WHITEPAPER

APM 4.0 with Predictive and Prescriptive Analytics

Using sensor data to maximize your return on investment

Authored by:

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Werner Meyer

APM Portfolio Strategy - Prescriptive Analytics Lead

Executive summary

Asset Performance Management 4.0 (APM 4.0) brings with it the promise of proactive asset performance management enabled by predictive alerts and prescriptive analytics. This can lower costs, reduce unplanned downtime, and optimize labor usage and equipment performance. Through Predictive and Prescriptive Analytics, companies will be able to implement asset strategies to avoid unplanned downtime for their most critical assets – while also deciding which preventative or corrective asset strategy is the best course of action to take for their less vital equipment.

True digital transformation requires enhancing the asset-oriented APM approach to a system that holistically connects Engineering, Operations, and Performance and thereby enables a quantum leap in Asset Performance. APM 4.0 creates a single integrated digital thread across the whole asset lifecycle. Two key factors play a pivotal role in the successful operation of this new digital thread. First, there must be connectivity among assets and workers. Second, decisions that are informed by sensors and intelligent data must be able to be executed in real-time. While APM 4.0 maintains the asset-oriented approach, it is focused on delivering critical business results. It will achieve Asset Excellence by enhancing safety, profitability, and sustainability.

Introduction

Since automation is becoming increasingly prevalent across industries, mechanical devices are being replaced by electronic components in manufacturing, industrial, and factory environments. This evolution means more sensors are being used to capture additional types of data. The more in-depth data these sensors are able to capture, the greater the visibility and insight for Owner-Operators.

One essential part of APM 4.0 is **sensor-based decision making with true Lead Performance Indicators:** A variety of sensors and mobile devices provide decision makers with real-time data on the condition, performance, and safety of their assets, enabling more precise decisions. In stark contrast to the widely used and typically lagging indicators that report failures only after they occur, condition monitoring, AI, and engineering expert systems use sensor data to predict performance degradations and component failures before they happen.

Industrial equipment necessitates planned shutdowns and scheduled maintenance times for its successful operation. Because of this, the promise of APM 4.0 isn't to keep assets in a perpetual online state; rather, APM 4.0 empowers you to maximize your return on investment (ROI) by letting you take full advantage of sensor data so you know exactly how each individual asset—from the most critical to the least vital—should be managed and maintained in order to best mitigate risk and capitalize on opportunities.

This whitepaper will provide you with insights into how predictive alerts and prescriptive actions need to work together to fully unlock the value that APM 4.0 promises. We will explain how they work together to help you better manage your assets, what potential challenges to avoid when implementing them, and what role they should play in your decision-making process. We will show you how you can create sensor-based decision-making with true lead performance indicators in your organization that will have a direct positive impact on your asset's ROI. It is an integrated and complete method that brings clear value to you as an Owner-Operator.

