POV

Active Condition Monitoring for **Accurate Predictive Maintenance**

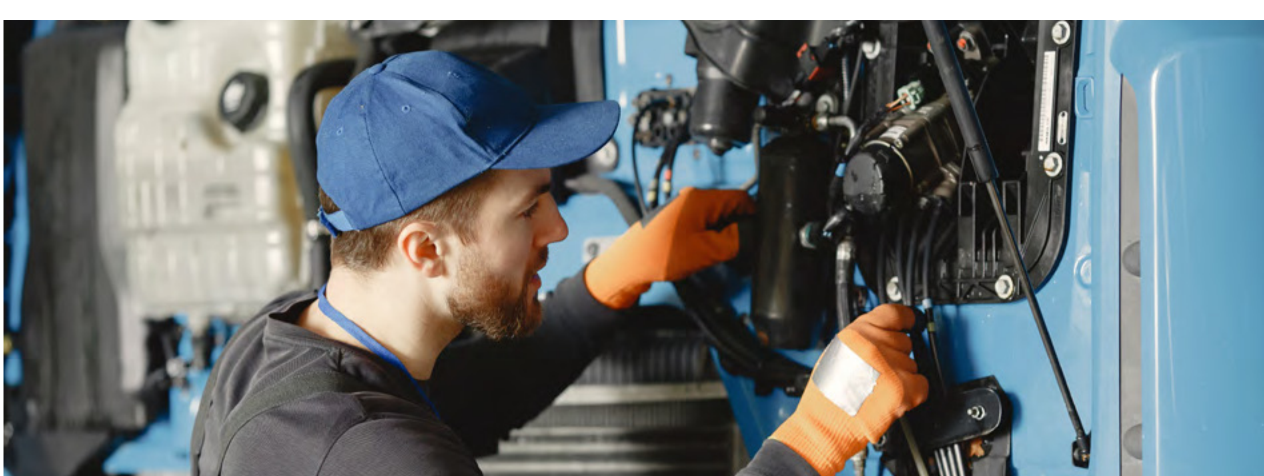
Executive Summary

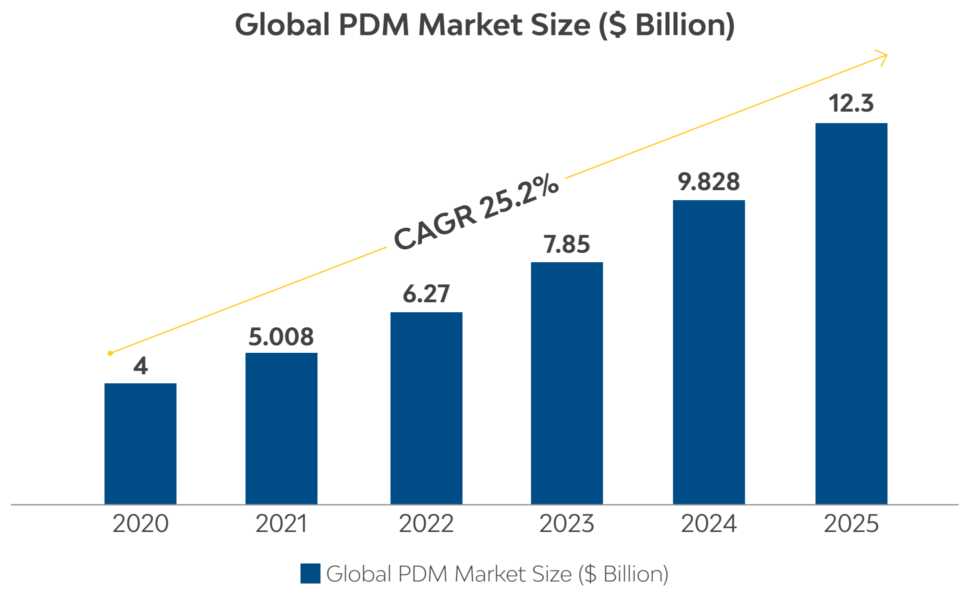
Smart Manufacturing and Predictive Maintenance

Industry 4.0 is revolutionizing the global manufacturing industry. It offers a more comprehensive, interlinked, and holistic approach to manufacturing, also called smart manufacturing, bridging the gap between the physical and digital worlds. According to Mordor Intelligence, "The Global Smart Manufacturing Market was valued at USD 172.60 billion in 2020, and is predicted to rise at a CAGR of 5.75% to USD 236.12 billion by 2026" [1]. Smart factory management systems couple data with smart prediction models and analytics tools to predict failures and recommend countermeasures. These predictive algorithms can also be applied to factory maintenance to improve equipment availability and overall equipment efficiency (OEE). Predictive maintenance is a crucial technology in the implementation of Industry 4.0 initiatives such as smart manufacturing. According to a Markets and Markets research report, the global predictive maintenance market is expected to grow from USD 4.0 billion in 2020 to USD 12.3 billion by 2025, at a CAGR of 25.2% [2].

