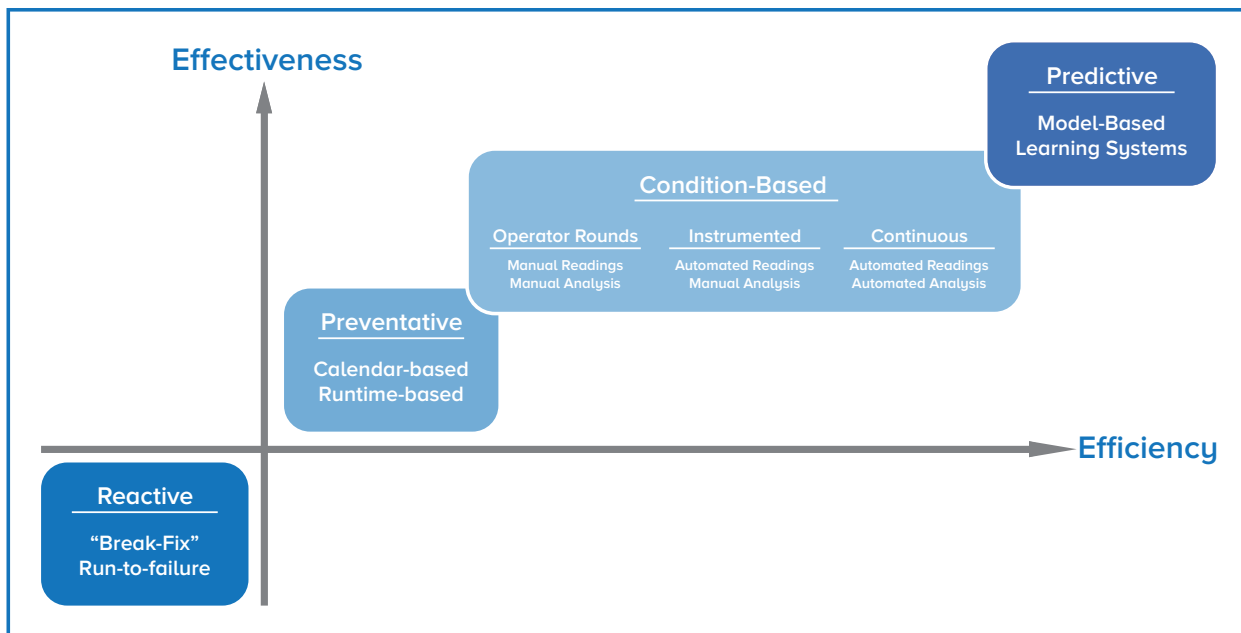


Figure 1: New maintenance strategies offer more efficient and more effective alternatives to reactive approaches.

A CBM program begins by monitoring asset parameters, then evaluates parameters in relation to limits, trends and other asset data. Eventually, it ties real-time data to comprehensive work management solutions.

CBM offers a number of highly attractive advantages over calendar-based maintenance systems, including:

- Reduced capital costs by extending asset lifecycles
- Lower maintenance costs because equipment that is operating well is not repaired or replaced
- Better asset reliability
- Improved asset availability
- Improved asset utilization including longer lifecycles and better informed capital expenditures
- Minimizing lost production time by better predicting asset failures
- Optimized maintenance intervals

Detecting Maintenance Issues Earlier

How do CBM and proactive maintenance strategies contribute to higher availability? In calendar-based maintenance strategies, asset replacement or repair is driven by conservative vendor recommendations. If an asset's lifecycle runs outside the historical norm, owner-operators run the risk of spending more than is necessary by replacing or repairing the asset too soon or too late to avoid catastrophic failures.

Once an organization starts collecting real-time data on specific equipment parameters, the actual condition of the asset is always known. In CBM/proactive maintenance strategies, the real-time condition of the asset drives maintenance requirements. Because CBM is performed while the asset is operating, equipment availability is increased and system disruptions are minimized.

