Predictive Maintenance

A World of Zero Unplanned Downtime

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For want of a nail the shoe was lost.
For want of a shoe the horse was lost.
For want of a horse the rider was lost.
For want of a rider the message was lost.
For want of a message the battle was lost.
For want of a battle the kingdom was lost.
And all for the want of a horseshoe nail.

—Traditional rhyme

Nothing grabs the attention of C-suite executives more effectively than talk of profits, which explains the current buzz around predictive maintenance.

Geeks and gear heads across the landscape of heavy industry have been hearing the siren song of predictive maintenance for decades. The basic idea is simple: with the right blend of math and sensors, machines are fixed before they break, valuable resources are spared, and unplanned downtime is rendered obsolete. But until recently, the processes that would have made predictive maintenance possible either didn't exist or were far too expensive to be considered practical.

Today, the situation looks very different. The combination of advanced analytics, low-cost sensors, and the Internet of Things (IoT) promises to elevate maintenance from a cost center to a profit center. True believers like Mark Grabb, the technology leader for analytics at GE Software, see predictive maintenance as a spark with the power to ignite an economic revolution.

From his perspective, broader adoption of predictive maintenance principles will enable companies to provide a far wider range of products and services than ever before. Early adopters are likely to be companies in the energy, transportation, manufacturing, and information technology sectors. As more parts of the economy become dependent on services and benefits flowing through the IoT, the appeal of predictive maintenance will spread rapidly.

Looking at the Numbers

A seminal study[1] by the U.S. Department of Energy's Pacific Northwest National Laboratory claimed that a "functional predictive maintenance program" can reduce maintenance cost by 30 percent, reduce downtime by 45 percent, and eliminate breakdowns by as much as 75 percent.

According to the report:

> The advantages of predictive maintenance are many. A well-orchestrated predictive maintenance program will all but eliminate catastrophic equipment failures. We will be able to schedule maintenance activities to minimize or delete overtime cost. We will be able to minimize inventory and order parts, as required, well ahead of time to support the downstream maintenance needs. We can optimize the operation of the equipment, saving energy cost and increasing plant reliability.

If maintenance makes the leap from the garage to the C-suite, it will follow paths that were pioneered years ago by drab back-office functions such as accounting, which evolved into finance and is led by chief financial officers (CFOs); and data processing, which evolved into IT and is led by chief information officers (CIOs).

Is this the dawning of the Age of Predictive Maintenance? Mike Hitmar, a global product marketing manager at SAS who specializes in manufacturing, offers a "resounding yes" to that question. "Analytics are cool now, and people are beginning to develop a better understanding of what analytics can do," he says. "Analytics are the flipside of BI (business intelligence). Instead of looking backward at what's already happened, you're looking forward and anticipating what's likely to happen."

1 *Operations & Maintenance Best Practices: A Guide to Achieving Operational Efficiency*, U.S. Department of Energy Federal Energy Management Program, August 2010

The economic potential of predictive maintenance—not wearable technology or connected refrigerators—will drive steady growth of the IoT, Hitmar says. Companies like GE, Cisco, IBM, and Intel are counting on predictive maintenance capabilities enabled by the IoT to create an additional $100 billion in value for the energy and utilities industries by 2020. According to Gartner,[2] the IoT will create nearly $2 trillion in new value across the global economy during the next five years and much of the value creation will be spurred by predictive maintenance.

Ganesh Bell, chief digital officer and general manager at GE Power & Water, sees three layers of value creation from predictive maintenance strategies, as outlined in Table 1.

Table 1. Multi-layer approach to predictive maintenance

Organizational Layer	Focus	Goal
C-suite	Market performance	Optimize corporate profitability
VPs	Operational optimization	Increase efficiency; lower overall operating costs
Managers	Asset performance	Increase asset reliability and availability; reduce maintenance costs

Describing the first layer, he says:

> For plant managers and maintenance managers, the primary focus will be asset performance. Their goal is zero unplanned downtime for every asset they have. That's the foundation—increasing the reliability and availability of assets while lowering maintenance costs.

