Reducing Facility Maintenance and Repair Costs with

PREDICTIVE MAINTENANCE

onPoint
by Buildings IOT

Chapter 1: Introduction to Predictive Maintenance

In recent years, the term predictive maintenance (PdM) has risen to prominence in the industrial and manufacturing sectors. With the advent of the Internet of Things (IoT) technologies, proactive maintenance – which includes predictive and preventive measures – has become a core pillar in the Industry 4.0 revolution.

For manufacturing, the benefits of this innovative, data-based maintenance strategy have been critical in:

- Maintaining competitiveness
- Reducing costs
- Improving efficiency
- Addressing the skill and labor gap
- Curtailing supply chain disruptions due to maintenance efforts

However, these benefits are not exclusive to the manufacturing sector. Experts agree that building maintenance programs can achieve similar success with PdM adoption, but, for the built environment, PdM remains in its infancy.

By the end of this white paper, you will well positioned to be an early adopter of predictive maintenance in the built environment. You will have gained a working knowledge of facility maintenance strategies, including PdM. You'll also learn the benefits of implementing a PdM program, what challenges you will face during your implementation process and how to overcome them, and the steps you need to take to implement a PdM program.

Chapter 2: Facility Maintenance Strategies

Maintenance and repair (m&R) is a significant operational cost of owning a facility. The lack of deliberate maintenance programs results in reactionary M&R as corrections of failures become normal daily operations and absorb significant operating budgets. This becomes cyclical as M&R is deferred and in turn accelerates the deterioration of facility equipment which contributes to increased energy usage and energy spend. However, there are substantial opportunities to minimize these costs through strategic facility management programs.

Today, many leaders of building engineering programs agree that proactive maintenance is the optimal strategy for their M&R programs. However, due to time and labor constraints, 60% of maintenance performed remains reactionary and perpetuates the reactionary M&R cycle. Implementing an effective maintenance plan that breaks that cycle requires the use and control of large amounts of information.

At the center of the modern facility maintenance movement is preventive maintenance. Preventive maintenance is performed on a fixed schedule and consists of manual check-point processes and activities on building equipment. However, planning maintenance in this way largely relies on guessing how much time or usage must occur before maintenance needs to be performed. Ultimately, time and run-time-based preventive maintenance can reduce heightened service costs associated with emergency maintenance but can still result in increased maintenance spending by relying on potentially unnecessary inspections and unnecessary repairs.

Fortunately, the digitization of building equipment and systems provides an opportunity to optimize this process with data. Predictive maintenance (PdM) relies on those large amounts of data and information to inform machine learning (ML) processes that improve maintenance efforts.

What is Predictive Maintenance (PdM)?

Predictive maintenance (PdM) is an equipment maintenance strategy that relies on real-time monitoring of equipment conditions and data to predict equipment failures. Advanced data models, analytics, and machine learning (ML) can reliably assess when and where failures are most likely to occur, including which components are most likely to be affected.

Chapter 3: How PdM Works

PdM uses historical and real-time data from connected systems and equipment to model performance and anticipates equipment or system failure before it occurs. Historical data from equipment, systems, sensors, and environmental factors is used to model what is called the P-F curve. The P-F curve depicts the performance of a piece of equipment or system over time and represents the point at which that equipment could fail – the potential failure or "P" in the equation – and the point at which that equipment does fail – the functional failure or "F" in the equation. The more data that is available to inform this model, the better equipped a PdM program is to identify the interval between the potential failure point and the functional failure point.

To achieve this, building system integration is a critical component of the PdM strategy. Namely, a successful PdM program works through the strategic convergence of the Internet of Things (IoT), ML, and system integration. When these technologies work together, they leverage the vast amounts of data produced to model a P-F curve that can pinpoint the interval when failure is likely to occur with impeccable accuracy. Building engineers and maintenance teams then access this information via software such as an integrated building management platform (IBMP) to address failures when they are going to occur.

