The Value of Foresight

Generating Value Through Integrated Predictive Maintenance

By Bill McBeath

August 2020

Table of Contents

The Maintenance Maturity Journey

For asset-intensive organizations, the maturity of their maintenance practices is a key determinant of their ability to operate reliably, without interruption, profitably. Investments in improving maintenance practices, processes, and systems can have a large return. The improvement of maintenance practices is a journey, not a destination, as outlined in the maintenance maturity model below.

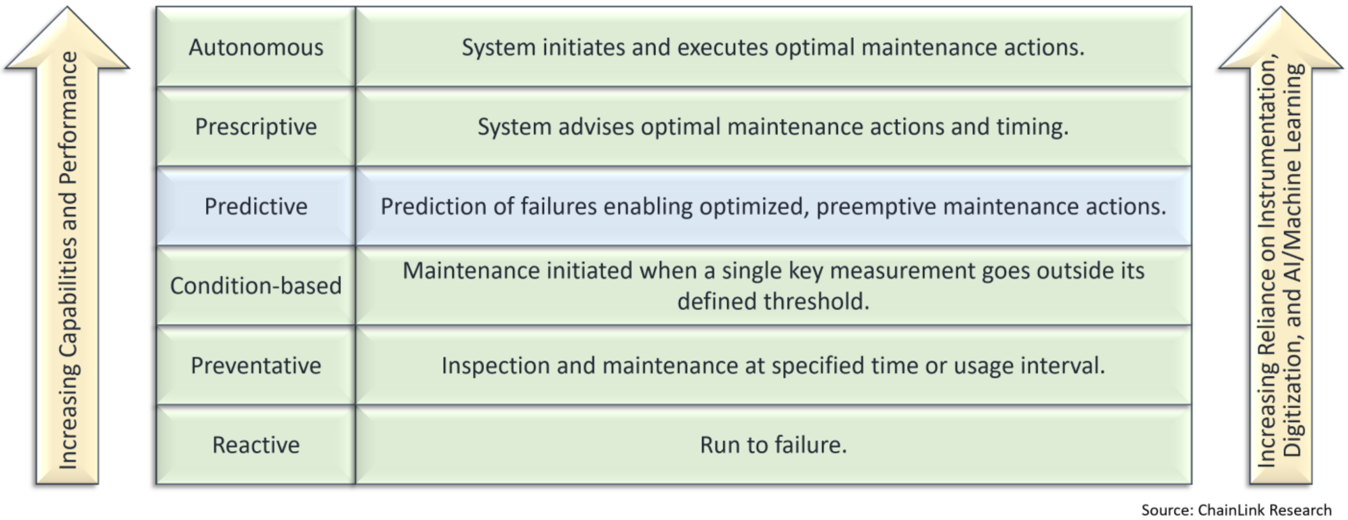


Figure 1 – Maintenance Maturity Model

As a company progresses and adopts each next higher level of maturity, it does not necessarily abandon lower-level, less sophisticated maintenance strategies. Companies that implement Reliability Centered Maintenance (RCM)[1] recognize that a one-size-fits-all maintenance strategy wastes scarce maintenance resources on less critical assets while underserving more critical assets. For example, a company may continue a reactive approach to very-low-criticality items (e.g. light bulbs, pencil sharpeners, etc.) ignoring them until they fail. Preventative maintenance may be appropriate for low-medium criticality assets requiring periodic inspection, replacement of lubricants, and so forth. However, with preventative maintenance, some equipment will be serviced before necessary, whereas other equipment will fail before being serviced.

Condition-based maintenance starts to address uptime and maintenance costs by monitoring one or more key measurements, such as temperature, vibration, pressure, or other indicators of an out-of-spec condition. Thus, maintenance tasks are more likely to be performed when they are actually needed. However, condition-monitoring typically involves monitoring only a few key measurements in isolation, lacking a more comprehensive view of overall asset health and more subtle indicators of deteriorating operation.

Predictive maintenance (PdM) typically involves a broader set of input data and more sophisticated analysis (e.g. motor current analysis, oil analysis, infrared thermography, ultrasonic analysis, etc.). More importantly, predictive maintenance analyzes these multiple variables together to provide a more reliable indicator of the

