

Operationalizing
Predictive Maintenance
The Five Essential
Ingredients for Success



Predictive maintenance is considered the leading use case for digital transformation enabled by the industrial Internet of Things (IIoT). Predictive maintenance can cut maintenance planning time by 20-50%, increase equipment uptime by 10-20%¹ and, by conservative estimates, reduce maintenance costs by 12-18%². That's huge: unplanned downtime costs industrial manufacturers an estimated \$50 billion annually—and equipment failure is behind 42% of this unplanned downtime³. Manufacturers are voting with their budgets: the predictive maintenance market is expected to grow from US\$1.4 billion in 2016 to \$4.9 billion by 2021, a compound annual growth rate of 28.4%⁴.

But the reality has fallen far short of expectations. The key challenge has been operationalizing predictive maintenance—that is, translating the exotic realm of data science algorithms to the messy real world. The fact is, operationalizing predictive maintenance takes much more than connecting your assets to an IIoT platform, streaming in data and analyzing the data the assets produce. Achieving real business results requires attention to the entire solution lifecycle—from concept to implementation to measuring business outcomes. Think of predictive maintenance as a team sport that requires collaboration from your maintenance, production, quality, inventory, human capital and customer service departments.

Delivering on the promise of predictive maintenance requires a blend of expertise from multiple disciplines. You need expertise in each discipline—and collaboration among the experts in each area to drive success.

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¹Infor, 2018

²Mintel, "42 ROI Statistics"

³IndustryWeek in collaboration with Emerson, How Manufacturers Achieve Top Quartile Performance

⁴MarketsandMarkets Research, 2018

Operational Consulting: Building the Business Case

Failing to identify the right business drivers for a predictive maintenance program can send you down the path to failure from the start. Therefore, begin with a deep dive into key maintenance metrics and value drivers including:

- Specific KPIs you want to impact and measurable targets for each of them. Important KPIs for predictive maintenance including Overall Equipment Effectiveness (OEE), Mean Time to Repair (MTTR), Mean Time Before Failure (MTBF), On-Time, In Full (OTIF) and Maintenance Effectiveness.
- Comprehensive assessment of Failure Modes, Effects and Criticality Analysis (FMECA) and calculation of Risk Priority Number (RPN) scores. This requires intensive asset class level know-how, domain expertise and analysis of past maintenance records to identify key value drivers for each class.
- Asset class identification, as shown in Table 1.

A common mistake in predictive maintenance programs is to paint everything with the same brush—that is, use the same maintenance strategy for all asset classes. To avoid this mistake, develop a separate predictive maintenance cost and benefit analysis for each asset class and calculate the ROI for the business case. The numbers might point to reliability-centered maintenance (RCM) for high-value assets with high production impact, and reactive maintenance for certain non-critical assets. Gartner places maintenance strategies on a continuum: reactive, time-based, usage-based, condition-based, predictive forecasting, RCM and financially optimized.⁵

Criticality Class	% of assets (typical)	Assessment criteria for determining the significance of an asset						Maintenance Strategy
		Impact on Production (OEE)	Redundancy	Utilization	Defect & Failure True Cost (DAFT)	Age of asset (in terms of bathtub curve)	Risk Priority Number (RPN)	
Cat 4 (Critical)	5%	Very High MTTR is > 3 shifts	Low No spare available	Very High >85%	Very High	Between late "Useful Life" to "Worn Out" stage	>300	<ul style="list-style-type: none"> • Continuous monitoring • Multiple monitoring techniques • Predictive & Prescriptive maintenance
Cat 3 (High)	10-20%	High/Medium MTTR is between 1-3 shifts	Low No spare available	Medium 85%-60%	Medium	Late "Useful life"	200-300	<ul style="list-style-type: none"> • Continuous/periodic monitoring • 1-2 monitoring techniques • Predictive maintenance
Cat 2 (Medium)	30-60%	Medium/Low MTTR is equal to 1 shift	Medium/Low Spare available but takes 1 shift to replace	Medium/Low 60%-50%	Low	In "Useful Life"	100-200	<ul style="list-style-type: none"> • Periodic monitoring • 1-2 monitoring techniques • Preventive maintenance
Cat 1 (Low)	30-60%	Low MTTR is <1 shift	High Spare available and takes <1 shift to replace	Low <50%	Low	Early "Useful Life"	<100	<ul style="list-style-type: none"> • No monitoring required • Scheduled maintenance

Table 1. Match the maintenance strategy to the asset class and criticality

⁵Gartner, Mapping a Route to Asset Management and Reliability, May 11, 2017

Operational Technology Expertise

Operational technology (OT) may not sound as exciting as data science but it's just as vital to successful predictive maintenance programs (Figure 1). That's why the experience of senior maintenance workers is highly prized—and why the aging workforce poses such a big challenge worldwide.

