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Using Predictive Maintenance of Industrial Assets: Your Starting Point to the Digital Manufacturing Journey

People matter, results count.

Contents

Abstract

Digital Manufacturing, or Industry 4.0, is changing manufacturing through exponential levels of information and connectivity. Business models are evolving, driven by the advent of smart manufacturing and operations.

Systems and networks are capable of independently exchanging and responding to information in order to manage industrial production processes. In the heat of becoming industry leaders, organizations are competing to figure out the right strategy for adopting technologies that collectively define digital manufacturing. Companies are cognizant of the benefits that these technologies can deliver to an organization, but are often naive when it comes to the adoption and implementation of such technologies.

Digital manufacturing focuses on achieving the promised benefits of the end-to-end digitization of all physical assets, as well as integration into the digital ecosystem with value chain partners. There is no “big bang” approach for organizations to begin their digital transformation journey. The proven model involves assessing an organization’s readiness in categories such as technology, infrastructure, people, and culture and then selecting a key business case with which to start.

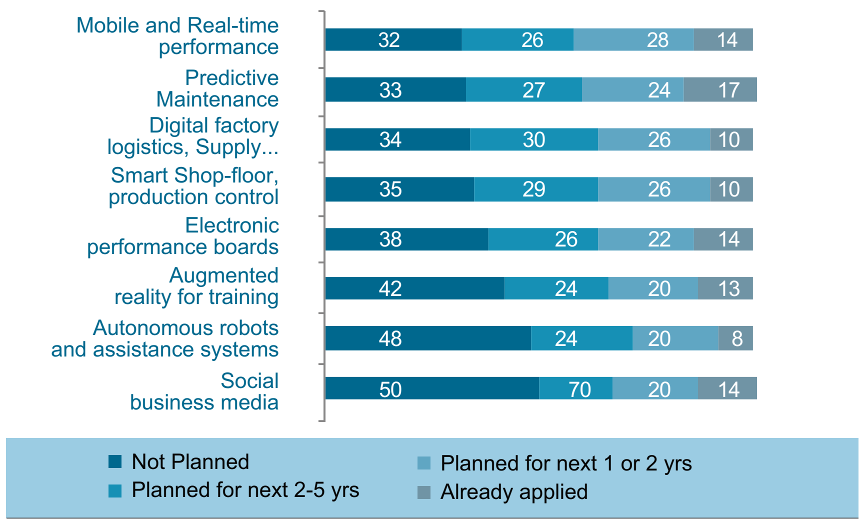
This whitepaper highlights why predictive maintenance should be considered the key business case as a start point for digital transformation, how the predictive maintenance technique works, and how an organization should systematically approach designing a predictive maintenance solution.

1 Introduction

1.1. Digital Manufacturing—Manufacturing organizations understand the benefits, but struggle to deliver them

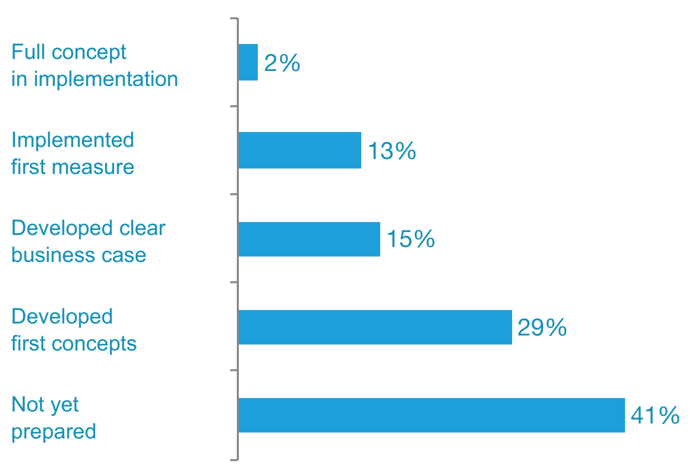
Digital Manufacturing, or the digital revolution in manufacturing, has enabled systems and networks to independently exchange and respond to information, ensuring seamless process flows. It focuses on the end-to-end digitization of all physical assets and integration into the digital ecosystem with value chain partners. Manufacturing organizations, which are under mounting pressure to improve productivity and be agile in the face of shifting customer needs, are aware of the transformational impact that digital manufacturing technologies can bring across functional areas (such as smart supply network, predictive maintenance, big data-driven quality control, additive manufacturing and so on). According to a BCG analysis report, a combination of Digital Manufacturing technologies could help reduce production costs (excluding raw materials) by **20 to 40 percent.**[1]