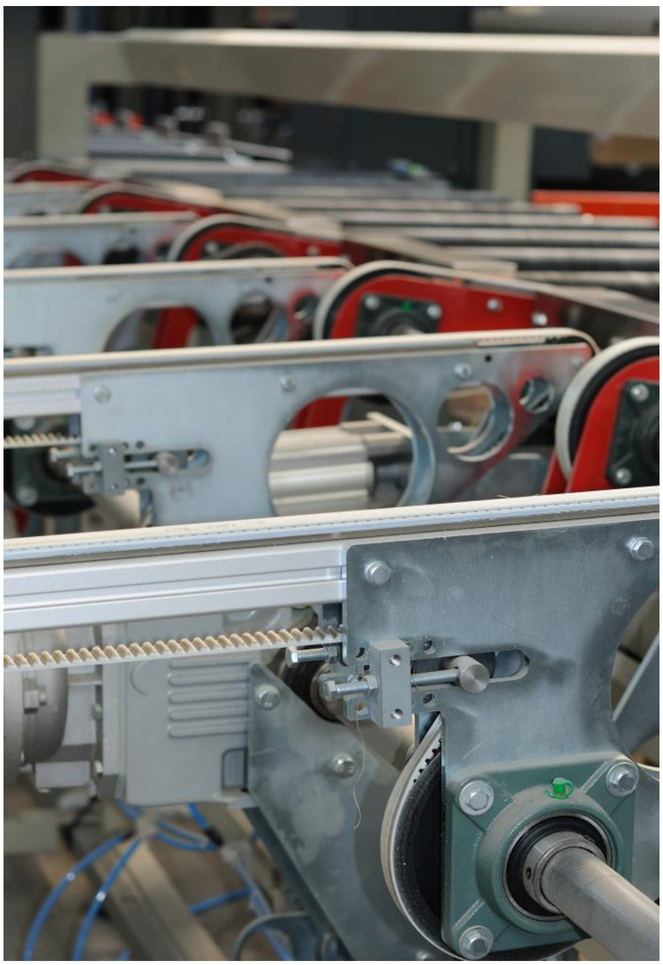
---

[1] RCM is a systematic approach to optimizing the mix of maintenance strategies by prioritizing the failure modes and impact of failure for various assets. It's roughly analogous to the risk-based approach used by some organizations to optimize the use of scarce compliance resources.

overall health and condition of the asset and a more accurate prediction of when a piece of equipment is going to fail and what should be done about it.

The Advantages of Predictive Maintenance (PdM)

With predictive maintenance, equipment is serviced more in line with actual wear and tear and need for service, while reducing unexpected outages. It brings the multiple advantages of making fewer scheduled maintenance repairs or replacements, using fewer maintenance resources (including spare parts and supplies), while *simultaneously reducing failures*. A well-run predictive maintenance program can have a dramatic impact on OEE (Overall Equipment Effectiveness). It impacts each of the three components of OEE: higher availability (uptime), increased performance (% of full design speed/output being achieved), and higher quality (first pass yield). According to the DOE,[2] implementing a functional predictive maintenance program can reduce equipment breakdowns by 70%-75%, reduce maintenance costs by 25%-30%, reduce downtime by 35%-45%, and increase production by 20%-25%.



Predictive Maintenance also provides the prerequisite foundation for Prescriptive and Autonomous Maintenance. Prescriptive maintenance builds on the infrastructure and data collected for predictive maintenance, observing the various corrective actions taken by maintenance personnel and the outcomes that resulted. Using machine learning, prescriptive maintenance learns and recommends the best timing and course of action for a given set of conditions. Autonomous maintenance takes it a step further by executing those actions automatically, without human intervention.[3] Currently, autonomous maintenance is largely a vision for the future, rather than a current reality for most organizations. Even prescriptive maintenance is in early stages at only the most advanced companies. In contrast, many companies are ripe for implementing predictive maintenance, to gain substantial benefits and significant improvements over their current approach.

[2] See *Operations & Maintenance Best Practices: A Guide to Achieving Operational Efficiency*

[3] There are still humans involved in the physical steps such as gathering spare parts and performing the actual maintenance tasks. However, the system automatically makes decisions about what tasks to execute and when, optimal replenishment and location of spare parts inventory, assignment and scheduling of maintenance resources, and so forth.

A Holistic Integrated Approach to Predictive Maintenance

Integrating Across Systems and Organizational Functions

Predictive maintenance works best within a holistic, integrated approach—i.e. bringing together and integrating data, systems, and human expertise from engineering, manufacturing, field service, logistics, supply chain, HR, finance … and of course maintenance. The foundation for this approach is building and maintaining a 'digital thread' for each asset—i.e. a full-lifecycle, digitally-connected approach to asset management, connecting all of the data and systems for each asset, from concept/design to manufacturing, service, and ultimately end-of-life/recycle.

In the ideal world, design engineers provide input to service analytics; CAD design is used in combination with sensor data to help simulate and predict the stresses and wear on machines; PLM systems ensure accurate BOMs are being used with the exact as-built and as-maintained configurations; supply chain planners receive (from predictive maintenance algorithms) better forward-looking indicators of spare parts demand and are thus better able to optimize spare parts inventory replenishment; logistics and field service personnel and systems are able to more efficiently allocate resources (equipment and personnel) and more cost-effectively plan tasks, based on more accurate forecasts; maintenance and service professionals receive highly accurate information about equipment configurations, status, and reliable remote diagnosis of issues, enabling them to bring the right tools and parts with them the first time, increasing first-time fix rates; parts provenance and remaining life is more accurately known; and design engineers receive highly granular data on the usage, failure rates, failure modes, and likely causes across the entire fleet of equipment deployed, enabling them to improve future designs.