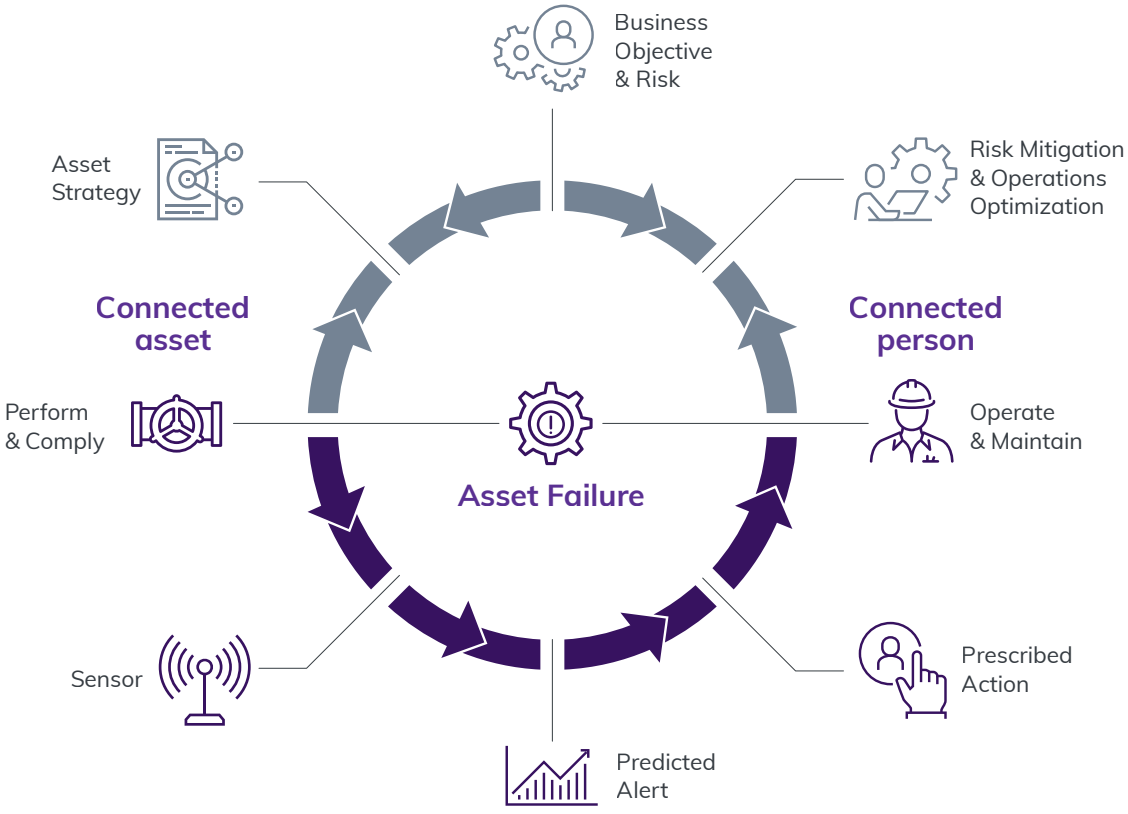
A leading cement company was able to get insight into asset degradation and improve maintenance strategy on all assets leading to a reduction of corrective maintenance costs through predictive maintenance resulting in an ROI of 1:19.

An Energy company avoided catastrophic failures causing over $10 million in damages by filling the gap between inspections and engineering by online continuous monitoring for early warning notifications.

The complete picture: analytics and risk management

Predictive and Prescriptive Analytics that utilize sensor data to make better decisions offer enormous opportunities to improve your Asset Performance. However, it is important to realize that it is not feasible in all cases to implement predictive asset strategies to mitigate your asset's risks and optimize its performance. First, from an engineering perspective, it might not be possible with current sensor technology to measure the emerging asset failure or to measure some type of proxy of the failure mechanism which will enable us to predict the failure in advance. Second, for some assets it might not be financially feasible to apply predictive strategies because the cost of the cure (sensors, infrastructure, analytics, contingencies) might be more expensive than the value of the benefit (e.g. planned downtime instead of breakdown).

In order to create a complete APM solution, the Owner-Operator must complement its Predictive and Prescriptive Analytics with a sound approach to asset risk management, as depicted in the figure below. Furthermore, the Owner-Operator needs to assess the asset context and define its criticality based on the impact on its context if it fails. For the company's most critical assets (A-critical), it will be straight forward. The Owner-Operator will maximize all the opportunities to monitor and control their condition and performance. But for the B-critical and C-critical assets this will require a more structured Asset Strategy Optimization approach.



Asset Performance Management 4.0

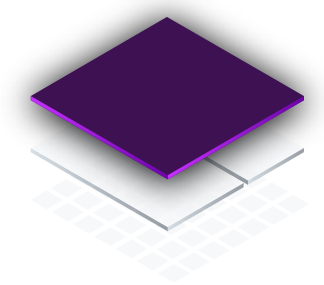
Upgrading APM from an asset-oriented approach to a system that holistically connects Engineering, Operations, and Performance.

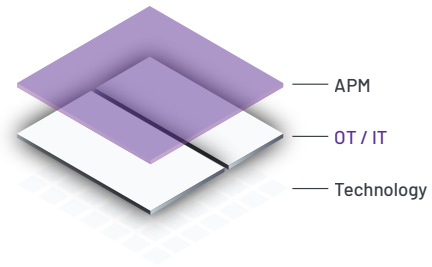
Traditional APM focuses on reliability engineering methods (e.g. Reliability Centered Maintenance (RCM), Root Cause Analysis (RCA), Failure Mode Effects and Criticality Analysis (FMECA) and Information Technology (IT) such as Computerized Maintenance Management System (CMMS), Enterprise Asset Management (EAM), Enterprise Resource Planning (ERP), and Business Intelligence (BI)).