Bell adds, "The next layer are the VPs, who are thinking in terms of optimizing the entire plant operation, not just the physical assets, but everything, including the supply chain and human resources."

The third and highest layer is the C-suite, which focuses on optimizing profitability across the enterprise. "In the energy sector, when we talk about a 1 percent fuel savings, it translates into about $65 billion in value for our customers," he says. "From our perspective, we see predictive maintenance having a significant business impact at all three layers."

2 *Forecast: The Internet of Things, Worldwide, 2013*, Peter Middleton, Peter Kjeldsen, and Jim Tully, Gartner, Inc., November 2013

Each layer has different perspectives and goals. At the bottom layer, it's essential for managers and operators to understand the physics of individual parts and machines. At the next layer, the interplay between resources, machines, processes, and human behavior is critical. At the topmost layer, the focus is on making sure that the efficiencies achieved at the lower layers add up to market advantages and real profits.

Clearly, predictive maintenance is more than a tool or a solution; it's an integrated business strategy, with multiple layers, interconnected processes, and complex relationships among various stakeholders across the enterprise and beyond its traditional boundaries.

Bell says he sees similarities between the evolution of predictive maintenance and the evolution of ERP (enterprise resource planning), CRM (customer relationship management), supply chain management, and other systems that have become indispensable staples of the corporate IT portfolio. "We're already seeing CIOs getting involved in this and partnering with the head of assets or the head of operations at their companies to build up the IT infrastructure necessary to support predictive maintenance," he says.

It's important for CIOs to stretch beyond their traditional roles as "digitizers" when they prepare IT for the shift to predictive maintenance, he adds. "Predictive maintenance isn't the same as replacing atoms with electrons or using software to perform business processes. This is something fundamentally different; it's about creating new value and new revenue for the company."

Preventive Versus Predictive

The difference between *preventive maintenance* and *predictive maintenance* is more than merely semantic. Imagine a pyramid with three levels. At the bottom is *reactive maintenance*, where the operative philosophy is "wait until it breaks and then fix it." The next level up is preventive maintenance, in which repairs or alterations are made at scheduled intervals. The goal of preventive maintenance is extending the useful life of machines and their parts.

At the top of our imaginary pyramid is predictive maintenance, which seeks to stave off problems before they actually occur. In predictive maintenance scenarios, the goal is eliminating unplanned outages or breakdowns entirely. It's not hard to see why utility companies are leaders in predictive maintenance: power outages are expensive to remedy, create a variety of real dangers, and are guaranteed to anger customers. Medical device manufacturers are also at the vanguard of predictive maintenance, for similar reasons.

Based on information from the DOE, Tables 2 and 3 show key differences between preventive and predictive maintenance.

Table 2. Advantages of preventive maintenance and predictive maintenance

Preventive Maintenance	Predictive Maintenance
Cost effective in many capital-intensive processes	Increased component operational life/availability
Flexibility allows for the adjustment of maintenance periodicity	Allows for preemptive corrective actions
Increased component life cycle	Decrease in equipment or process downtime
Energy savings	Decrease in costs for parts and labor
Reduced equipment or process failure	Better product quality
Estimated 12% to 18% cost savings over reactive maintenance program	Improved worker and environmental safety
	Improved worker morale
	Energy savings
	Estimated 8% to 12% cost savings over preventive maintenance program

Table 3. Disadvantages of preventive maintenance and predictive maintenance

Preventive Maintenance	Predictive Maintenance
Catastrophic failures still likely to occur	Increased investment in diagnostic equipment
Labor intensive	Increased investment in staff training
Includes performance of unneeded maintenance	Savings potential not readily seen by management
Potential for incidental damage to components in conducting unneeded maintenance	

Follow the Money

Greg Fell is the former CIO of Terex, a heavy equipment manufacturer. Previously, he held technology management roles at Ford Motor Company. Fell believes the practical and economic arguments in favor of predictive maintenance have become too powerful to ignore.