Building an Integrated Foundation for PdM

The Wonderful Company is a $5B vertically integrated grower and bottler/packager of fruits, nuts, flowers, water, wines, and juices. They are the world's largest grower of tree nuts, America's largest citrus grower, and the world's largest flower delivery service.

Having expanded through acquisitions, Wonderful inherited disparate legacy systems, which stymied their desire to leverage synergies across divisions and implement advanced capabilities such as PdM. They solved this by migrating to an integrated cloud-based suite based on Oracle ERP Cloud and Oracle Supply Chain Management Cloud, including Oracle Maintenance Cloud.

This holistic integrated approach has provided Wonderful with better end-to-end visibility, better leverage of economies of scale, and the ability to selectively drive standardized best practices into the business units. It has provided the data integrity and consistency they needed as a foundation to advance their predictive maintenance vision.

Assessing Current Capabilities, Data, and Systems

Few companies have achieved this entire ideal state yet. It is a journey that can be addressed in 'bite-sized' pieces, while keeping the ultimate goal of end-to-end holistic capabilities front and center at each step of the way. An assessment of current capabilities, data, and systems can be used to determine where a company will get the most bang for the buck. This should include a 'data inventory,' looking at what relevant data exists across the company and assessing the quality and completeness of that data. Shop floor, field service, and maintenance professionals should be involved in the data inventory project. They are best suited to identify which data are valuable and what kinds of insights might be gleaned from that data.

The data inventory exercise will reveal shortcomings. Often people think they have a certain set of data, when upon examination they discover the data is missing, or difficult to retrieve, or inconsistent (different incompatible formats, spottily collected, etc.), or inaccurate, or has other issues. Some of these data issues require process changes. Others may be fixed by changes to systems or implementation of new systems.

Systems and Platforms Involved in Integrated PdM

A variety of organizational functions, platforms, systems, and data sources are involved in creating a holistic and integrated predictive maintenance capability, as shown below.