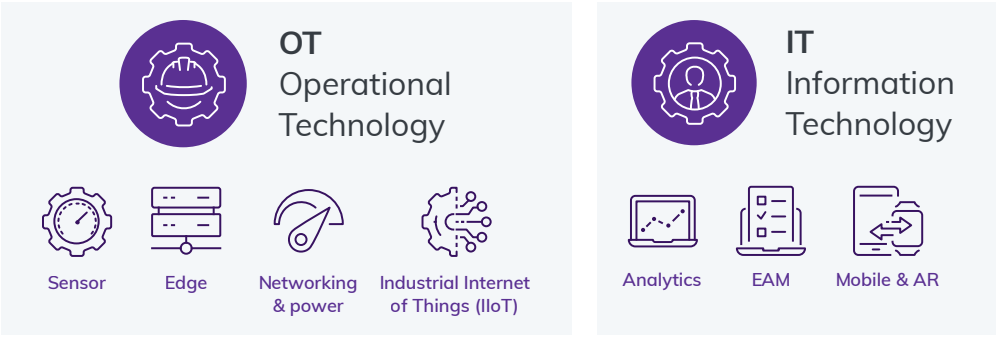
APM 4.0, however, integrates IT with operational technology (OT) and connects the asset to the person in the different stages of the asset lifecycle (engineering, operations, and performance) through several layers of enabling technologies.

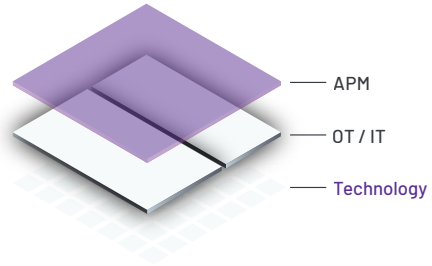
APM 4.0 lays the groundwork for predictive analytics and data science and transforms time-series sensor data into powerful predictive indicators. This allows Owner-Operators to avoid asset failures and optimize asset performance.

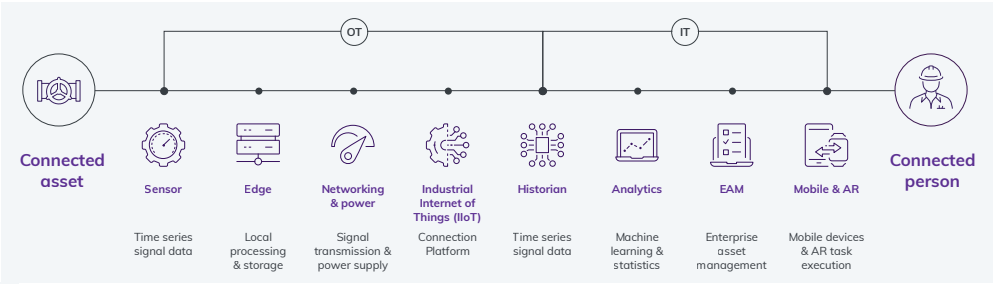
The following technology layers work in tandem in APM 4.0:











Using sensor data to maximize your ROI

Shareholders invest in assets because they expect to see a reasonable Return on Investment (ROI). The ROI is primarily defined by the operating profit that can be achieved from an asset. However, the ROI is also dependent on the Owner-Operator's license to operate. If the asset's integrity is challenged and does not comply with safety, quality, or environmental regulations, the Owner-Operator risks the asset being shut down by the responsible authorities.