You need several types of OT expertise:

- Anatomy and instrumentation of all asset classes. Someone on the team needs to understand the impact of asset failures on cost, throughput and quality; the frequency of such failures; and the feasibility of detecting various failure types.
- How assets fail and what type of sensor data can pre-empt that failure (Table 2). This requires familiarity with the physics of each asset and its components. For example, vibration monitoring is useful for detecting some problems, but not loose electrical connections. Don't fall victim to the "If I have a hammer, every problem looks like a nail" syndrome.
- The asset's operating context, such as ambient conditions, operational environment, operational mode and usage. Effective algorithms consider context as well as sensor data.

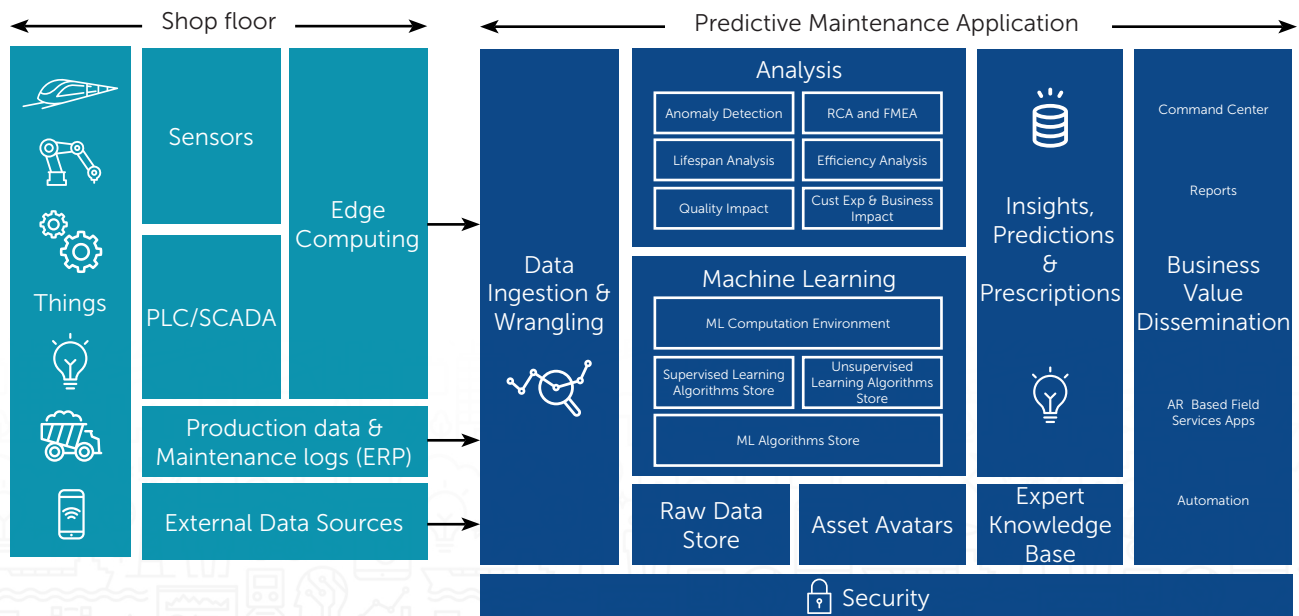


Figure 1. Predictive Maintenance requires OT expertise (at left) as well as data science expertise (at right)

Sensor Type	Failure Modes Detected
Vibration	<ul style="list-style-type: none"> Bearing wear and tear Over or under lubrication Shaft and coupling misalignment Bent rotor Broken rotor bar Loose foundation
Oil and lubricant analysis	<ul style="list-style-type: none"> Engine wear analysis Oil/lubricant contamination Remaining useful life of oil/lubricant Current oil viscosity Dissolved gases Sludge content
Ultrasound	<ul style="list-style-type: none"> Leakage detection Bearing friction and foreign particle detection Pump cavitation Worn out, dirty and leaky valves Structural faults, equipment housing cracks
Current signature	<ul style="list-style-type: none"> Static or dynamic air gap irregularities Broken rotor bar or cracked rotor end-rings Stator faults
Thermal	<ul style="list-style-type: none"> Bearing heating Coupling heating Rotor/stator heating Impeller heating Fan heating

Table 2. Matching the Sensor to the Task

Cross-Functional Change Management

Predictive maintenance is not an island unto itself. It links with production, inventory management, quality and customer service functions. A well thought out predictive maintenance program can significantly reduce quality issues, improve production-scheduling accuracy, reduce on-hand spare parts requirements and enhance employee safety.