US Manufacturing Companies – Industry 4.0 Plans



Manufacturing organizations, though aware of the benefits that digital manufacturing technologies can deliver, struggle to effectively adopt and implement digital technologies. According to that same BCG study, almost half of the organizations in the U.S. are not yet prepared for the arrival of new technologies for digital manufacturing. From a manufacturing perspective, less than 40% of U.S. manufacturers have either applied or planned to apply new technologies.

Readiness to Implement - US Companies



Source: BCG Survey, 2016

2 Organization approaches for enterprise-level digital manufacturing adoption

For asset intensive organizations, the journey to digital manufacturing begins by selecting a key business case, conceptualizing it, running a pilot, analyzing results and adapting the model's goal to scale. The assessment of expected financial and non-financial benefits can help organizations to select the priority use case for implementation. Typical steps an organization should follow to embark their digital journey are outlined below (Figure 1):

Figure1

Conceptualize	Pilot	Scale	Manage
• Select Business Case • Define Roadmap • Assess Infrastructure needs • Identify risks and mitigations	• Business case validation • POC development • Analyze results for business case justification	• Enterprise Architecture design • Systems integration • Solution implementation and roll out	• Identify possible extensible case • Broad base expertise • Refine business model

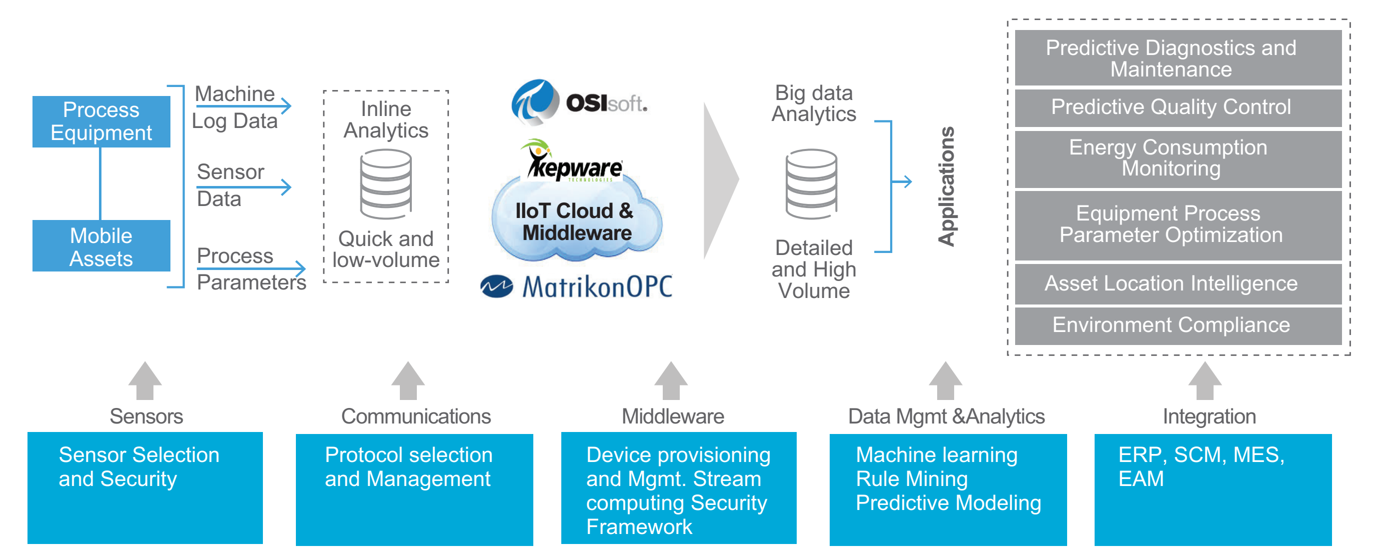
Such an approach typically begins by evaluating the technological capabilities of an organization. The reference architecture provided below helps organizations to realize the necessary technology requirements for digital adoption.