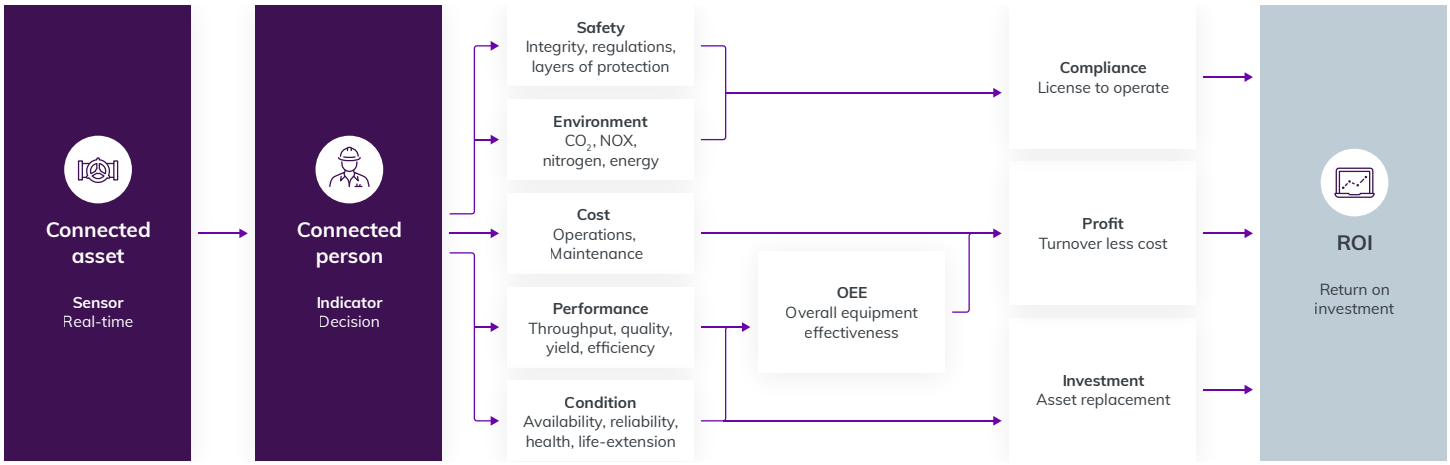
APM 4.0 establishes a direct link between the sensor and ROI. It creates meaningful key performance indicators from sensors and enables decision-makers to optimize the performance of the asset. For the first time in history these performance indicators are truly "leading" in that they can change performance before it happens.

"With APM 4.0, lead indicators adjust and improve performance in real time."

To date, performance systems have been primarily based on "lagging" indicators (e.g., cost, availability, number of safety incidents). These indicators only report on issues after the fact.

APM 4.0 and its sensor-based decision-making impacts our understanding of asset performance. Profit is turnover generated by the asset minus the conversion costs of producing the product that results from running the equipment; turnover is directly related to the overall equipment effectiveness (OEE) indicator of an asset, and the cost consists of the conversion/production costs and the maintenance costs of the equipment. APM decisions have a direct impact on the OEE and the costs of running that equipment and, hence, on the ultimate profitability of the asset.

APM 4.0 utilizes sensors and indicators to monitor and optimize the performance of the production process and your machines. With APM 4.0, **lead indicators adjust and improve performance in real time.**



Asset and process excellence

Asset Performance Management (APM) focuses on achieving asset and process excellence in five key areas:

1. **Safety**: Ensuring that the people that operate the asset are safe and adhering to equipment-specific regulatory requirements. Often these are local requirements defined by country and industry. Breaching compliance carries the serious risk of losing your license to operate.
2. **Environment**: Complying with regulations regarding impact (e.g., emissions, footprint) of the asset's operations on its environment. This also includes all sustainability objectives.
3. **Cost**: The total operating and maintenance cost of the asset. These two cost elements are highly interdependent and need to be managed in an integrated way (e.g., running equipment outside of the operating window will increase the degradation mechanism and deteriorate the asset's condition). Cost directly influences the Operating Income of the asset.
4. **Performance**: How efficiently and effectively the asset is operating to create the desired output. This is heavily dependent on the type of industry. Typically, it is based on the throughput, yield, and quality of the manufactured product. Performance will directly impact the revenue that is generated by the asset.
5. **Condition**: The traditional field of APM, where the emphasis is on achieving high levels of asset reliability and availability. The asset's health is dependent on the condition of its maintainable items, and the investments that are required for asset replacement heavily depend on how well the condition can be maintained. Asset Availability directly affects Asset Revenue.