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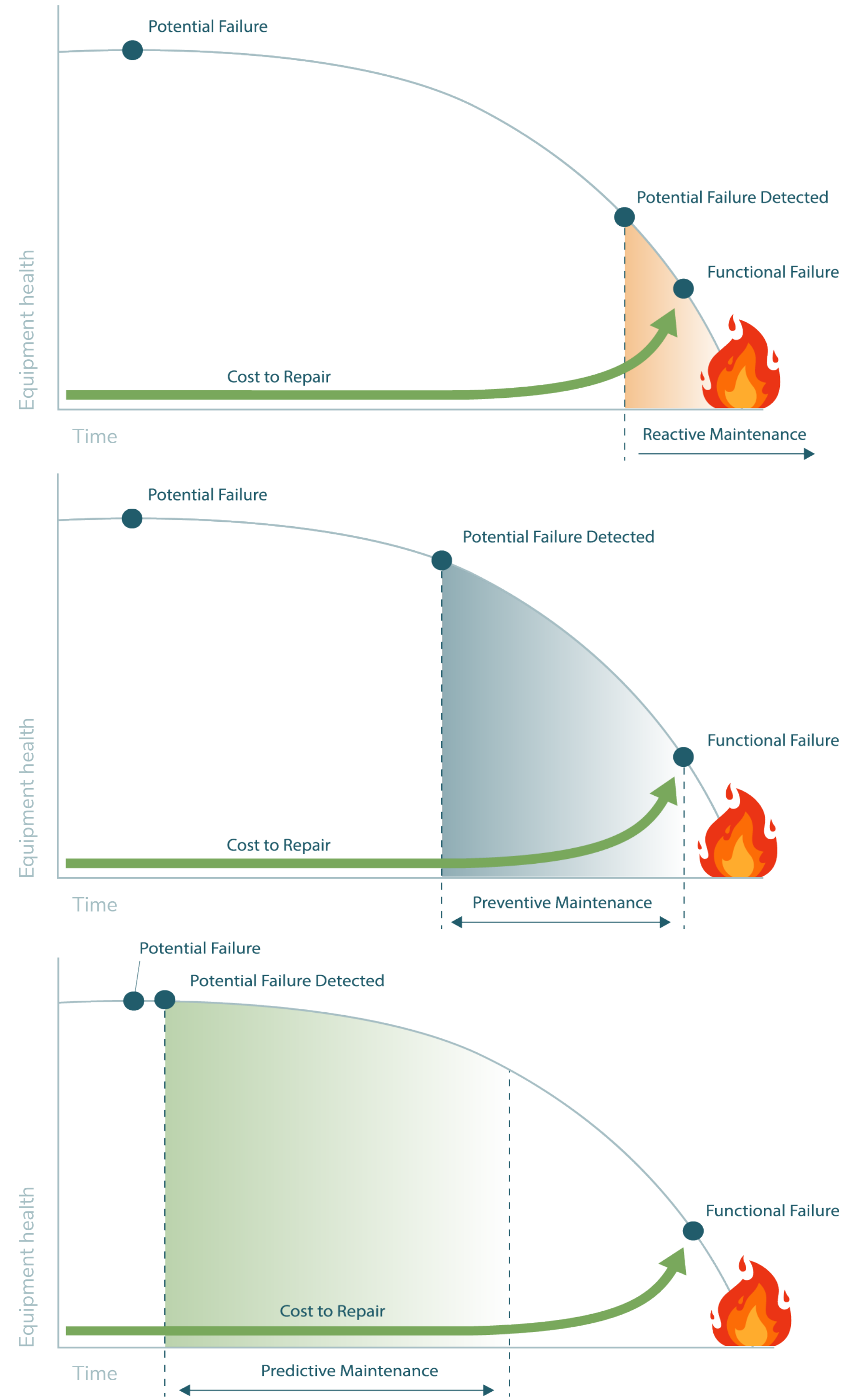


Chapter 4: Benefits of PdM

An effective PdM program results in facility maintenance and repairs being performed just before failure is likely to occur. It also helps to optimize performance by indicating issues that result in equipment performance inefficiencies. This allows for targeted maintenance that reduces unnecessary inspections and repairs and enables early intervention to prevent serious and complex problems down the line.