2.1. Technology—Evaluate your technology readiness for digital manufacturing

The architecture (Figure 2) provides organizations with the typical technology landscape involved in adopting digital manufacturing technologies. Equipment and machine data is captured using various sensors (sensor selection is based on the equipment type), and securely communicated through the middleware, which collects, aggregates, and provides secure access for industrial data. The collected and stored equipment data is analyzed using suitable rule engines and analytical models built for applications such as predictive diagnostics and maintenance, equipment process parameter optimization, and predictive quality control.

Organizations should focus on suitable sensor selection, communication protocol selection, appropriate middleware selection, analytical model selection, comprehensive security framework design, and integration with other existing systems. *All such platforms exist to provide useful insights that affect productivity and quality.*

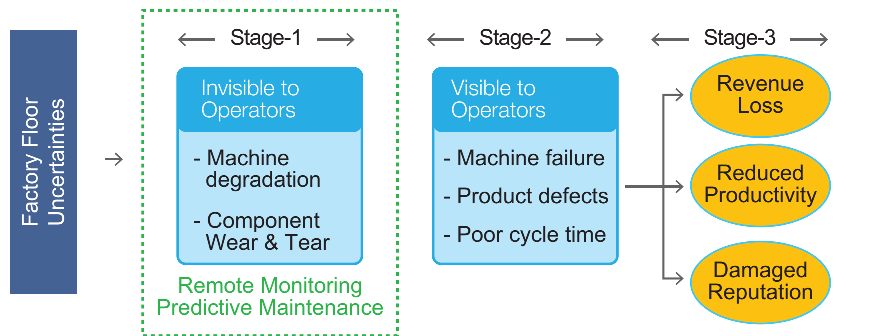
Figure 2



3 Predictive maintenance – The case for success

For asset-intensive companies such as metals and paper mills, mines, and chemicals plants, predictive maintenance often represents the highest value area. Predictive maintenance addresses key business challenges on the factory floor—unplanned machine breakdown or a lack of asset visibility—and delivers the highest returns. The predictive maintenance case, upon successful implementation, creates substantial infrastructure and expertise for widening the digital footprint across the organization.

Figure 3



3.1. Why predictive maintenance?—Challenges faced on the factory floor

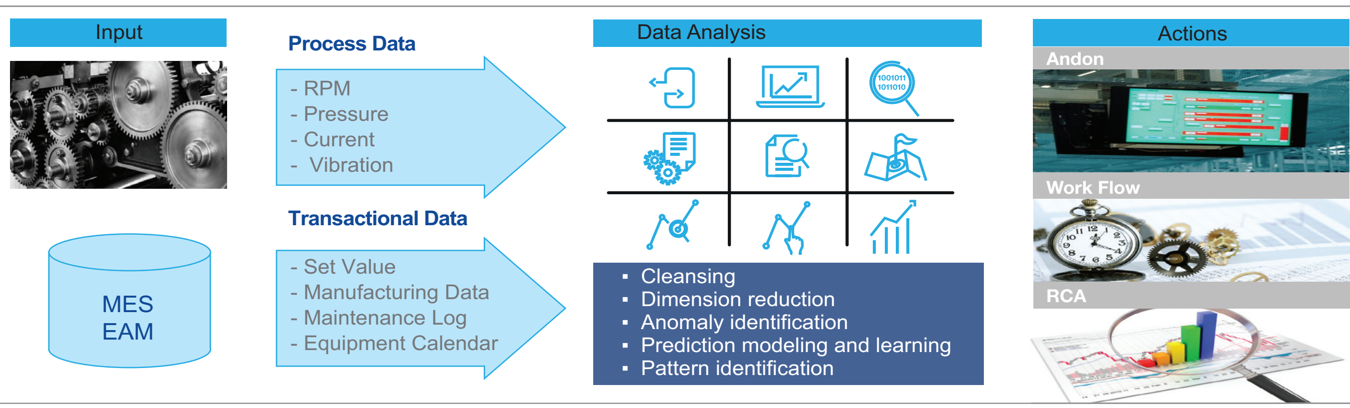
The major challenge faced on the factory floor is the breakdown of equipment that occurs due to machine degradation, component wear, and other factors invisible to operators. These machine breakdowns have direct implications on the organization's finances, productivity, and reputation. Other challenges include a difficulty in manual monitoring of equipment health, a lack of asset visibility, and a lack of standardization in efficient maintenance planning processes.