The P-F curve in Figure 2 illustrates the behavior of equipment as it reaches failure. Point P represents the first possible point on the curve when personnel

can detect equipment performance degradation. This point can be detected by tracking any of a number of asset characteristics, such as a slight change in temperature, a higher-than-normal vibration rate, or a change in power usage. Point F represents the point of equipment failure. The time between those two points is the organization's opportunity window. The further up the curve point P occurs, the more time maintenance personnel have to replace the asset, order parts or labor, or schedule an outage before the equipment fails.

In any industry, unexpected failures present the greatest risk to availability and often the highest repair costs. In a CBM/proactive system, early detection of performance degradation not only reduces or eliminates the unexpected and unplanned costs associated with a reactive maintenance approach, it also gives personnel a better opportunity to plan maintenance activities and manage costs.

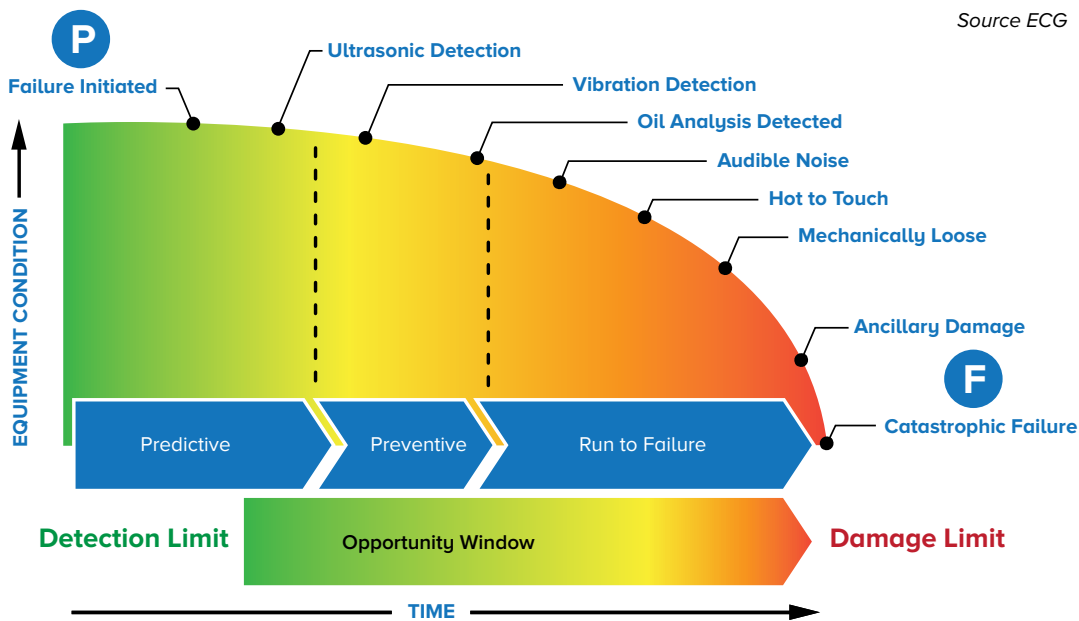


Figure 2: Initial failure detection depicted on a curve. The earlier point P occurs, the more time plant personnel have to solve the problem.

Organization-Wide Impact

In a more generic sense, condition monitoring practices used in CBM can be extended to determine the “health” of both mobile and infrastructure assets. In this scenario, maintenance personnel collect multiple data values, analyze the data by looking at rates of change or comparing values to a norm, create an algorithm for a group of assets based on multiple indicators, and then calculate a “health” score for each asset based on how it rates compared to other pieces of equipment in its peer group.

By comparing maintenance histories of many similar assets, operators can build confidence in recommendations. Once stakeholders start relying on analysis results, they can reduce parts inventory costs and decrease overall risk associated with operational variability. Thus, CBM programs based on high fidelity data can be highly useful not only for maintenance programs, but also for guiding capital expenditures or defining work prioritization schedules.