"The best way of thinking about predictive maintenance is by tying it into a revenue stream," he says:

> When your machines are up and running, you're making money. When your machines are down, you're losing money. A typical automobile manufacturer can produce a car every 60 seconds. If retail value of each car is $40,000, your gains or losses add up very quickly.

While preventive maintenance relies on the straightforward concept of "mean time between failure" to create practical maintenance schedules, predictive maintenance is based on a deeper and more fundamental understanding of the physics underlying the operations of machines and their various parts.

"Instead of just looking at the average time between failures, you're looking for subtle clues within the machine itself," Fell says. "You're measuring sound, heat, vibration, tilt, acceleration, compression, humidity, and checking to see if any of those are out of spec." Fell adds:

> The basic idea of predictive maintenance isn't new. What's changed is that it's much less expensive to get data off a machine today than it was in the past. Twenty years ago, an accelerometer cost thousands of dollars. Today, every smart phone has one built into it. The technology required for predictive maintenance has been miniaturized and the cost has fallen dramatically.

The cost of transmitting data from machines to data repositories has also fallen. In the past, operational data generated by a machine was collected manually by a technician on the shop floor. Today, that data can be send wirelessly to the Internet via Bluetooth or Wi-Fi.

Not All Work Is Created Equal

Another problem facing traditional preventive maintenance scenarios is the assumption that every machine of a certain type will be operated under similar conditions or within similar parameters.

Clifton Triplett is Managing Partner of SteelePointe Partners, a management consulting firm. He is also a former CIO at Baker Hughes, a $20 billion global oil field services business, and manufacturing process executive at General Motors. A West Point graduate, Triplett knows firsthand that equipment is often operated in situations and circumstances that can be unforeseen by the design engineer or manufacturer.

"It's important to remember that not all work is created equal," Triplett says. "If you run a tool within its designed operating constraints, it will require a certain level of maintenance. But if you run it outside, well under or over normal operating specifications, a different level of service is generally going to be optimal."

For example, a truck designed primarily to deliver mineral ore in Canada will require a different level of service if it's used to haul ore up and down mountains, on flat paved roads, or across dirt roads in a hot, dusty desert. In the oil and gas business, a drill bit primarily used in conventional "straight down" drilling operations will require different reliability parameters and service requirement when compared to a bit being utilized in more challenging unconventional horizontal drilling. Reliability is in part defined by design, but reusable equipment is highly dependent upon the maintenance services performed on it.

"In the military, we would run tools and equipment in as many different scenarios as possible to understand how they would perform and react to the different environments," Triplett says:

> We would test equipment at various altitudes, temperatures, and levels of humidity. We would test equipment to see whether freshwater or saltwater would affect its performance. You name it, we tried it and we assessed how we should adapt our maintenance schedule to adapt to the conditions we place our equipment.

Companies that emulate the military's attention to maintenance issues can charge a premium for their services. For example, as drilling conditions become more extreme, the value of reliability grows. If you're an independent oil driller and you have a great predictive maintenance program in place (assuming it's proven by reliability metrics and performance), it is possible to demand higher service charges or take on more challenging opportunities. Non-productive time (NPT) is the "evil all drilling companies seek to eliminate," Triplett says. Service or operating failures are the number one contributor to NPT, and trust in the maintenance program of service companies builds confidence in the minds of the customers when awarding work.

"Oilfield operators are also more likely to let you use existing equipment longer if they trust your maintenance program, since they will worry less about it breaking down," Triplett says. "If you have a poor maintenance strategy or record, they're more likely to demand that you use new equipment every time you start drilling. Being forced to always use new tooling can be incredibly expensive, and most likely noncompetitive."

Smart operators understand that predictive maintenance translates into pricing power and now, with more complex drilling techniques, a large market share opportunity. Halliburton, for example, has developed a reputation for being able to perform reliably in high temperature environments longer than its competitors. That reputation creates pricing power and generates higher profits.