Such unpredicted machine failures can be avoided at stage-1 (Figure 3) by adopting advanced maintenance techniques that systematically process the continuously generated equipment data.This provides insight into the operational condition of the equipment, thereby allowing maintenance supervisors and process supervisors to make more informed decisions.

3.2. How does predictive maintenance work?

The predictive maintenance approach helps to monitor and assess equipment health based on the analysis of various parameters, including temperature, pressure, vibration, RPM, and flow rate. Various data processing systems capture this data using sources like OPC, Historian, and SQL. They then perform data analysis, where the streamed equipment data is compared with pre-identified failure patterns, captured and stored using historical data. Machine learning processes enable the system to analyze and store machine failure patterns that iteratively learn from data, allowing systems to find hidden signs without any explicit conditions. A match in the streamed equipment data with pre-identified failure patterns triggers alarms and notifications indicating a deterioration of machine health and the potential for equipment failure.

Figure 4



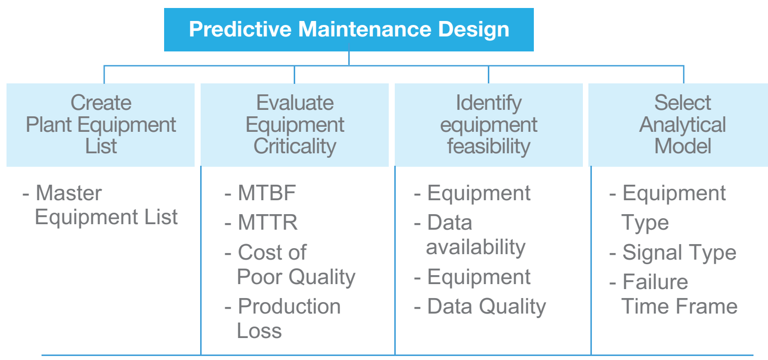
3.3. How to approach predictive maintenance design

The predictive maintenance approach varies across industries and largely depends on the types of industry-specific machines and equipment in use. A structured process for organizations to design the predictive maintenance strategy is detailed below.

3.3.1. Create list of plant equipment

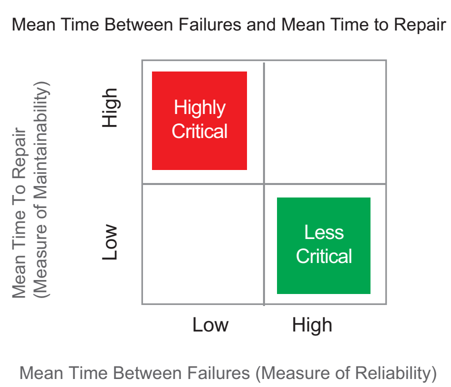
It is essential to have a master list of all the equipment on the plant floor so as to ascertain which machines require continuous monitoring for seamless operations. The equipment list needs to be reviewed for completeness to ensure no critical equipment is ignored.