An overview of APM 4.0 with predictive alerts and prescriptive actions

Below shows an overview of APM 4.0 with Predictive and Prescriptive Analytics solution. First, the foundation is created with time-series data that is consolidated and centralized by the historian tool. Second, predictive analytics uses this time-series data to create meaningful indicators and alerts that forecast risks or sub-optimum asset performance.

Third, each alert should have its specific prescriptive actions pre-defined. Once the alert is triggered, these actions enable the person to manage the alerts and to solve the problem before the failure will have an impact.

1

Time-series data | 2 Predictive alerts | 3 Prescriptive actions

Standard process control sensors

- Continuous sensor/signal data
- Flow, pressure, temperature, viscosity, speed, etc.

Mobile inspection measurements

- Time interval data recording

Dedicated condition monitoring sensors

- Vibration Analysis (VA)
- Current Analysis (CA)
- Acoustic Emission (AE)
- Thermography (TG)
- Ultra-Sound (US)

Historian

- Centralized time-series data base (points/tags)
- Plant & enterprise historian

2

Time-series data | Predictive alerts | 3 Prescriptive actions

Condition monitoring

- Indicator with fixed threshold alert
- Indicator y has clear y=f(x) function to sensors x

Anomaly detection

- Indicator is based on Machine Learning algorithm
- Advanced Pattern Recognition (APR)
- Overall Model Residual (OMR) robust indicator defines deviation from “normal”

Failure Prediction

- Indicator on Failure Mode level (link sensors to failure)
- Maximize prediction accuracy, reliability & specificity
- Engineering Expert Decision Rule System (Fault Diagnostics), that interprets relative trends among sensor data.

3

Time-series data | Predictive alerts | Prescriptive actions

Critically: $€£

What is the impact?

- Effect of Failure Mode occurs

Urgency: Days

How much time do I have?

- Predict WHEN failure mode will once Indicator Alert triggered (PF interval)
- Inherent to the failure mechanism

Action: Task

What action will I take?

- Contingency preparation and response for Alert trigger
- Tasks, skills, tools, permits, isolation (LOTO) work instructions

Action: Spare

What spare part do I need for task?

- Spare part strategy: replacement level, spare location, safety

Time-series data and the historian

Machines and their sensors are typically connected to a platform that enables efficient connection and transmission of time-series data to the data historian. Each sensor's data is stored in a separate tag or point in the historian. There are typically three sources for time-series data tags:

- **Standard process control sensors**: These are the sensors that are required for the automation of asset operation. They help you ensure a particular piece of equipment is operating within a desirable range. For example, a temperature sensor monitors whether or not a freezer is maintaining a cold enough environment to keep its contents frozen.
- **Dedicated condition monitoring sensors**: These sensors are not required to automate and control the asset's operation. Instead, they capture data that yields insight into the health of an asset, such as measuring the vibrations of a bearing.
- **Mobile inspection measurements**: Rather than data captured continuously via a sensor, these are asset measurements captured by a person and entered into a mobile device during inspection rounds.

Predictive alerts

APM 4.0 applies predictive analytics to the time-series data to create meaningful, accurate, and specific indicators and alerts that enable decision makers to influence the performance of the asset before a failure happens.

Predictive analytics includes the following three strategies to create alerts:

Condition monitoring

This strategy requires the most basic implementation. It involves taking one or more sensors, defining a meaningful indicator as a clear function of the input, and setting a fixed threshold. Should the indicator breach this defined threshold, it is then considered indicative of a problem or failure and an alert is subsequently triggered. With condition monitoring, the indicator is typically defined and calculated in the historian. Also, most DCS systems will include standard fixed threshold alerts as part of their monitor and control solution.

Anomaly detection

This strategy requires AI, or, more specifically, machine learning technology. The algorithm learns a set of time-series training data that reflects "normal" operation of the asset. Next, the accuracy of the algorithm is checked by running it on a new set of data to test if it can reliably pick up any anomalies. There are two major advantages to this strategy. First, you do not need to define a mathematical function between the indicator and the sensors. Second, it can monitor many different sensors at the same time.