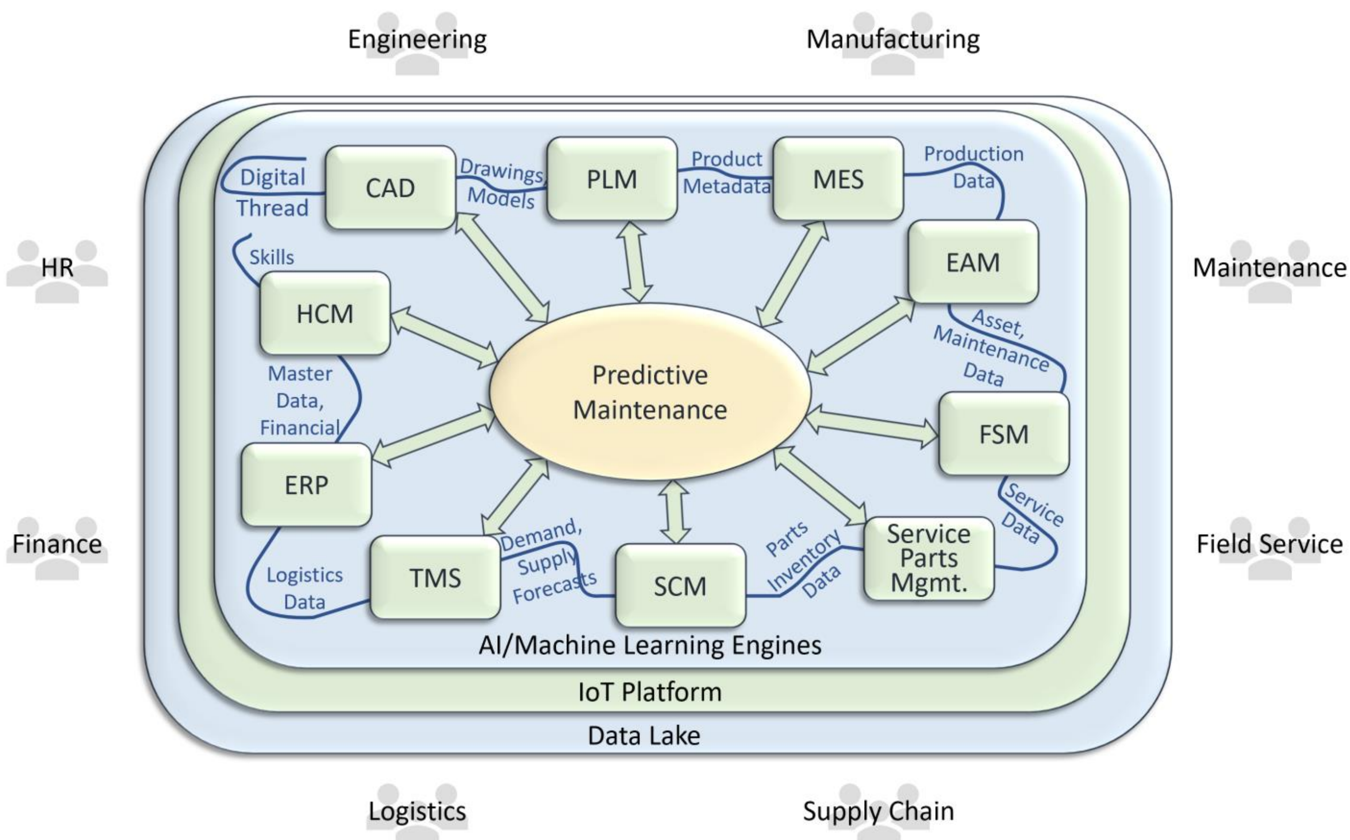


Figure 2 – Holistic Integrated Predictive Maintenance

Systems comprising an integrated PdM approach include:

- <u>*CAD*</u>—Computer Aided Design systems provide precise design data that can be useful in downstream activities such as product configuration; developing, documenting, and visualizing service procedures; and enabling augmented/mixed-reality-based maintenance and repair capabilities.[4]

[4] For example, helping a repair technician using an augmented/mixed reality headset or phone/tablet to highlight, right on the actual asset being repaired, which screws or part to remove or attach next, and even showing how to do it, as well as overlaying instrumentation readings and other key asset information onto the asset.

- *PLM*—A Product Lifecycle Management system can help in organizing and cleaning up product-related data, such as part numbers. Clean accurate product and component data is a prerequisite for the machine learning of predictive maintenance to work well.
- *MES*—Manufacturing Execution Systems help gather real-time data from production equipment. That data is vital to doing predictive maintenance on those machines. MES systems can also help in the execution of production schedules to allow the repairs that PdM identifies.
- *EAM*—An Enterprise Asset Management system is core to more advanced maintenance capabilities. It provides full-lifecycle management of assets and the management and execution of maintenance tasks. EAM is critical for asset-intensive, highly regulated industries. The EAM system is both a source of asset-related data for PdM, as well as the means to schedule and execute the maintenance and repairs.
- *IoT*-Internet of Things capabilities can augment thinly instrumented assets with sensors providing real-time data to drive the ability of machine learning algorithms to better predict failures and maintenance needs. An IoT platform that can ingest, organize, filter, and analyze enormous streams of real-time data is a foundational element of an integrated PdM approach. The value of an IoT platform is realized by the applications built on top of it, such as PdM, production monitoring, fleet monitoring, and asset management.

Precision Group's Integrated Approach

Founded in 1985, the Precision Group is a $10M designer and manufacturer of engineer-to-order dies & tools and batch-manufacturered injection-molded plastics for automotive, aerospace, medical, energy, electronics, and consumer markets. Predictive maintenance is a key element of their roadmap to Industry 4.0 and "Zero Unplanned Downtime."

Precision migrated from 25 year old legacy systems to a modern integrated foundation, based on Oracle ERP, including Oracle Manufacturing Cloud and Oracle Maintenance Cloud.

This has given Precision real-time inventory and production visibility, activity based costing, real-time available-to-promise, and reduced lead times. Next they are implementing real-time supply chain and predictive/prescriptive maintenance capabilities using Oracle Machine Learning. Precision estimates the integrated suite will bring an increase of 100 basis points in their profitability.

- *FSM*—Field Service Management systems provide for scheduling, dispatching, and execution of service and repair, driven by predictive maintenance. Mobile apps provide more error-free and efficient execution of predictive maintenance tasks and may also provide more accurate data for *prescriptive* maintenance to learn by understanding precisely what actions were taken.
- *Service Parts Management*—These systems optimize the placement of the service parts required for PdM tasks to be executed. More accurate service predictions (resulting from PdM) allow service parts optimization engines to keep less inventory. Increased predictability allows better advanced planning of repairs. Thereby, fewer spare parts are needed, kept in centralized pools, rather than having to scatter a lot more inventory across the network to rapidly deal with emergency repairs.
- *Supply Chain*—Supply chain systems have the overall picture of demand and supply, driving production and maintenance schedules. The advanced warning provided by predictive maintenance allows supply chain professionals to help identify the best time to do maintenance on production equipment, taking into account upcoming demand, supply, and production schedules. Supply chain systems also play an important role in ensuring the purchase and production of spare parts needed for repairs.
- *Logistics/Transportation*—These systems manage the delivery of parts and supplies for maintenance activities. They can do better optimization of resources when a PdM capability provides them with more advanced notification of upcoming maintenance activities requiring transportation resources.