Other benefits of PdM include:

- **Longer lifespan of equipment**
  Well-maintained equipment performs better and lasts longer. Data-driven PdM reduces wear and tear, minimizes malfunctions, and allows maintenance teams to act quickly when anomalies occur. PdM utilizes ML algorithms to evaluate the series of inter-related data points collected by building systems and identifies potential issues that may impact future equipment performance. This extends the life of your equipment, ensures you get the most value out of your equipment, and reduces the frequency of costly capital expenses.
- **Lower maintenance costs**
  According to the PRSM 2012, HVAC Benchmarking Report, reactive service calls after equipment breaks are, on average, three times as expensive as proactive calls. That's an average of around $400 more per call. When applying a predictive maintenance strategy, these savings are even more substantial by helping to optimize maintenance frequency. When done right, PdM can all but eliminate unplanned reactive maintenance while still reducing preventive maintenance costs.
- **Less downtime**
  PdM empowers engineering teams to avoid unplanned downtime while also reducing planned downtime. In addition to shortening the downtime of equipment for maintenance, PdM allows engineering teams to better plan downtimes around usage to minimize disruptions.
- **Enhanced routine maintenance activities**
  Armed with data in real-time, the ML technology behind PdM can also enhance routine maintenance activities. It does this by providing data-driven fault detection and diagnostics (FDD) capabilities with an advanced and increasingly accurate assessment of equipment performance. This helps mitigate the time technicians and contractors spend locating and assessing issues by providing root-cause insights into the problem.
- **Budget control**
  The ability to plan repairs and maintenance in advance gives real estate operations teams enhanced control over maintenance budgets. Equipment service requests can be scheduled at opportune times to maximize cost savings.

Chapter 5: Disadvantages of PdM

While predictive maintenance has its benefits, it isn't without its downside. There is of course an upfront cost of predictive maintenance. For it to be effective, the technology solutions must be able to access the vast amounts of data produced by the various building entities. If it has not already been done, this will require the help of a master system integrator (MSI) to integrate the various equipment, systems, and sensors successfully and thoroughly across your site. This may also require investment into new technologies such as IoT devices and sensors or updates to legacy system controllers.

If done incorrectly, a master system integration project can also result in additional costs down the line as new technologies that are onboarded are not easily integrated into the existing technology stack. This risk is minimized through the proper vetting and hiring of a trusted MSI provider that leverages open-source protocols and data standards and is committed to remaining equipment agnostic. Similarly, not all failures within your building equipment ecosystem are more cost-effectively managed with a PdM strategy. Relying on an experienced MSI that can provide guidance on how to decide whether a particular asset is best served with a PdM solution can help ensure that each asset receives the best maintenance program for its particular use.

Additionally, accurate interpretation of the resulting performance models often requires a new or elevated skill level and experience that can result in higher labor costs to maintain the program. Leveraging the subject matter expertise and staff augmentation of the managed services provided through your software provider and outsourcing this function can often offset this need for additional team members while ensuring you are gaining the maximum results of a PdM strategy.

Consider your needs for:

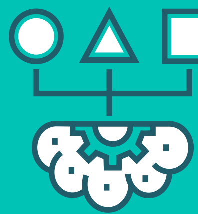
Upfront Costs

System Integration

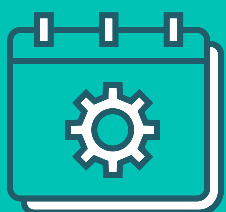
Elevated Skill Level

Chapter 6: Challenges of Implementing PdM

While a PdM strategy is an attractive option for facility operations, implementing a successful program is accompanied by several challenges that must be overcome.



Data Challenge



Processes Challenge

Adoption Challenge

The data challenge

A PdM strategy is only as good as the data that it uses. While the built environment's counterparts rely on intelligent technologies to ensure the data accuracy of equipment, many building maintenance plans that tout a PdM strategy still rely on human input to provide the necessary data that informs P-F curve models. With human input comes human error.

For instance, busy engineers may wait until the end of the data to enter their daily setpoint information which in turn could result in an inaccurate representation of performance at specific times of the day. Additionally, the engineer is only capable of reporting the data that they are aware of. If a particular piece of equipment's setpoint fluctuates throughout the day, the engineer may only be aware of the setpoint that they observed, missing out on crucial data that may signify potential failure by analyzing patterns.