Predictive Maintenance

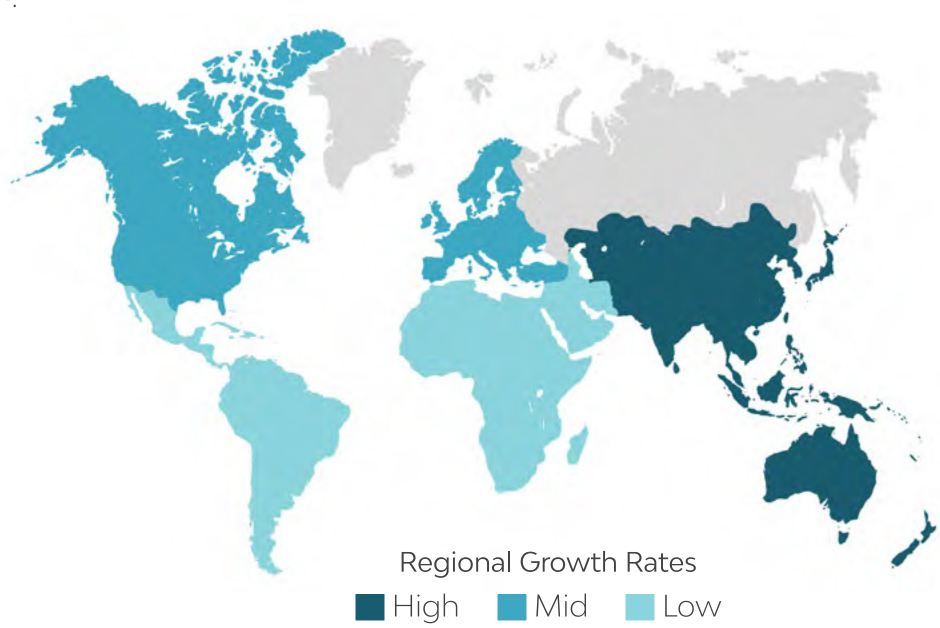
Ineffective maintenance practices have been shown to diminish a plant's overall productive capacity by 5% to 20%. In addition, unplanned downtime is estimated to cost industrial organizations USD 50 billion each year [3]. Maintenance teams in organizations are left in a dilemma to either maximize a part's usable life at the cost of machine downtime (reactive maintenance) or maximize the plant's uptime by replacing potentially good parts early (preventive maintenance). Predictive maintenance aims to eliminate these compromises by enabling businesses to extend the usable life of their parts while preventing unnecessary downtime, and helps maintain appropriate inventory of the components.