Integrating a predictive maintenance program with all of these business functions requires effective change management. Every department that is affected by predictive maintenance needs an answer to “What’s in it for me?” For example, the operations team can benefit by learning the ideal operating envelope for maximizing throughput. The quality team can reduce defects caused when equipment operates under sub-optimal conditions. The customer service organization can reduce truck rolls for repairs and will be more eager to cooperate if shown the cost savings.

Predictive maintenance initiatives often end up with an undeserved bad rap for not delivering outcomes for certain functions—when the actual problem is that the outcomes have not been measured and widely communicated. Be sure to take baseline measurements of KPIs, measure them regularly and share the results throughout the enterprise.



4 Data Science Expertise

Creating predictive models and proving their accuracy may get most of the attention in the predictive maintenance world—but it's not the end game. The real value of predictive maintenance emerges once you've deployed the models into production, integrated them with the core business applications, and closed the loop from analysis and insight to action.

Applying data science to predictive maintenance also requires a leap of faith. The industry is accustomed to managing the maintenance function based on experience—and data science insights can at times seem counter-intuitive. This will become less of an issue when explainable AI emerges, where machine-learning systems can explain their rationale for the recommendations they provide.

A comprehensive approach to automated data curation and model governance, including model build and subsequent deployment, model management, etc. goes a long way towards operationalizing predictive maintenance. It is also imperative to avoid model fatigue by periodically refreshing models to make sure they reflect feedback and new contextual information.

5 Content Partner Ecosystem

Predictive maintenance requires specialized expertise across sensors, PLCs, gateways, IoT platforms, data science and more. A “go-it-alone” approach rarely works because the space is evolving too fast for one organization to keep pace. Examples of innovations that require specialized expertise include the application of artificial intelligence to predictive maintenance⁶, computer vision, augmented reality applications and self-healing machines.

Predictive maintenance will continue to evolve rapidly, and manufacturing leaders have begun piloting emerging technologies on an experimental basis to select the ones that produce the best outcomes. Partners are essential—those with complementary ecosystems can also provide platform neutrality and avoid vendor lock-in. They can also build solutions that leverage customers' existing technology investments, address their specific operating context and pull together diverse technologies to achieve business goals.

Take a Holistic Approach to Predictive Maintenance

Operationalizing predictive maintenance requires as much attention to people and process as to technology and analytics. An exclusive focus on one area at the expense of another can be a sure-shot recipe for failure. Success requires a blend of skills—across operational consulting, OT and IT, change management and data science.

When embarking on your predictive maintenance journey, realistically assess your in-house competency in the five capabilities outlined in this paper, and then identify the gaps where you'll need external support. Successful predictive maintenance programs require careful orchestration of these five capabilities, a meticulous approach and a focus on business outcomes. Therefore, be sure to engage with partners with the right blend of expertise—and the passion to go the distance, from concept through measuring business outcomes.

⁶One analyst estimates that applying AI to predictive maintenance in the auto business will increase productivity by up to 20% and lower maintenance costs by more than 10%.

Author



Rajesh Devnani

Vice President
Global Solutions Management
Hitachi Consulting
moreinfo@hitachiconsulting.com

Rajesh heads the Global Solutions Management function and is the Global Lead for the Hitachi Predictive Maintenance solution at Hitachi Consulting. He focuses on creating differentiated world-class solutions leveraging the best capabilities of Hitachi across digital technologies. Under his leadership, Hitachi Consulting has developed unique, market-facing solutions addressing key digital transformation opportunities.

Rajesh's background includes two decades of manufacturing industry experience across ERP programs, business consulting and IoT/analytics-led digital transformation engagements. He holds a Bachelor of Electrical Engineering degree and an MBA in Marketing and Finance. He also holds multiple professional certifications including CSCP and SAP certifications. Rajesh speaks at multiple industry and professional forums and authors blogs on various technology topics.

About Hitachi Consulting

Hitachi Consulting is the global solutions and professional services organization within Hitachi Ltd., a global innovation leader in industrial and information technology solutions and an early pioneer of the Internet of Things. Hitachi Consulting is a business integrator for the IoT era and a catalyst for digital transformation. Using our deep domain knowledge, we collaborate with clients to help them innovate faster, maximize operational efficiency and realize measurable, sustainable business and societal value. As a consulting-led solutions company, we can help you leverage data as a strategic asset to drive competitive differentiation, customer loyalty and growth.