Moreover, with an open infrastructure such as OSIsoft’s PI System, fleet managers can use advanced pattern recognition (APR) modeling

tools or standard BI tools to further leverage data collected by real-time systems. By automatically analyzing large amounts of data, these tools can reduce the need for manual monitoring, detect anomalies in critical equipment very early in the performance degradation process, and help support operations by avoiding equipment failures and optimizing maintenance schedules.

As organizations realize their value, CBM and proactive maintenance strategies can be easily scaled from pilot projects and individualized pieces of equipment to fleet-wide implementations. The PI System’s highly extensible infrastructure, for example, enables operators to integrate fleet maintenance requirements into corporate EAM systems such as SAP PM or IBM Maximo.



Potential Obstacles to CBM Implementation

Companies considering the implementation of CBM face a number of challenges. From a technology perspective, a CBM system must first and foremost ensure that each person has access to the data they need to make effective decisions. At the enterprise level, this typically requires the collecting data from disparate systems and then integrating it so that is consistently formatted. Data collected in real time must be time-stamped in a uniform manner to correctly attribute data variations and exceptions to specific events. Finally, users must be able to share data across the organization to scale expertise and collaborate.

Data governance for CBM can be improved by aligning asset hierarchies to data points so stakeholders can build effective and accessible data visualization strategies that are critical to the success of any CBM system. Fortunately, recent advances in CBM tools have simplified this task.

A more imposing challenge might come from an organizational point of view. CBM often requires culture change. Any effort to move from a calendar-based or reactive maintenance approach to one based on online condition health information requires a significant initial setup stage that typically brings organizational disruptions. Getting personnel aligned and available for consensus and implementation can be difficult.

A CBM program affects a wide range of assets, especially in large, geographically dispersed networks like rail and maritime organizations. The prospect of making such a wholesale transition can seem overwhelming. One way managers can overcome this concern is by starting CBM implementations with just a few critical assets. After demonstrating tangible returns, stakeholders can leverage the PI System's inherent scalability and templated asset framework to expand CBM to other areas of the enterprise. This approach is taken by international standards such as ISO55000.

Finally, before implementing CBM, management should consider the following up-front costs and potential liabilities:

- Staff training costs
- Equipment monitoring & instrumentation costs
- Older assets that might require modifications to retrofit the system with sensors
- Fatigue or uniform wear failures, which are not easily detected with CBM measurements
- Unpredictable maintenance periods
- Network costs and availability for mobile asset data

How the PI System Supports CBM

Implementing the PI System across mobile and fixed assets provides a digital infrastructure for real-time machine, operating events and environmental data. Choosing an infrastructure approach brings data from isolated sources together, even when assets are traversing disparate networks. Finally, the PI System provides context to improve governance, even across geographical and functional boundaries. Engineering, SMEs, operations and maintenance staff can consolidate and share information to make decisions within complex operational environments.

Without the PI System, periodic assessments may miss critical equipment changes that can be detected in real time. Collecting, aligning and synchronizing data from multiple sources is a time-consuming task. Why require an engineer to spend valuable time collecting and manipulating data from different tools when that time could be better spent on analysis and problem-solving?

Using the PI System for CBM offers multiple advantages. First, the PI System transforms asset health monitoring from a periodic, static to a dynamic, real-time process. Second, engineers can create a more comprehensive data environment to conduct more complete, accurate analysis of current conditions. Finally, the PI System provides both process and event contexts to easily parse through raw time series data to create actionable information.

Key capabilities:

- Capturing and sharing data in its original fidelity without averaging or aggregating, using proven methods that scale to an enterprise level.
- Providing efficient real-time data management from a wide variety of operational sources in a highly secure manner.
- Standardizing and centralizing data to enhance accessibility and governance across the enterprise.
- Displaying asset health information that can be consumed by a wide variety of users.
- Developing performance trending and analysis systems to determine each asset's maximum reliable capacity.
- An Asset Framework organizes data streams and related process information by asset and plant topology, giving the data functional and operational context.
- Providing asset-based analytics that convert raw data streams into meaningful information and values.
- Email or text Notifications facilitate fast responses to potential operational or equipment problems.
- Off-the-shelf integrators automate time series data cleansing, augmenting and shaping to work with advanced analytical and BI tools.
- Automating integration of operational data with business systems like SAP® HANA®, Esri® and data warehouses.