- *ERP/Financials*—ERP systems contain much of the master data consumed in the predictive maintenance process, such as part numbers and asset-related data. They provide the financial data and framework for costing and prioritization of resources and activities.
- *HR*—Human Resource (aka Human Capital Management or HCM) systems often provide tools to match the service technicians with the right skills for the specific needs that predictive maintenance uncovers. They also provide the tools to recruit and train technicians and maintenance professionals, who are often highly specialized.
- *AI/Machine Learning*—Artificial Intelligence (in particular Machine Learning) is a core component of predictive maintenance, needed to extract insights and predictions from massive amounts and varieties of data.
- *Data Lake*—A data lake is needed to clean up, consolidate, and make useable all of the diverse sources of data needed by the AI/ML engines.

Demand Management for Maintenance

Predictive maintenance provides 'demand management for maintenance.' It changes the maintenance planning paradigm. Ideally, predictive maintenance analytics estimate the probability of failure (and specific type of failure) at different time horizons. Based on the criticality of the various equipment at a location and the probability and consequences of failure, maintenance can be scheduled in batches to make the most efficient and cost-effective use of resources. Furthermore, all of the supporting functions (such as supply chain/logistics, spare parts, field service planning, etc.) are given a longer range, more accurate forecast of expected demand, so they can prepare better, more appropriately, at a lower cost. By integrating all of these functions and systems together, workflows and resource usage are better optimized, while simultaneously improving uptime and OEE. This increases overall productivity from a given set of resources, ultimately improving Return on Capital Employed (ROCE).

The Value of a Holistic Integrated Approach to PdM

A holistic integrated approach involves integrating many different systems into the PdM capabilities. This enables PdM to get the data it needs, but more importantly allows more integrated automation of the supply chain and service functions involved in executing maintenance and repair driven by PdM. To this end, organizations should seek integrated suites that bring together all of these components—advanced AI/ML, IoT, Data Lake, PLM, MES, EAM, FSM, Service Parts Management, SCM, TMS, ERP, and HCM. To the extent those components are pre-integrated, from a single provider, it becomes an enabler to rapidly implement more advanced PdM capabilities.

Predictive Maintenance (PdM) for Customer/End User Organizations

Predictive maintenance can be used within asset-owning organizations to optimize maintenance for extractive industries' systems (e.g. mining systems, oil platforms), manufacturing plants, warehouses, transportation fleets, and facilities management.

Extractive Equipment PdM (oil, mining, lumber, agriculture, fishing)

Extractive industries—such as oil and gas, mining, lumber, agriculture, and fishing—have unique maintenance requirements. Their equipment is frequently in remote locations (such as offshore oil platforms, logging trucks in remote forests, mining equipment in the middle of vast deserts, etc.). This remoteness makes bringing in repair resources (technicians, repair equipment, parts) especially expensive and time-consuming. Some of these assets are very large, complex systems, such as oil platforms, autonomous mining equipment, and advanced autonomous planting/harvesting systems. These are usually mission-critical for the business—when the asset is not working, production stops and the business stops making money. In some cases, such as agriculture or fishing, there is a limited time-window for harvesting, and downed equipment results not just in a delay of income, but the loss of the harvested resource[5] for that portion of the season.

Thus, predictive maintenance has extremely high value in extractive industries. It compliments remote monitoring and allows for repair and maintenance to be scheduled much further in advance. This allows for much more cost-effective staging of the necessary resources and scheduling of the scarce skilled technicians. More importantly, any reductions in downtime can prevent substantial lost revenue. Offshore oil platforms can pump over a million dollars of oil a day.[6] The world's largest mining machine[7] can excavate about $5M worth of lignite per day. Large (24-row) cotton planting machines can plant 20+ acres/hour and large (6-row) harvesting machines can pick eight acres/hour.[8] When one of these machines goes down, it can cost thousands, tens of thousands, or even hundreds of thousands of dollars per hour in lost production. Predictive maintenance can dramatically reduce losses from unplanned downtime and the high expense of emergency repairs.