Failure mode prediction

The ultimate goal in Predictive and Prescriptive Analytics is the accurate and reliable prediction of specific failure modes. This is because it enables a precise preparation (e.g., available spare parts) and a swift follow-up action to solve the problem. Sometimes this goal can be achieved with monitoring fixed thresholds of sensors (e.g., pressure difference across filter that indicates clogging of the filter), but for most failure modes, this goal requires a more advanced approach. It really depends on the type of failure mode and what is technically feasible to measure, model, and predict.

This advanced method is an extension of the machine learning algorithm used to detect anomalies. It adds an engineering first principle and expert rules system that monitors multiple sensors and tracks their relative behavior. It defines the rules and conditions that indicate a specific fault diagnostic. Ideally, the fault diagnostic represents a specific failure mode. However, with the current sensors that are available in the field (most often the standard process control sensors), it is not always possible to create such specific alerts. In that case, you try to maximize what you can infer from the sensors; the alert indicates multiple potential causes of the problem and requires a smart sequence of Diagnostic Actions (DA) to first establish what the exact failure mode is before the repair or pre-emptive replace Maintenance Action (MA) can be authorized and released for execution.

Prescriptive Diagnostic Actions are analogous to going to the doctor.

The doctor has the means to measure your temperature and test your blood or do visual inspections which can be automated with image recognition. But there are cases where the doctor will also resort to methods that are not necessarily measured to determine a diagnosis, such as asking questions about recent travels out of the country before taking your blood to test for malaria. It goes without saying that you would want to have as much confidence as possible about what the nature and cause of your malady is before you would let anybody operate on you.

It should be noted that accurate predictions can only be made based on the quantity and quality of data available, meaning this capability is tied to the limitations of sensor technology. As sensors continue to advance, so too will failure mode prediction capabilities.

Alert management

Systems that monitor, predict, and create alerts to help you optimize asset performance are a good idea. However, you must be able to follow up on the alerts provided by those systems.

If you do not effectively manage your alerts, you could find yourself overwhelmed by any of the following problems:

- **Asset failure**: The failure that was predicted occurs and causes an asset breakdown. This means you are unable to react and follow up on all the predicted alerts with prescriptive actions that diagnose and solve the failure before it occurs.
- **Alert overrides**: If your team lacks time and resources to effectively address all the alerts that are raised, they may simply start to ignore and overrule them —especially if they are deemed to be low priority. Over time, this will lead to a culture of alert insensitivity, which will have a serious effect on asset safety and performance.
- **Alert monitoring overhead cost**: Ineffective alert management tools will cause unnecessary overhead costs with people spending inefficient time on discussing what needs to be done, instead of focusing and solving the problems.
- **Reduce value realization of predictive analytics**: The inability to act swiftly on alerts will result in losing the benefits of implementing APM 4.0 technology in the first place.

Prescriptive Analytics for Predictive Alerts

The right APM 4.0 solution enables you to make prompt decisions on the prioritization and scheduling of alerts, so that you can prepare tasks and ensure spare parts are available. By adding prescriptive analytics to the predicted alerts, you maximize the benefits of APM 4.0 and successfully follow up with actions that will improve asset performance.

To achieve this, each triggered alert should be linked to prescriptive actions that consist of four attributes:

- **Criticality:** What is the financial impact of this predicted failure? Impact is the total effect of the event if the predicted failure mode occurs, as defined in terms of financial loss. It is important to note that impact in this regard is only the effect factor and not the risk factor, which includes the element of probability.
- **Urgency**: How much time do you have? Urgency is a reliable prediction of when the failure mode will occur once the indicator alarm is triggered. Traditionally in the field of condition monitoring, this is referred to as the "PF interval," where "P" stands for potential and "F" stands for failure. This attribute is inherent to the failure mechanism of the predicted failure mode.
- **Action**: What action will you take? This attribute defines your ability to prepare for and respond to a triggered alert. It defines the tasks you need to execute and includes the required skills, tools, permits, work instructions, and required asset safety isolation (i.e., lock out/tag out, or LOTO).

- **Spare part management**: Having the right spare part on hand determines whether or not a predicated failure can be avoided before it occurs. It will be extremely frustrating if you predicted a failure but failed to keep the required spare part in stock and cannot replenish the spare part in time to solve the problem as a result.