Advantages of a PI System Infrastructure

To fully capitalize on industrial data, organizations are faced with finding ways to bring growing volumes of sensor-based IoT data, including transportation, even as its sources are becoming more mobile and geo-dispersed. Developing cost-efficient solutions for many aspects of performance, including asset health, are relying more and more on the ability to integrate diverse data sets and tools. Many studies and papers imply that the value of IoT is tied to the volume of data that it will produce. Undoubtedly, with IoT, the number of devices and sensors is exploding; however, industries will **monetize** IoT by creating environments that make IoT data durable and integrate it with larger operational contexts and tools to generate actionable intelligence. In these environments, IoT makes it possible to operationalize structures, assets and systems where it was previously neither possible nor cost-effective.

A PI System infrastructure serves as the backbone that integrates IIoT with core information systems. Connecting IIoT data to the PI System enables industrial leaders to create a scalable digital infrastructure to expand operational visibility and create rich historical records of the behavior of mobile and geographically dispersed assets. This strategic approach provides a framework to optimize enterprise data for data-driven CBM programs ultimately affecting system capacity, fuel costs and network reliability.

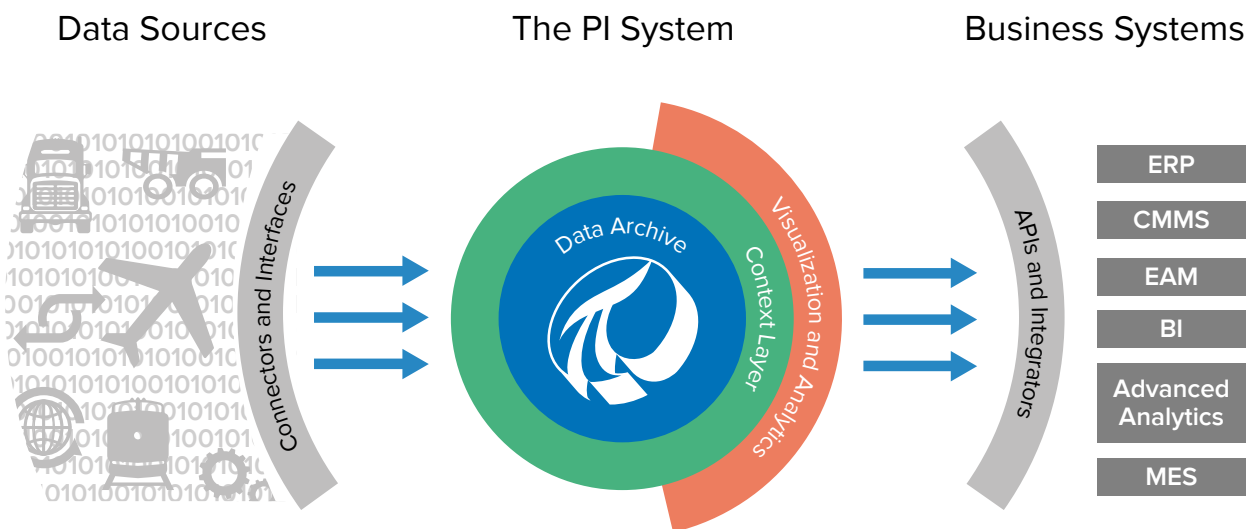


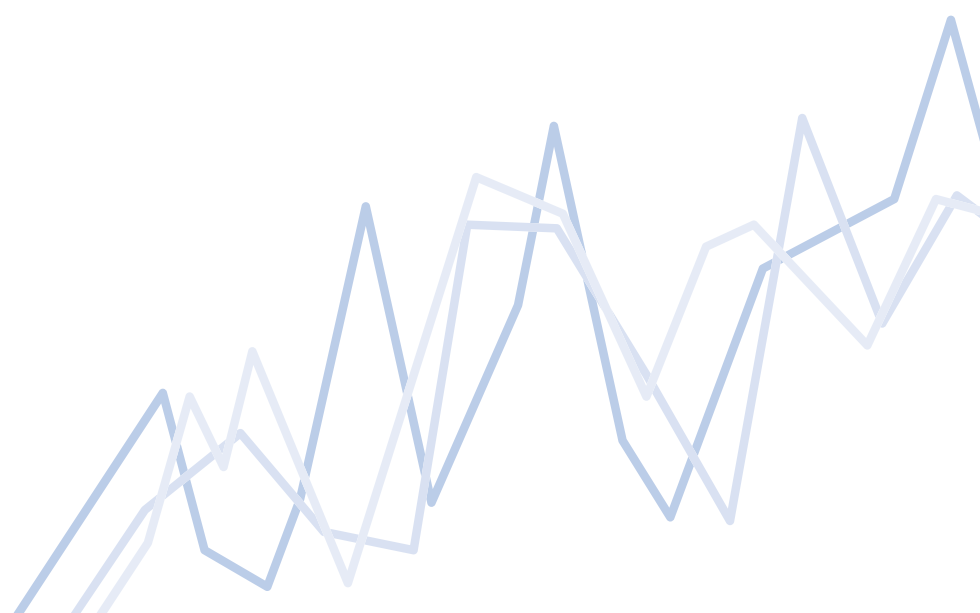
Figure 3: The PI System acts as a bridge between real-time operational data and business systems

CONCLUSION

Whether shipping goods, supporting daily commuters or extracting raw materials, transportation has always been at the heart of global business. Today's consumers demand on-time deliveries, seamless transit and have little tolerance for accidents compromising safety or damage to surrounding environment. In today's volatile business climate, predictive maintenance strategies are gaining momentum. Yet, many organizations use multiple, disparate data systems, static equipment condition assessments and have a high reactive maintenance impact. The key to reducing maintenance costs and increasing availability to relieve capacity constraints will be rapid adoption of proactive, CBM-based techniques based on real-time data.