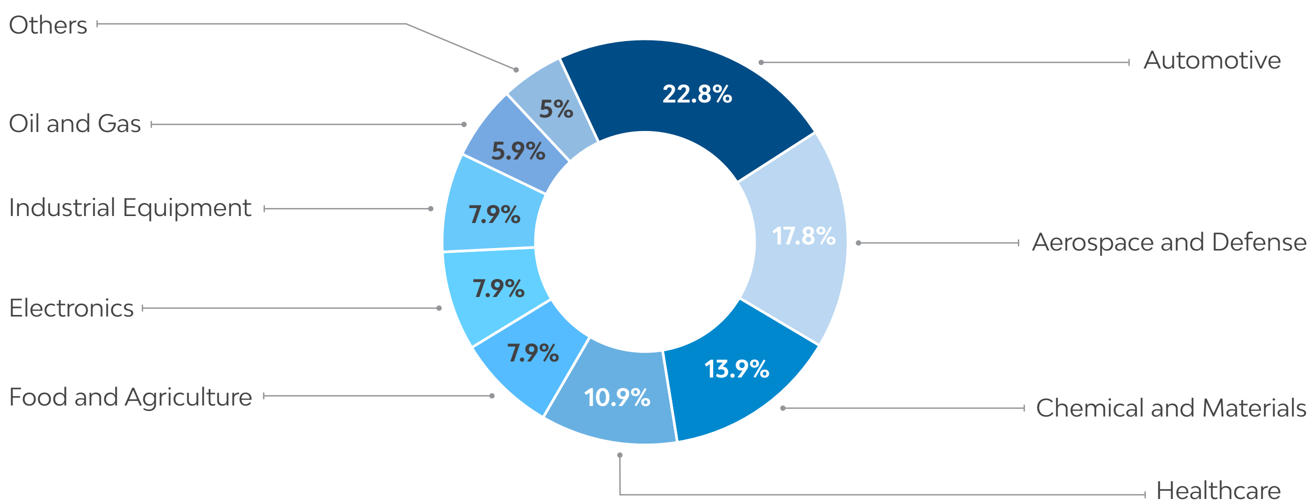
Condition Monitoring

Accurate predictive maintenance is possible only with active condition monitoring (CM), defined as the continuous monitoring of machines during process conditions to ensure optimal usage. Condition monitoring aids smart manufacturing by saving maintenance cost, time, and effort by detecting flaws in machines that might otherwise go unreported. It enables the gathering of baseline data and trending on equipment, which aids in the rapid identification of issues. According to Mordor Intelligence, the global machine condition monitoring market was valued at USD 3.1 billion in 2020, and is projected to be worth USD 5.2 billion by 2026, registering a CAGR of 9.4% during the forecast period of 2021-2026 [4].



Machine Condition Monitoring Market – Growth Rate by Region (2021-2026) [4]

The use of condition monitoring is beneficial in any industry or business that involves machinery and technology, especially where dealing with harm is more expensive than investing in its prevention. Condition monitoring solutions need to be platform-agnostic and hardware-independent for broader use with different machine OEMs. Some current industry trends [5] which favor the use of CM are:



Automotive Industry

CM helps automobile industries to manage component wear and failures in an improved manner using techniques such as vibration analysis, oil analysis, and infrared imaging.

Oil and Gas Industry

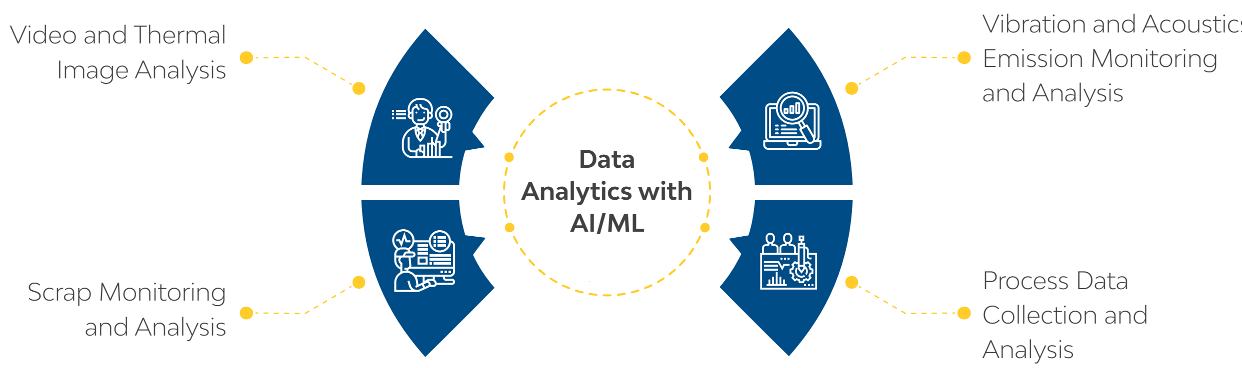
Equipment failures can cause tremendous harm, and CM can help keep checks on generators, compressors, turbines, and motors failures before they result in disaster.

Industrial Equipment Segment

CM helps to track machine health using vibration analysis to detect imbalance, misalignment, faults, cracks, etc.

LTIMindtree's Perspective

Industry X.0 is our methodology, IPs and ecosystem to digitize factory assets and processes to provide integrated visibility and enable autonomous operations. LTIMindtree's Industry X.0 methodology has a heavy emphasis on predictive maintenance and condition monitoring. LTIMindtree's offerings are oriented towards the vision of the Cognitive Manufacturing Plant, which is the future of manufacturing. Having considerable experience with Smart Manufacturing solutions, LTIMindtree employs a maturity assessment framework to evaluate case-by-case requirements and provides end-to-end solutions ranging from sensorization, software deployment, integration with plant data bus and deployment of digital command centers with a feedback loop factory system, directly impacting customers key KPIs. Due to the base-level productization of solutions, the implementation timeline is also shortened. LTIMindtree's expertise in condition monitoring has a solid core of data analytics with proficiencies in four main areas of condition monitoring, as shown in the figure.



LTIMindtree's Condition Monitoring Expertise

Acoustics Emission and Vibration Monitoring and Analysis

Acoustic emissions are elastic waves caused due to mechanical shocks, impacts, friction, or cracking. They are high-frequency waves above 100KHz. The processing of acoustic emission signals is relatively more straightforward and cost-effective. Acoustic emission signals are also not affected by noise and do not require extensive filtration. Hence, acoustic emission analysis is used for the detection of anomalies in the very early stages. It can also be used in an environment with considerable ambient vibrations at low RPMs with non-continuous operations [6]. Moreover, there is considerably less post-processing required in this method. Hence, its application with edge devices for quick and live peripheral display of results is prevalent.