This strategy also becomes counter-productive to the efficiency goal of PdM by playing more responsibility on already thinly stretched engineering teams to ensure data accuracy.

Facility management's slow adoption of technology-driven data collection is not without just cause. The root of the problem is a web of data inconsistencies, naming protocols, data standards, and relationship modeling in the built environment. Getting the HVAC system to connect with the occupancy sensors and the access control system and the lighting system isn't as easy as just hooking them all up to the same software. Each system tends to operate within its own ecosystem of languages, databases, user interfaces, and reporting tools. To fully achieve the benefits of PdM each of these ecosystems needs to be standardized first before the data can be used. This creates a significant barrier to developing and deploying functional technology solutions for PdM.

In recent years, the solutions to this problem have progressed with the continued adoption of open communication protocols. However, the data and relationship modeling remains highly disparate. The underlying technology and modeling solution must solve for the myriad of naming protocols, data standards, ontologies, and relationship models that exist across the different systems and equipment within a building. It must do all of this with an eye to the future, anticipating that new technologies emerge exponentially and will need to be quickly and easily added to the ecosystem to continuously improve the P-F curve model's accuracy.

The processes and procedures challenge

Assuming the data challenge has been met, a new challenge emerges. With a stream of accurate, reliable, and consistent data comes an inundation of information and insights about potential equipment failures and inefficiencies. Maintenance teams can become inundated with alerts and alarms, and it can be challenging to know where to start. Establishing a set of priorities, and even better, implementing them into a software solution that automatically prioritizes alarms based on that set of priorities can help teams systematically manage the influx of problems that a PdM program can uncover. Every facility management team – and organization – will have its own unique priorities. It's important to work with your software provider to establish ahead of time what those priorities are and ensure that your team is aligned with that decision.

Some examples of priorities include:

- Improving occupant comfort
- Energy efficiency
- Healthy indoor space and air quality
- Optimizing maintenance productivity

The adoption challenge

Adoption of analytic software to the facility management technology stack can seem like an additional chore for users. Aside from the learning curve associated with new software, new technologies often require changes to the status quo of users. They often require new skill sets, new training, and new responsibilities. Significantly, in 2018, the World Economic Forum (WEF) predicted that more than half of all employees will require significant reskilling by 2022. And in 2022, this challenge came to a head as the widening skill gap has hit the building sector particularly hard. This has exacerbated the barrier to adopting technologies that can provide PdM solutions as it significantly extends the learning curve associated with new technology adoption.

Fortunately, there are technology solutions out there that empower adoption and mitigate the need for significant reskilling. These technologies offer solutions that bridge the skill gap by extending the domain knowledge and expertise of the developer's team to empower boots on the grounds to do their jobs more efficiently and productively. These solutions provide expertly guided insights via intuitive user interfaces that are easily digestible with the current knowledge of facility engineering teams. These insights aren't just alarms or reports. They are results – that is, a specific finding of operational issues that are presented to the user in a clear understandable view. These views tell engineers and maintenance teams exactly what the issue is, when it occurred, how long it lasted, the status of all related operating conditions, and even the cost impact of the issue. Insights enable teams to find patterns and issues they weren't aware of – patterns that they didn't expect or couldn't have imagined. They provide results that show how a building's systems really operate versus how the teams thought they were operating.

Beyond the software itself, managed services – such as Buildings IOT's comprehensive Digital Services – support these technologies and insights by augmenting facility personnel with subject matter expertise to monitor, analyze, and enact PdM solutions across portfolios. These solutions collect multiple sources of equipment data and advise on equipment utilization and operation to minimize disruption, costs, and complaints.

Chapter 7: Implementing PdM across your portfolio

As we've alluded to in this whitepaper, there are several considerations to account for when deciding on the adoption of PdM into your facility maintenance strategy. To ensure the successful implementation of a PdM program, it's necessary to address these considerations in a thoughtful and strategic way. In this section, we will outline the steps necessary to get you started on your PdM journey.