Moreover, these proactive strategies can impact processes beyond industrial operations, enabling leaner, customer-focused and more sustainable organizations. First and foremost, real-time visibility and predictive maintenance ensures safety, especially across larger networks where mechanical failures can negatively impact environment and public safety. CBM-based data can also be employed in asset management strategies, vendor performance reviews and root cause analysis techniques as well as environmental monitoring and regulatory compliance.

OSIsoft's PI System provides a universal data infrastructure that is capable of collecting, managing and analyzing information from multiple isolated sources across the enterprise and presenting that data in a way that allows management, engineering, operations and maintenance staff to share information, solve and even predict problems in time to affect the bottom line. As IoT, connected devices and even automated and autonomous equipment continue to expand the role of data in operations, creating digital infrastructure for operations, maintenance and cost structures will become even more important.



About OSIsoft

With the belief that people can improve process efficiency, manage assets and mitigate risk if they have access to the data they need, OSIsoft created the PI System as a common data infrastructure to capture and store real-time data and make it available wherever and whenever needed. For over 30 years, OSIsoft has delivered the PI System with the singular goal of creating a common data source to connect enterprise data with people making decisions and solving problems.

Today, the PI System is trusted to do just that. Processing over 1.5 billion data streams across 19,000 sites, the PI System is embedded in operations and critical infrastructure in over 125 countries. Our customer base includes Fortune 100 and Fortune 500 companies in power generation, oil and gas, utilities, metals and mining, transportation, critical facilities and other industries. To see any of the 1100+ customer success stories, product descriptions or global initiatives, please visit www.osisoft.com.

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