---

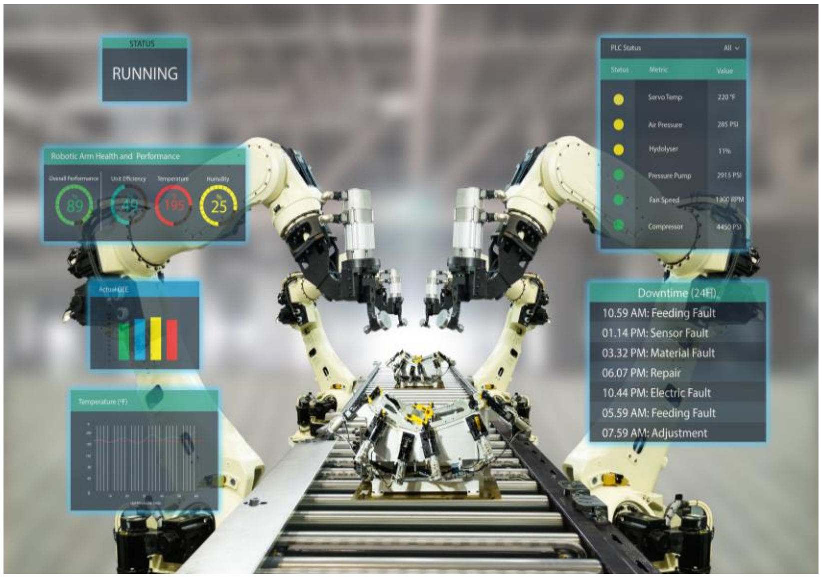
[5] Even forgiving crops, such as bell peppers, have a harvest window of only two to five days. Finicky crops, such as blueberries and strawberries, are almost worthless if not picked on the optimal day. During harvest season, farms are working at full capacity. Any interruptions (such as breakdown of a pre-cooling system or harvester) will result in crops going to waste in the field. Similarly, international fishing agreements limit fishing of specific species to specific dates. Once those windows are missed, no more fishing (of that species) is allowed.

[6] A typical offshore platform produces about 200,000 – 250,000 barrels per day. At historical average oil prices of $40-$60 per barrel, this is about $1M/day.

[7] The Bagger 288 can excavate 240,000 cubic meters per day. At $20/ton, that is about $5M worth of lignite.

[8] See *Planting and Harvesting Capacity in Cotton Production*

Manufacturing Plant and Warehouse PdM



Manufacturing plants contain some of the most complex equipment systems in the world. They can eclipse even extractive systems in the value per hour being produced. Downtime on a semiconductor manufacturing line can cost millions of dollars per hour. A single automobile assembly line can produce over 100 vehicles per hour, equating to $2M to $4M per hour or more depending on the vehicle. Large oil refineries[9] produce a million or more dollars' worth of oil per hour.

While downtime prevention is a key driver of value for manufacturing plants, PdM technologies can also be used to improve quality, productivity, and safety. Predictive quality algorithms use the same technologies as PdM (machine and IoT data fed into machine learning engines) to provide early warning of impending decreases in quality.

This allows adjustments to be made before quality is compromised, rather than catching it after substandard or out-of-spec parts have been produced. Productivity is improved by PdM primarily by reduction in downtime, but it may also be used to predict when machines will be running at less-than-full performance, before their performance actually degrades, thereby allowing corrective actions to be taken ahead of time. Safety is improved by predicting and averting catastrophic failures that could potentially result in injury or death.

Warehouses and distribution centers increasingly have sophisticated material handling equipment and/or robotics. With the surge in ecommerce, many retailers have invested in robotic systems to aid in pick, pack, ship operations. PdM can provide these facilities with many of the same benefits as manufacturing plants, i.e. reduced downtime and improved performance and safety.

Predictive Maintenance, Not Just for Large Manufacturers

[Noble Plastics] is a family-owned contract manufacturer of injection molded parts. They are a small company (~$5M in revenue), yet have implemented a high degree of automation, connectivity, and instrumentation in their two Lousiana-based manufacturing plants. They have over a dozen injection molding presses, and about a dozen and a half robots (mostly six-axis robotic arms) that are automated enough that they run a completely lights-out third shift.

They have been using Oracle IoT Cloud to enable better process monitoring and PdM. This warns them of pending quality issues that they can address before making any bad parts. It also increases uptime. Higher quality and equipment utilization has provided the ROI to more than justify the investment. (For more details, see *Noble Plastics gets proactive, predictive with Industry 4.0*)

[9] The world's largest refinery has a capacity of 1.24 million barrels per day, which equates to $2M - $5M per hour, depending on the current price of oil.

Transportation Fleet PdM

Transportation fleets are diverse, encompassing a huge variety[10] of automobiles, trucks, ships, aircraft, and rail vehicles. The motivations and drivers for implementing PdM programs for different types of vehicles will thereby vary, depending on the type of fleet and what it is used for.

For aircraft, safety concerns and regulatory compliance reign supreme. Anomalous instrument readings or non-functioning subsystems can ground a plane.[11] If passengers are on the plane or at the gate waiting, it can have a terrible impact on their flying experience. PdM can help avert many issues, by providing early warnings, so that preemptive action can be taken at an opportune time before the fact, rather than once passengers are onboard or waiting to board.

Today's large ships are complex platforms containing many interconnected machines, piping systems, pumps, electronics/computers, and other subsystems.[12] Breakdowns at sea can cause delays, drifting, and/or danger of running aground or collision. Predictive maintenance allows issues to be fixed before they become issues. It also can prevent expensive fines levied by port authorities for malfunctioning equipment.