Setting goals and priorities

As with the implementation of any new program, the first step to implementing a PdM program across your portfolio is to establish a specific goal. Start with establishing a wish list of things that you would like to accomplish with a PdM program and then assign them a priority based on the highest impact to your organizational goals. Goals should be performance-based and may include one or more of the following:

- Reduce "clipboard" site management
- Reduce disruption due to failure
- Implement a more cost-effective and efficient approach to facility management
- Replace aging equipment
- Reduce BMS alarms
- Augment scheduled maintenance with prioritized checklists
- Reduce service calls and vendor expenses with just-in-time work orders
- Faster adoption of new technology
- Cybersecurity
- Migrate to a smart, sustainable, energy-efficient building
- Integration into productivity and financial systems
- Real-time information and reporting

Establishing your unique goals will help you to establish your PdM solution's priorities. As mentioned previously in this white paper, this is critical to ensuring smooth adoption and reducing insight overload when you bring your PdM program online.

Making it manageable

It is important to understand that the implementation of predictive maintenance will change your day to day. You will require a team that supports these efforts and can work with you to develop a staged onboarding program to transition to a data-driven operation. This program is modular and considers your current infrastructure, resources, needs, and outcomes against a timeline that is manageable. A phased approach helps to mitigate the impact on your day to day and brings with it several cost advantages.

When developing your PdM program, consider each asset individually and prioritize according to:

- Criticality of the assets
- Operational cost to maintain assets (work orders, failure codes, maintenance issues, age, routine tasks)
- Energy consumption

Assessing your assets with a gateway

PdM requires analytic rules that measure the actual performance of your building's equipment. This means analytics will require access to reliable historical and real-time data. You will need to assess your building assets and environments to determine if your systems are non-proprietary and communicate data in a standard way such as BACnet IP and/or Modbus TCP. The most efficient means to assess your existing architecture is a gateway (either a physical device or virtual machine) that collects and aggregates data. A gateway device such as Buildings IOT's LaunchPad will help you quickly understand the state of your infrastructure and what equipment and devices within your building's ecosystem are eligible for PdM. This is where your program planning begins.

Assessing network requirements

Now that you have decided the least disruptive and most cost-efficient way to start obtaining data from existing equipment, consider the network requirements. This typically not as difficult as it seems. Most gateways require outbound internet access. To implement this step, the network information you should have at hand include:

- IP address
- Outbound ports
- Number of VLANs

Addressing equipment and technology gaps

Not all of your equipment may support IP-based technology requirements for open communication protocols. Equipment may be old or not support an IP connection. That's okay. This is why it is a program that provides steps to prioritize your needs and current state against your timeline and budget. Any modifications can be planned to get you to the final goal. This is also the time to consider any new sensors and equipment you may need for a comprehensive program.

These may include:

- Temperature sensors
- Pressure sensors
- Chemical and gas sensors
- Level sensors
- Vibration sensors
- Motion detectors
- Location tracking
- Water sensors/leak detection

Luckily, these sensors can not only assist you in a predictive maintenance strategy, but they are also invaluable to reaching energy, sustainability, and governance (ESG) goals. If budget is an issue, collaborate with sustainability professionals in your organization. In addition, sensors are invaluable in validating issue resolution. For example, if a vibration sensor detects excessive noise or motion on a motor, the sensor will identify the issue, compare it to the baseline or asset specification, and notify you. And, the sensor will continuously check until the issue is resolved.

Ensuring data is usable

Up to this point, we've talked about the steps necessary to access the data from your various technologies within your building's ecosystem. But access isn't sufficient to implement a successful PdM program. As we mentioned previously in this white paper, in order for a PdM program to be functional, its imperative to overcome the data challenge. This means ensuring you are using a solution that aggregates and normalizes the various inconsistencies across different building systems and technology siloes within your buildings and portfolio. You'll need to ensure data is aggregated and normalized to a standard naming ontology, preferably one that utilizes Haystack, Brick Schema, or Google Digital Buildings Ontology. Additionally, the deployment of an Independent Data Layer (IDL) that provides access to the APIs that are often used by IoT devices. This is a much more comprehensive way of data ingestion. With an IDL, you have many options for analytic engines, user interfaces, and reporting tools.

