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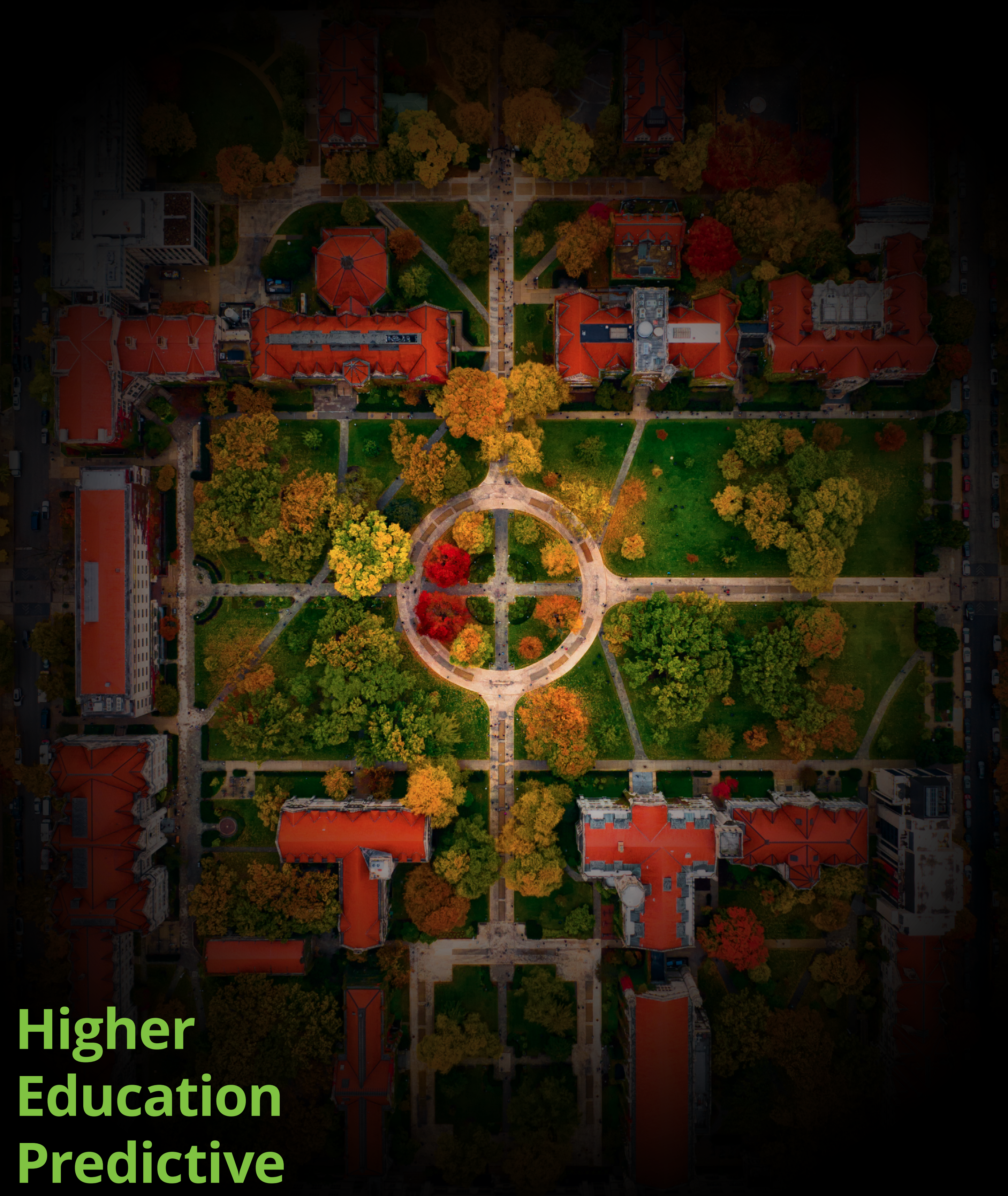


Higher Education Predictive Maintenance (PdM)

Introduction

Higher Education institutions are facing a growing facility maintenance backlog with many campuses grappling with aging infrastructure and equipment across their campuses. Campus facilities across the country are aging, with as many as 75% of facilities being 30-40 years old.[1] This aging infrastructure leads to increased maintenance and energy costs, inefficiencies, and a higher carbon footprint. The Association of Physical Plant Administrators (APPA) estimates that the deferred maintenance backlog at domestic higher education institutions is approximately $112 billion.[2] In 2024, the deferred capital renewal costs, pulled from a data base of over 43,000 higher education campuses, "have risen to over $140 per gross square foot (gsf)" with a "a larger jump from just under $125/gsf in 2022".[3] Funding for higher education has decreased over the years[4] and institutions remain under sustained budget pressures, contributing to the growing backlog of deferred maintenance. This mounting backlog not only undermines the physical condition and safety of facilities but also diminishes the overall student experience – impacting retention, learning environments, and institutional reputation. With limited or constrained funding for modernization, many universities are forced to delay necessary upgrades or repairs, compounding costs over time and placing critical facilities at risk of failure.