Fleets of trucks can benefit greatly from PdM. Loss of power, braking, or steering while the vehicle is in motion can be extremely dangerous, resulting in tragic loss of life, destruction of cargo, reputational damage, and increased insurance costs. Breakdowns cause delivery delays, furious customers, expensive repairs, towing expenses, and lost driver productivity. PdM can not only prevent these accidents and breakdowns, but help identify poorly running equipment, thereby improving fuel economy (fuel costs are most fleets' largest single operating expense), improving safety, and extending equipment life.

Facilities Management PdM

Office buildings, high rise apartments, retail, and other buildings have lots of equipment and systems to provide comfort, safety, and convenience such as HVAC, people movers (escalators and elevators), fire systems, lighting and power systems, and access control/security systems. Outages in these systems can cause reduced productivity, compromised safety, or in extreme cases make the facility unusable. PdM can be an important part of an overall building management strategy and systems, to ensure uninterrupted full value is being generated by these expensive assets.

---

[10] For example, trucks can include box trucks, flatbeds, tractor-trailer, dumpers, tankers, concrete, heavy haulers, etc. Ships include container ships, tankers, bulk cargo, RORO, cruise ships, aircraft carriers, destroyers, fishing vessels, etc. Aircraft may be commercial passenger jets, cargo planes, fighter jets, helicopters, etc.

[11] A typical commercial passenger jet generates about a million dollars of revenue per hour while in flight.

[12] These include the engine(s), propulsion system, bow thrusters, navigation systems, control systems, bilge pumping systems, fuel system, and so forth. Military vessels will also include armament handling systems, guns, radar, and much more. Aircraft carriers comprise some of the most enormous and complex mobile systems in the world.

Driving Business Model Evolution for Product Manufacturers

Since the latter part of the twentieth century, we have been witnessing an evolution towards an 'outcome economy' in which people and companies don't buy things, but rather they buy outcomes. They buy the end results they are looking for. When a manufacturer sells a product-as-a-service, it is a sizeable step towards an outcome-based business model. Additional value-add services are wrapped around many of these programs.

There are many intermediate offerings or business models between "Make Only" and pure "Selling Outcomes" which most manufacturers keep providing, even as they start to offer more sophisticated services and product-as-a-service. This evolution represents ever-increasing servitization within a manufacturer's portfolio of offerings. This change shifts the cost of maintenance and repairs from the customer to the manufacturer, incentivizing manufacturers to make more reliable products that cost less to service. It can also deepen the relationship because manufacturers are forced to better understand exactly what their customer is trying to achieve. Additionally, manufacturers are able to offer higher value services, such as taking on related outsourced processes from the customer, which demand deeper organizational and technical integration into B2B customers' systems, processes, and functions.

Examples of Product-as-a-Service

Examples of product-as-a-service include all three major aircraft engine manufacturers selling power-by-the hour instead of selling engines; Schaeffler Industrial Services offers bearings-as-a-service for large complex machines like wind turbines or cruise ships with a multi-year, pay-per-rotation contract; Contract Air service from Atlas Copco provides compressed air at specified pressure, dew point, and purity—the customer pays by the cubic meter; Philips Healthcare offers pay-per-use programs for their whole technology portfolio.