Vibration analysis is the traditional method of condition monitoring via sensorization. It is also called the proper condition monitoring method, as the analysis considers the history and configuration of the machine. Vibration analysis can detect small misalignments and variations in the machine at very high speeds and detect component-level anomalies. However, it is not cost-effective in some cases as it requires high-end equipment and expertise to gather and analyze the data. In addition, there is a considerable amount of post-processing of the signal, most commonly using FFT (Fast Fourier Transform) method. As a result, vibration analysis has been consistently replaced by acoustic emission analysis, but it has its niche application. Especially in cases where cost concerns and unknown variables are minimal, extremely high-speed components under controlled conditions need precise monitoring.

Video and Thermal Image Analysis

Computer vision is the fastest-growing field in artificial intelligence (AI) and machine learning (ML). Last year, 49% of the patents filed in the world in AI were related to computer vision technologies [7]. The use of computer vision via video and thermal image analysis is prevalent and influential in condition monitoring in hazardous and hard-to-access environments, especially where humans wander.

Video analysis is a method where each video frame is analyzed, and actionable data is deciphered via AI and ML algorithms. With a consistent increase in the processing power of computers and a decrease in storage cost, video analysis has become a cost-effective method for monitoring large spaces to detect unpredictable anomalies. It is also very effective in monitoring non-cyclic activities in machines to determine if performance is in acceptable parameters.

Most electromechanical industrial equipment, when operated, generates some amount of heat. Thermal image analysis follows the similar principle of video image analysis, however, is slightly expensive than video analysis due to the specialized imaging equipment. Thermal image analysis is very effective when the monitored component is concealed or has no moving parts. Environments where visibility is compromised due to smoke, smog, or excessive light, e.g.: - welding, heating furnaces, also use thermal image analysis for condition monitoring.

Scrap Monitoring and Analysis

Scrap monitoring and analysis is a niche area of condition monitoring. Instead of the process or machinery, the byproducts of the process are analyzed to detect anomalies. Chemical manufacturing is an excellent example where scrap monitoring and analysis can be effectively used. Another example is the high-speed machining process where the shape, size, and coloration of the cutting chips can determine the tool health and conformance of machine parameters. Scrap monitoring and analysis is a specialized area and requires considerable domain expertise to analyze data effectively. This condition monitoring method is used when other monitoring methods are impractical, and spot checks are sufficient to know the status.

Process Data Collection and Analysis

Process data collections and analysis form the foundation layer of any condition monitoring regime. This aspect of condition monitoring forms the crux of data democratization and decision-making. It comprises software components that enable quick integration of OPC UA or other protocol-based systems with the network and APIs to capture and store the data, maintain data accuracy, apply business rules, and analyze the data to get actionable insights. The process data collections and analysis capability complete the integrated visibility layer of LTIMindtree's Industry X.0 methodology. Most of the clients and customers who approached LTIMindtree struggled to implement this technology layer in their Industry 4.0 implementation journey. However, LTIMindtree's Industry X.0 methodology helped them move up in their Digital Manufacturing Maturity Matrix.

Click here to learn how we solved for a leading Automotive OEM.

Click here to learn how we solved for a Midstream Oil and Gas client.

Conclusion

Condition monitoring has benefited the manufacturing sector by replacing the traditional monitoring and maintenance processes. The technology has shown its wide implementations in welding process, machining lines, and monitoring motors, pumps and spindles. With condition monitoring, manufacturing industries can improve machine performance substantially by cutting the operational downtime of machines. One of the important aspects of LTIMindtree's Industry X.0 methodology is integrating condition monitoring model outputs into the feedback loop of process control. This also improves the product quality by ensuring the selection of the optimal set of operating conditions that helps in maintaining a more consistent manufacturing process.

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About the Authors

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Abhijit has a rich and diverse experience of IoT and business consulting in automotive, mining, construction, and heavy industries. He has a Master's degree in manufacturing systems engineering from the University of Kentucky and an MBA from the University of Chicago Booth School of Business. In his career spanning 16 years, Abhijit has worked with some of the world's leading manufacturing and automotive companies. His experience also includes leading a joint public – private incubation center. Abhijit is currently responsible for business implementation of IT-OT convergence in the manufacturing industry.

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Pratap comes to LTIMindtree with 21 years of experience in the Multimedia and Manufacturing industry. He has Ph.D. in Video Analytics, and Master's degree in Mechatronics Engineering from the University of Pune. Pratap has worked with leading engineering companies as a solution architect where he was involved in R&D related to Healthcare and Modelling, Simulatin of Mechanical components. With LTIMindtree for the last nine months, Pratap is involved in providing Data science solutions of Machine Learning and Computer Vision for Manufacturing, Retail, Media and Entertainment industries. He has a deep passion for Image, Signal, and Video Processing.

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