Validating and reviewing your setup

Once data is normalized, analytics rules are applied. You will want to source a comprehensive solution that allows users to add specific rules as well as prioritization of alerts by urgency (low to high) and by type of impact (energy, comfort, operations, etc.)

Once implemented, you now know the data that is available from connected equipment. Use your analytics solution to evaluate this data. Is there something you're missing? This could be due to proprietary equipment, non-connected equipment, equipment failure, separate VLANs or something else. When validating your setup ask these questions:

- Am I seeing the data that I should be?
- Am I missing zones or spaces?

Once you've asked these questions, evaluate your goals, and address your hardware and infrastructure needs.

Next, review the analytic insights from your connected equipment. Determine if there are any exceptions and whether this changes your program. Use the insights to help guide your strategy for the improvement of infrastructure or operational programs.

Getting the most of your PdM program

Now that your PdM program is actively producing insights from your connected equipment consider integrating and automating those analytics into your CMMS, asset management, or work order systems. An additional benefit of PdM is the ability to provide contractors with advanced FDD such as precise equipment information, root cause of predicted issues, and verification of work completion.

Once your program is up and running, consider the impact it has to your existing workflows and align it to accommodate for the changes in your daily routine. Take time to assess your team's skill gaps and identify super users and promoters to help gain buy-in from your organization's stakeholders. The more buy-in you get, the more successful your program will be. Note, if you don't have a team that has the expertise or time to implement predictive maintenance on a daily basis, consider outsourcing to a third party that will provide services to monitor conditions, alert of priorities, provide a checklist for routine maintenance and remote support building automation system (BAS) issues at a minimum.

Setting expectations

A successful PdM program will most likely take months or years to fully implement but when done with these expectations in mind it will be best aligned with your resources, budget, and needs without overwhelming your already busy schedule. A methodical approach has many positive outcomes. Evaluating the current state and taking a phased approach ensures minimal disruption to your team and your budget. As opposed to traditionally executed projects that are built on often erroneous manual site assessments, wrong information, and wish lists of technologies that may or may not work for you, a phased program allows you to retrofit based on your current state. It ensures your program is built according to your goals in a systematic and specific manner. In the end, you will have a smart building and a comprehensive PdM program that meets your key performance indicators (KPIs) while avoiding the long delays and high contingency fees associated with traditional building retrofit projects.

Chapter 8: Predictive Maintenance Success Story

When implemented correctly, a predictive maintenance program can result in significant cost savings across a facility's maintenance operations. One example of such a success story comes to us from Melbourne Australia where a 20-year-old, 29-story office tower implemented a predictive maintenance strategy for its HVAC systems. The PdM strategy involved accessing data not previously used from complex assets such as chillers and vibration sensors.

Depending on the age and nature of the facility, a typical office tower may cost an average of $95,000 to $190,000 a year for routine maintenance and management, with another $50,000 to $120,000 incurred for repairs (including contractors and parts replacement). With the implementation of its predictive maintenance program, the Australian office tower has saved an estimated $17,000 in operating costs in addition to $32,000 in avoided repair costs. The project also reduced the building's energy costs by 11 percent.

By way of example, an anomalous reading detected malfunctioning bearings within the building's systems before failure occurred. Instead of costing the facility anywhere from $40,000 to $50,000 and approximately two weeks of downtime due to equipment failure, predictive maintenance enabled the building's engineering team to address the issue at a mere $6,000 replacement costs while simultaneously preventing disruption in performance.

Chapter 9: Conclusion

Predictive maintenance (PdM) is an exciting addition to the facility maintenance landscape. By leveraging the vast amount of data produced by buildings and their environments, users of PdM solutions can optimize maintenance and equipment performance with increasing accuracy.

While PdM is an attractive option for optimizing maintenance, adoption does require astute attention to the planning process to ensure proper setup for your PdM programs. It's important to partner with a master system integrator (MSI) to ensure your building is ready for a digital solution. This includes addressing several challenges in PdM implementation. Finally, once your PdM program is up and running, ensure you're getting the most out of the system. Leverage analytics and advanced FDD to gain buy-in and to showcase success of the program to stakeholders. When done correctly, successful PdM programs can result in significant savings and efficiencies across portfolios.

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