Building a Foundation

Daniel Koffler is chief technology officer at Rio Tinto Alcan (RTA), the global leader in the aluminum business and one of five product groups operated by Rio Tinto Group, a multinational metals and mining company. RTA annually produces 31.4 million tons of bauxite, 7 million tons of alumina (aluminum oxide), and 2.2 million tons of primary aluminum. Koffler is responsible for making sure that RTA's machinery keeps running.

"There's inherent downtime in any sort of run-to-fail scenario. And you're forced into keeping extra assets on hand to pick up the slack when your primary assets fail," Koffler says. "Either way, you're losing production capacity during the repair time, and you're spending money on extra assets that are sitting idle."

Although a scheduled maintenance model allows you to avoid unplanned downtime, there's also a good chance you'll end up repairing equipment or replacing parts unnecessarily. "With a predictive maintenance model, we can keep assets running longer *and* we avoid unscheduled downtime," Koffler says.

According to Koffler, reliable data and a solid computational model are foundational to predictive maintenance. Additionally, the corporate culture must adjust to a process that doesn't always yield perfect results.

"At the management level, people need to accept that a data model doesn't start at 100 percent maturity. It's a process that takes time. You're not going to start at the peak," Koffler says. "That means you have to accept additional risk. There may be unexpected failures. They are part of the process."

Koffler stresses that predictive maintenance isn't a magical formula; it's an iterative, scientific process that builds slowly to maturity:

> You need collaboration between subject matter experts such as mechanics and data scientists. The mechanic understands how the machinery works and the data scientist knows how to build a data model. The mechanic's knowledge should be codified into the data model. The mechanic and the data scientist need to communicate over a period of time to refine the model. There's no way to do this without cross-functional collaboration.

Like any process based on statistical analysis, predictive maintenance is inherently imprecise. The risk posed by predictive strategies must be "negotiated" and understood by the stakeholders involved, he says:

> You may want to negotiate an ultra-conservative approach where you're changing a part earlier, but you're still maximizing value by pushing the part closer to its predicted failure. Then it would be a discussion about risk, not about analytics. Those kinds of discussion—about cost, productivity, and risk—happen every day in business. It's the nature of real life.

Koffler isn't convinced that predictive analytics will become a mainstream consumer product in the near future. "You'd have to do the cost-benefit analysis. Placing sensors, collecting data, analyzing data —it all costs money," he says. "Just because you can do something doesn't mean you have to do it. Take the belts in the engine of your car, for instance. You could put sensors on the belts, but it makes more sense economically to run them until they break, and then replace them."

It's Not All About Heavy Machinery

Not every aspect of predictive maintenance revolves around heavy machinery and industrial processes. Doug Sauder leads the research and development team at Precision Planting, a company that makes technologies that help farmers improve seed spacing, depth, and root systems in their fields.

"The agricultural challenges of the future are all about doing more with less in a sustainable way," Sauder says. "It's about meeting the demands of a growing population and being environmentally responsible." From his perspective, predictive analytics play an absolutely critical role in any reasonable solution.

"We can be smarter about maximizing every square inch of ground, everything from what kinds of seeds to plant, how many seeds, planting the seeds properly, watering the seeds, and applying just the right amount of fertilizer," Sauder says:

> For example, it's important to model the nitrogen in a field. You need to model the rainfall and understand how it disperses into the ground. You need the ability predict where the nitrogen is moving so you can tell when it's time to apply more nitrogen to the field.

Sauder and his team not only help farmers understand more about their fields; they also "train" farm equipment to perform better. "We call it 'smart iron' and it's essentially technology that allows the farmer's equipment to think for itself as its going through a field," he says.

From the air, all corn fields look fairly similar. But at the ground level, every field is unique. When a corn planter travels through a field, it continually encounters a range of soil conditions. Some soil is hard; some soil is soft. If the planting pressure on the equipment is static, some seeds will be deposited deeper than others, resulting in uneven growth. But the farmer won't discover the problem until months later, and by then it will be too late to fix.