Implementation challenges of APM 4.0: Event-based vs. plan-based APM

APM 4.0 with Predictive and Prescriptive Analytics triggers alerts that create events. These events are prioritized, scheduled, and followed up on with actions to address the failure mode that caused the alert trigger. This is in stark contrast to traditional APM, which uses time-based maintenance (TBM) and usage-based maintenance (UBM) asset strategies. With traditional TBM and UBM strategies, actions can be planned. TBM defines a fixed interval or cycle that specifies when maintenance actions must take place. Meanwhile, UBM uses a counter to measure usage (e.g. machine hours, tons throughput) and defines fixed usage intervals.

The advantage of traditional plan-based APM is that events can be planned and prepared for in advance. Budgets and contracts can be established, scope of work can be fixed, and spare parts can be purchased Just-In-Time (JIT). With event-based predictive asset strategies in APM 4.0, work hours and spare part requirements vary and have to be estimated in advance.

Predictive Alerts and Prescriptive Actions with event-based tasks requires the implementation of a "pit stop" approach, and its successful execution requires:

- Careful task preparation and spare part availability in the APM execution systems (e.g. Enterprise Asset Management, or EAM, and Computerized maintenance management system, or CMMS)
- Flexibility, agility, and discipline
- A high level of execution maturity in processes and organization
- Advanced tools for prioritization, scheduling, and tracking of alerts, cases and work orders

Asset strategy optimization

Predictive and Prescriptive Analytics offers many opportunities to improve the way we manage our Asset Performance. However, it is important that we remain realistic and manage our expectations.

Not all failure modes can or should be addressed with predictive strategies. It might not be technically, financially, or organizationally feasible to implement predictive strategies for all failure modes. The cost of the strategy must be in line with the risk being mitigated. The risk depends on the failure effect that would be caused by the asset failure mode, which in turn depends on the function of the asset and on the context of the asset's location in the production process.

The structured method to define the optimal asset strategy for each asset context and failure mode is called Asset Strategy Optimization (ASO). In the "Why predictive analytics alone is not enough for successful asset management" whitepaper, we will cover all these strategies in detail and explain how to optimize and deploy the strategies in an effective way by using the concepts of Asset Classes and an Asset Strategy Library.

What is important to note is that the prescriptive capability is applicable to all types of asset strategies. Knowing the criticality, urgency, action, and spare part associated with each failure is essential, regardless of whether the strategy for a given asset is planned, predictive, or corrective.

A further point to note is that no single strategy is always better than another. It depends on the context. Your critical assets will require predictive alerts, and, if technically feasible, you would want to maximize your resources to hopefully predict failures. For other assets, a run-to-failure corrective strategy may be acceptable– especially if this is coupled with an aggressive spare part strategy that minimizes the downtime of the breakdown.

> Predictive APM requires a "pit stop" approach to execute tasks within PF interval of the alert.

Conclusion

APM 4.0 brings with it the promise of proactive asset management made possible by predictive alerts and prescriptive analytics: lower costs, reduced unplanned downtime, and optimized labor usage and equipment performance.

Through predictive alerts and prescriptive analytics, companies will be able to implement preventive asset strategies to avoid unplanned downtime for their most critical assets while also deciding which preventive or corrective asset strategy is the best course of action for their less vital equipment.

Some companies are close to achieving APM 4.0. Others may not be quite sure where they should begin their adoption journey.

Take this free, 15-minute assessment and benchmark against competitors and guide your APM strategy development: aveva.com/campaigns/apm-maturity-assessment

About the author

Werner Meyer is a technology transformation and innovation enthusiast. Transformation and innovation is never his ultimate goal, however. Rather they enable him to create quantum leaps in performance. He currently leads the Predictive and Prescriptive Analytics initiative at AVEVA as part of the APM Portfolio Strategy team. He has helped Owner-Operators for 23 years to achieve significant results in the areas of Supply Chain & Operations Excellence, Investments & Engineer-Procure-Construct, and Asset Performance Management. This puts him in the ideal position to integrate engineering, operations, maintenance, and performance across the complete asset lifecycle and realize the enormous potential that APM 4.0 has to offer. He understands that successful technology solutions fully engage people at all levels in an organization.

For more information about AVEVA's APM portfolio, please visit: aveva.com/asset-performance

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