1 "The real cost of deferred maintenance," [Online]. Available: https://www.centricabusinesssolutions.com/us/blogpost/real-cost-deferred-maintenance

2 "Campus Energy P3s—Fueling Infrastructure Improvements and Carbon Reduction Goals," October 2024. [Online]. Available: https://www.appa.org/facilities-manager/september-october-2024/campus-energy-p3s-fueling-infrastructure-improvements-and-carbon-reduction-goals/#:~:text=The%20estimated%20deferred%20maintenance%20backlog,sustainability%20and%20renewable%20energy%20goals.

3 "The State of Facilities in Higher Education, 12th Ed," April 2025. [Online]. Available: https://www.gordian.com/uploads/2025/04/2025-State-of-Facilities-Report.20250331220235713.pdf

The current state of facility asset management relies upon infrequent inspections leading to fix-at-failure and scheduled maintenance strategies. In response to escalating challenges of deferred maintenance, organizations across the industry are looking into more technologically advanced maintenance strategies to shift from reactive or preventive facility management to using data to drive their maintenance strategy. Recently, 53% of surveyed institutions indicated that they are exploring Artificial Intelligence (AI) driven applications to assist with facility management, and 11% of institutions have already actively implemented these technologies.[4] This reflects a growing interest in leveraging technology to enhance operational efficiency and address infrastructure needs.

As institutions move towards adopting AI-driven solutions, it's important to recognize that not all assets are uniformly weighted in their criticality. An "asset", in the context of facility management, refers to anything owned that has a monetary value, e.g., real property.[5] However, to truly revolutionize facility management and address the burgeoning maintenance backlog, higher education institutions should embrace a maintenance cadence that is predictive rather than reactive. Predictive maintenance (PdM) leverages advanced data analytics, machine learning, & internet of things (IoT) technologies to predict equipment failures before they occur, allowing for proactive maintenance actions. This approach can not only reduce unexpected equipment downtime and extends asset lifetime but it can also enhance maintenance schedules, reducing overall maintenance cost.

> "Funding for higher education has decreased over the years and institutions remain under sustained budget pressures, contributing to the growing backlog of deferred maintenance."

4 https://digitalcommons.umassglobal.edu/cgi/viewcontent.cgi?article=1175&context=edd_dissertations

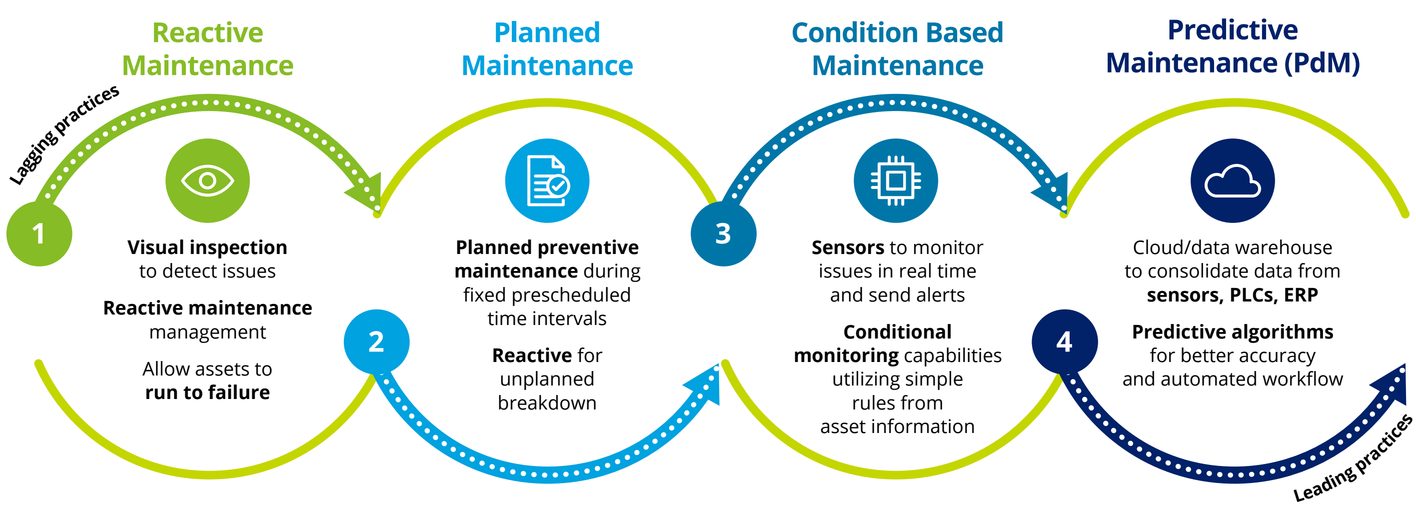
5 "10S-90 Cost Engineering Terminology," 7 December 2023. [Online]. Available: https://web.aacei.org/docs/default-source/rps/10s-90.pdf.