Sauder says:

> We put sensors on the planters that take hundreds of measurements per second. We can vary the pressure in real time as the planter goes through the field to make sure that every seed goes into the sweet spot. With "smart iron," we can literally micromanage every bit of the field and make certain that every seed is dropped into the right environment.

The ability to "micromanage" a cornfield requires the same blend of predictive capabilities needed to manage the performance of gas turbines, jet engines, nuclear generators, diesel locomotives, ore haulers, and magnetic resonance imaging devices. As Koffler suggests earlier in this report, predictive maintenance is a multi-disciplinary science, with roots and branches extending far beyond heavy industry.

The Future of Maintenance

The next steps in the evolution of predictive maintenance are likely to involve heavier doses of machine learning and closed-loop automation technologies. For the moment, predictive maintenance systems are limited to sending up red flags and issuing alerts of impeding failure. Future versions will undoubtedly include high-level decisioning tools and recommendation engines.

Prakash Seshadri, product development head at Mu Sigma, one of the world's largest decision sciences and analytics firms, sees predictive maintenance evolving inevitably into prescriptive maintenance. In a prescriptive maintenance scenario, the system won't just tell you that something bad is about to happen; it will offer helpful recommendations.

"It will go beyond saying, 'There's a likelihood this will break,'" Seshadri says:

> A predictive maintenance system will say, "Based on current and expected conditions, here's what you should do" and offer a range of choices, thereby guiding the human to make better decisions. But at the same time, if the human decides to override the recommendations, the system will capture that behavior and evolve through learning.

Today, predictive maintenance is practiced largely within the IT, manufacturing, healthcare, and energy sectors. In the near future, predictive maintenance will become more widely adopted in the retail, telecom, media, and finance industries. The potential for cross-pollination seems unlimited.

About the Author

Mike Barlow is an award-winning journalist, author and communications strategy consultant. Since launching his own firm, Cumulus Partners, he has represented major organizations in numerous industries.

Mike is coauthor of *The Executive's Guide to Enterprise Social Media Strategy* (Wiley, 2011) and *Partnering with the CIO: The Future of IT Sales Seen Through the Eyes of Key Decision Makers* (Wiley, 2007).

He is also the writer of many articles, reports, and white papers on marketing strategy, marketing automation, customer intelligence, business performance management, collaborative social networking, cloud computing, and big data analytics.

Over the course of a long career, Mike was a reporter and editor at several respected suburban daily newspapers, including *The Journal News* and the *Stamford Advocate*. His feature stories and columns appeared regularly in *The Los Angeles Times*, *Chicago Tribune*, *Miami Herald*, *Newsday*, and other major US dailies.

Mike is a graduate of Hamilton College. He is a licensed private pilot, an avid reader, and an enthusiastic ice hockey fan. Mike lives in Fairfield, Connecticut, with his wife and two children.

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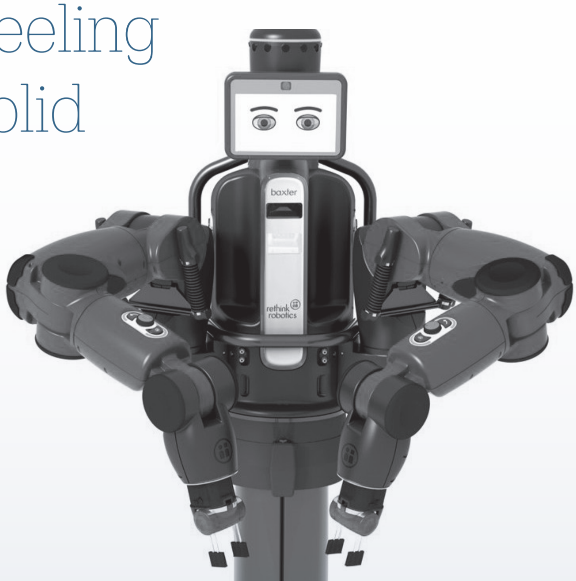

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