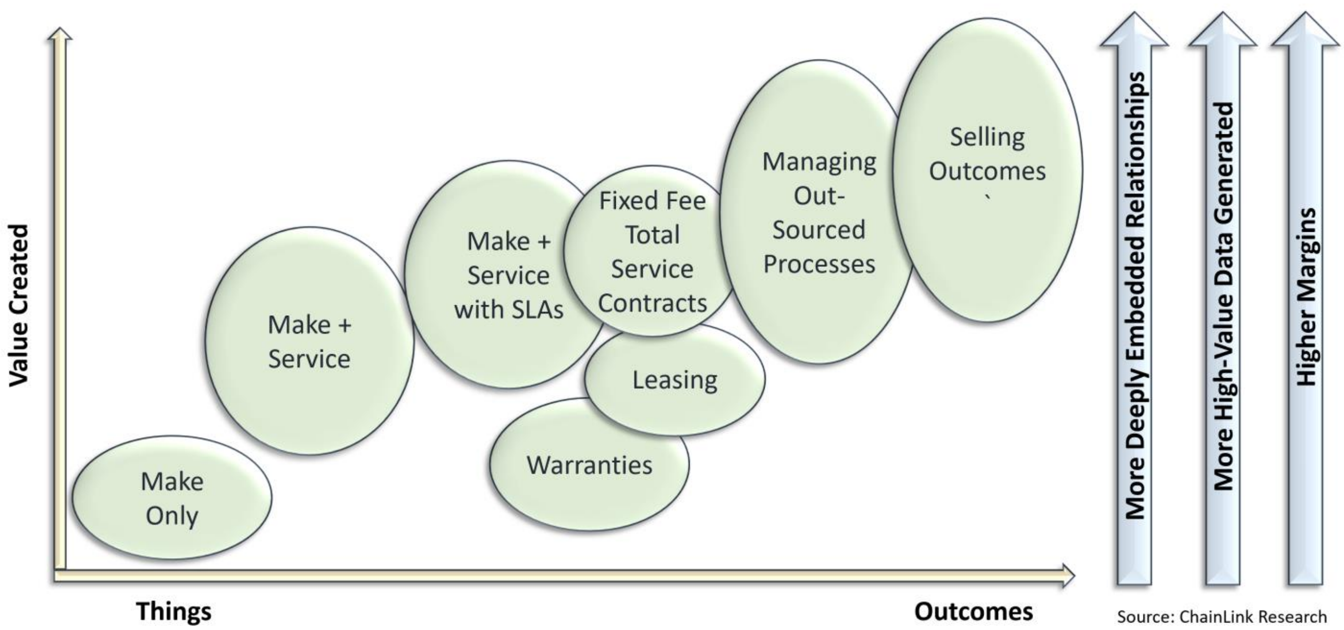


Figure 3 – Evolution to an Outcome Business Model

The Role of PdM in Manufacturers' Business Model Evolution

PdM plays a critical role in this evolution. It helps reduce the cost of providing service and enables higher SLA (service level agreement) guarantees to be offered and met. PdM enables higher uptime, which many customers are willing to pay a premium for. PdM often entails designing in sensors and connectivity to the products being sold and/or better leveraging existing sensors on those products.

As such, PdM-enabled products are generating a lot of high value data that can be used to create insights and high-value services for customers. For example, truck manufacturers can offer services to help their fleet-owning customers reduce fuel consumption and increase safety. The same infrastructure used for PdM enables product-as-a-service business models and differentiated services, thereby generating more value for the customers, more differentiated offerings, higher margins, and more stable and predictable revenue streams.[13]

Furthermore, this new data provides insights into how customers are using the products. This helps marketing professionals and product managers understand the relative value of the various product features and functionality, as well as uncover uses of the product that may not have been previously known. Product managers can remove costly features that no one uses while adding functionality or ease-of-use to help people better do what they are actually doing (or trying to do) with the product. The data lets engineers better understand the most frequent failure modes, enabling them to design for actual usage, conditions, and wear, rather than the theorized ones. They can thereby 'right size' the durability and reliability of components. All of this is enabled, at little extra cost, once an investment has been made in the PdM infrastructure.

High Value Services Via Integrated IoT, AI/ML, and PdM Capabilities

Founded in 1921, Mitsubishi Electric is a $40B global manufacturer of complex electrical and electronic systems, including factory automation equipment. In 2017, they announced their FA-IT Open Platform for edge-computing-based factory automation with IoT capabilities. The platform enables data collection and analysis to create smart manufacturing capabilities. It is integrated into Mitsubishi Electric's e-F@ctory ecosystem for factory automation and is built on Oracle IoT Cloud Platform, Oracle IoT Asset Monitoring Cloud, and Oracle Production Monitoring Cloud, as well as Oracle's AI and Machine Learning capabilities for Digital Twin and Digital Thread capabilities.

In May 2020, Mitsubishi announced the expansion of these capabilities with their new Clarisense integrated IoT technology. This technology spans Mitsubishi's product lines including factory automation, power generation, building equipment, smart city, and consumer appliances. It includes PdM capabilities as well as equipment lifespan estimation. By building on an integrated foundation, Mitsubishi is able to add significant value and differentiation to their hardware products via predictive maintenance and many other advanced capabilities. This has helped them become a high-value enabler of smart factories, smart buildings, smart cities, and smart homes.

The Predictive Maintenance Advantage

Predictive Maintenance can help asset-owning organizations reduce maintenance and service costs while simultaneously improving uptime. It enables product manufacturers to move up the path of increased servitization to realize deeper customer loyalty and satisfaction, higher margins, and more reliable revenue streams.

13 Subscription revenue streams are generally more stable than the one-time revenue from sale of products. Product-as-a-Service and other servitization offerings can also help smooth out seasonal revenue peaks and valleys.

About ChainLink Research

ChainLink is a recognized leader in custom research and advisory services, with a focus on supply chain, Internet of Things, and blockchain. Founded in 2002, our emphasis from the start has been on inter-enterprise interactions and architectures ('the links in the chain'). We have conducted over 75 primary research projects, interviewing and surveying over 10,000 executives and professionals. Much of our research focuses on industry-specific use cases, business cases and ROI, and drivers/inhibitors of technology adoption, and business change. As a result, we have developed a deep, multi-industry practice, founded on real-world, validated, supply chain-wide, end-to-end perspectives that have helped our clients understand, plan, and succeed as they move into the future.

For more information, contact ChainLink Research at:

321 Walnut Street, Suite 442, Newton, MA 02460-1927

Tel: (617) 762-4040. Email: info@clresearch.com Website: www.clresearch.com