Determining the Appropriate Maintenance Strategy

Selecting a maintenance strategy is essential for maximizing operational efficiency, especially as institutions face increasing capital investment deferrals and mounting challenges in maintaining assets and prioritizing future investments. While maintenance strategies are not one-size-fits-all, organizations that are transitioning towards PdM are well positioned to successfully identify anomalies or patterns indicative of potential asset failure, allowing maintenance to be performed before an emergency shutdown occurs. A well-defined maintenance strategy, especially one driven by data, allows organizations to understand the real-time health of their assets and make informed decisions.

For effective facility management, it is essential to identify a maintenance strategy for different assets based on several factors such as how critical the asset's continued function is, how long it takes to get replacement parts, and how expensive it is to replace. Most maintenance programs implement one of four primary maintenance strategies, each of which is outlined in Figure 1:

Figure 1: Primary Maintenance Strategies



What is Predictive Maintenance?

PdM is a maintenance strategy that involves ongoing or periodic monitoring and diagnosis of systems and equipment to anticipate asset failure. Unlike Condition-Based Maintenance (CbM), which triggers maintenance based on deviations from normal parameters, PdM elevates monitoring and leverages IoT sensor data and AI modeling to develop a predictive, data-driven approach. The integration of AI-driven analysis on data captured from IoT sensors provides asset owners with insights into their assets' current state to help enable the prediction of potential equipment failures. By effectively harnessing AI and IoT sensor technology, organizations may create effective maintenance schedules that efficiently allocate resources leading to a strategic emphasis on directing resources towards high risk and mission-critical assets, reducing unexpected breakdowns, minimizing downtime, and preventing unnecessary spending with lagging scheduled maintenance practices.

Potential benefits of Predictive Maintenance

As illustrated in Figure #2, a study[6] by the US Department of Energy shows that companies implementing a functional PdM program typically achieved the following results:

Figure 2: Benefits

Benefits [6]
10 times return on investment
20-25% increase in production
30-40% overall savings opportunities
35-45% reduction in downtime
70-75% elimination of breakdowns
25-30% reduction in maintenance costs

Furthermore, integrating AI and IoT sensors into an institution's asset management program can significantly enhance maintenance scheduling efficiency, which can lead to a reduction in planning time by 20 to 50 percent.[7]

Beyond the potential quantitative benefits outlined above, a well-developed asset management strategy may provide additional advantages for higher education environments. These additional benefits are presented in Table 1.

While the potential benefits of PdM are substantial, it is important to acknowledge that not all institutions will be adequately equipped to effectively leverage PdM. Factors such as an institution's technological maturity, data infrastructure, and workforce skills may influence its readiness to implement and realize the full potential of PdM. Recognizing these hurdles, a structured approach to implementation is essential for success.

6 Operations & Maintenance Best Practices," August 2010. [Online]. Available: https://www.energy.gov/femp/articles/operations-and-maintenance-best-practices-guide-achieving-operational-efficiency

7 Making Maintenance Smarter: Predictive Maintenance and the Digital Supply Network," May 2017. [Online]. Available: https://www2.deloitte.com/us/en/insights/focus/industry-4-0/using-predictive-technologies-for-asset-maintenance.html