Figure 5

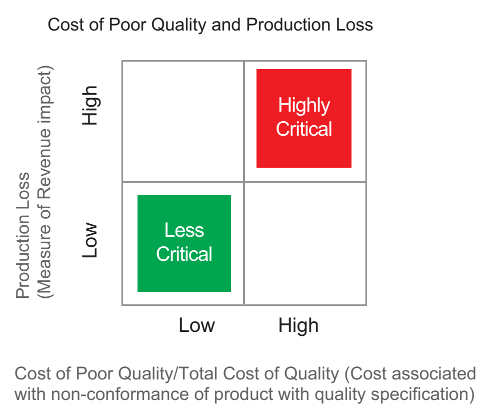


3.3.2. Evaluate equipment criticality

Once the equipment list has been created, the next step is to evaluate just how indispensible the equipment is with respect to overall operations and maintainability. There are various factors that influence the equipment criticality evaluation and a few critical factors are shown in the graphs below. All factors should be considered collectively when evaluating criticality.



Graph 1



Graph 2

3.3.3. Identify the equipment that is feasible for monitoring

Having arrived at the critical equipment list, the next step is to identify if the equipment is feasible to be monitored. Monitoring equipment with high criticality will be of less gain if the equipment doesn't produce reliable or quality data or the equipment is not compatible to be retrofitted with required data sources. A few critical factors that should be analyzed when determining the equipment feasibility for monitoring are detailed below.

- **Availability of equipment data**
  - The key factor that decides if the equipment is feasible to be monitored is the availability of equipment data. Either historical equipment data should be available, or the equipment should have the ability to stream data in order to derive insights for monitoring. The extracted data should have the following characteristics:
  - **Reliability:** the ability to produce stable and consistent result over subsequent iterations
  - **Resolution: the accuracy with which the gathered data can depict the exact health of the equipment**
  - **Networking:** the ability to collect data from equipment and share it with other sources for analysis

- **Possibility of retrofitting equipment with required data sources**

If there is no default mechanism to capture required data from the equipment, it is essential to retrofit the equipment with external data sources. The following factors need to be considered to evaluate the feasibility of retrofitting equipment with data sources:

  - Compliance and regulation complications
  - Cost to retrofit external data source
  - Technology compatibility

3.3.4. Selecting the appropriate analytical model

Once the critical equipment identified is feasible for remote monitoring and implementing preventive maintenance techniques, the next key step is to select an appropriate analytical model. The selection of the analytical model depends on the type of equipment, failure mode and cause, and the signal type and failure time frame.

- **Equipment and Signal Type**

Defining an analytical model largely depends on the type of equipment, failure mode and cause, and the signal type generated or captured. Capgemini's analytical model framework is shown below (Figure 6).

- **Failure Time Frame**

Another key factor to be considered while selecting an analytical model is the time frame between the occurrence of a symptom and the actual failure. Certain equipment tends to fail quickly; these require highly agile analytical models for monitoring.

Upon the selection of the appropriate analytical model for monitoring critical equipment, the next challenge lies in the predictive solution implementation.

Figure 6

Equipment Category	Equipment Types	Failure Mode	Failure Cause	Signal Type	Signal Captured	Statistical Model	Visualization
Rotating Machinery	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Reciprocating Machinery	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Thermal Equipment	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Repetitive Process Machinery	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Containment & Transfer Equipment	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

4 Business benefits

The key benefits that Predictive Maintenance approach brings to the organization are categorized as strategic benefits and operational benefits as shown below [3 4].

- **Strategic Benefits**

Revenue

Improved Yield due to increased equipment uptime

Operating Margin

Improved margin due to reduced maintenance cost

Asset Efficiency

Enhanced Efficiency due to increased equipment uptime

Market Position

High reputation due to perfect order fulfillment

- **Operational Benefits**

Maintenance cost reduction by upto **25%**

Breakdown elimination upto **70%**

Downtime reduction by upto **50%**

Scheduled repairs reduction by upto **12%**

89% Overall Equipment Effectiveness (OEE) for Best-in-class Organizations [5].

About the Authors

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