Table 1: Potential Benefits to Deploying PdM Solutions

Potential Benefit(s)	Description
Reputation	Consistently building asset reliability through PdM not only reduces downtime but also establishes a reputation for reliability, earning the trust of stakeholders. This positive perception enhances the institution's standing and reinforces its commitment to delivering the highest quality educational experience to students.
Education Opportunity	Utilizing IoT to collect data on equipment operations provides students with greater insights into how disciplines such as mechanical, electrical, and industrial engineering may be applied in practical settings. Additionally, developing predictive models requires knowledge in data analytics, computer science, and system architecture, broadening its applicability to other courses.
Optimized Resource Allocation	PdM optimizes the allocation of resources and spending by prioritizing critical assets. This promotes a more precise focus on maintenance efforts, enhancing operational efficiency and minimizing unnecessary costs.
Increased Asset Performance	AI and IoT sensors enable real-time data analysis and trend identification to enhance asset performance for greater reliability and lifespan. These technologies work together to identify root causes of failures, enabling targeted insights and fostering a culture of continuous improvement, ultimately enhancing system reliability.
Cost Savings	A well-structured maintenance schedule, guided by AI and informed by IoT data, supports prioritization and effective spending on critical assets. This integration results in reduced downtime, streamlined resource allocation, and minimized breakdowns, leading to tangible cost savings.
Increased Infrastructure Reliability and Lifespan	AI and IoT sensors work together to help maintain ongoing health and lifespan of critical infrastructure. The early detection capabilities reduce equipment downtime, allowing organizations to concentrate on value-added activities, contributing to increased operational efficiency.
Scalability & Adaptability	AI and IoT solutions, known for scalability and adaptability, allow institutions to accommodate a growing number of assets and adjust to evolving requirements. This flexibility facilitates long-term relevance.
Change Management	PdM enables better change management by predicting potential equipment failures, allowing organizations to proactively schedule maintenance and manage operational changes. This reduces disruptions during equipment upgrades or replacements, facilitating smoother transitions and minimizing impacts on classes, campus events, and other facility uses.

Deloitte's Approach

Deloitte has developed a three-phased approach to facilitate an effective transition to PdM, specifically tailored to help institutions advance their asset management program towards a more predictive state. This approach can be delivered as a full-scale package or segmented into individual steps. The PdM Gap Analysis is critical in understanding and evaluating the current data and technology infrastructure and organizational state. The PdM Gap Analysis will lay the groundwork for subsequent phases, which focus on data collection, data management, data processing, and data analytics. The three-phased approach is outlined in Figure #3 below.

Figure 3: Three-Phased Approach

1	**PdM Gap Analysis**
1.1	Evaluate Current Asset Management Processes
1.2	Assess Current Technology Infrastructure
1.3	Develop PdM Implementation Strategy and Pilot Program
2	**Sensor Strategy and Data Collection Architecture**
2.1	Build Cloud Architecture
2.2	Create Data Pipeline
3	**Predictive Analytics and Scaling**
3.1	Establish Predictive Models
3.2	Integrate Model and Train
3.3	Scaled Implementation & Execution

1. PdM Gap Analysis: This initial phase assesses current state processes, data, and technology, and designs a roadmap with use cases for predictive maintenance. The PdM Gap Analysis provides clients with the framework for an effective PdM adoption.

- 1.1 Evaluate Current Asset Management Processes - Assess the current processes to align strategic goals and objectives in moving towards a more sophisticated asset management approach.
- 1.2 Assess Current Technology Infrastructure - Assess technology infrastructure and identify critical assets to determine data readiness for implementing PdM.
- 1.3 Develop PdM Implementation Strategy and Pilot Program - Develop a strategic PdM implementation plan, which details the tasks and responsibilities for the remaining phases.

2. Sensor Strategy and Data Collection Architecture: This phase involves developing a sensor strategy architecture, installing sensors (if needed), generating cloud architecture, exporting data from sensors to ingestion, and performing data cleansing and exportation to a database.

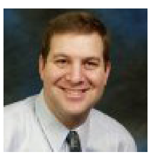
- 2.1 Build Cloud Architecture - Validate data availability and create a centralized repository with a data structure that reduces redundancy while housing the necessary data values.
- 2.2 Create Data Pipeline - Determine the procedure to Extract from the sources and sensors (if applicable), Transform and clean it as necessary, and Load it into the data repository.

3. Predictive Analytics and Scaling: This final phase includes dashboarding of PdM analytics from models, integrating PdM into the asset management workflow, scaling PdM across the portfolio, data modeling using AI/ML, and insight-driven capital planning.

- 3.1 Establish Predictive Models - Adapt previously created models to train, test, and refine AI-driven predictive models to forecast future asset failures.
- 3.2 Integrate Model and Train - Determine the procedure to Extract from the sources and sensors (if applicable), Transform and clean it as necessary, and Load it into the data repository.
- 3.3 Scale Implementation and Execution - Leverage the results of the pilot integration to scale across the organization, while continuing to maintain and refine existing models based on feedback.

The majority of activities involved in delivering our comprehensive PdM approach are designed to have minimal impact on the day-to-day operations of campus facilities while simultaneously providing significant, long-term benefits for their critical infrastructure. Recognizing these benefits, taking steps towards implementing PdM becomes a strategic investment that not only improves operational efficiency and reduces costs but also promotes the longevity and reliability of critical infrastructure. By adopting and integrating PdM, higher education institutions can proactively address maintenance challenges, fostering a safer, more sustainable, reputable campus environment.

Contacts



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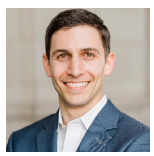

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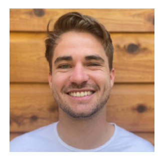

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