RZESZOW UNIVERSITY OF TECHNOLOGY

CHAPTER 5

TPM
TOTAL PRODUCTIVE MAINTENANCE

LEAN MANUFACTURING

Co-funded by the European Union

TET - The Evolving Textbook
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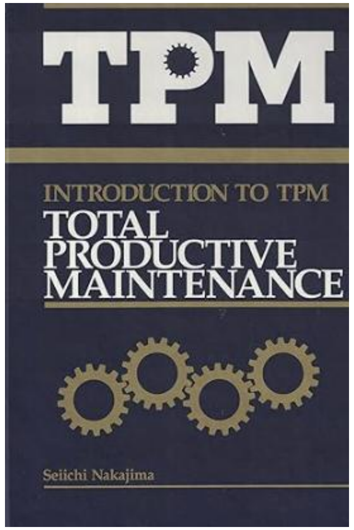
Definition of TPM (Total Productive Maintenance)

TPM (Total Productive Maintenance) is a Lean Manufacturing strategy that integrates machine maintenance with employee engagement at all organisational levels. The goal of TPM is to maximise the efficiency of machines and equipment by eliminating breakdowns, reducing downtime, and improving production quality. TPM fosters a culture of continuous improvement and involves operators in preventive actions, thereby reducing reliance on the maintenance department.

Nakajima, S. (1988). Introduction to TPM: total productive maintenance.(Translation). Productivity Press, Inc., 1988, 129.

Ohno, T. (2019). Toyota production system: beyond large-scale production. Productivity press.

Antosz K., Stadnicka D.: TPM in large enterprises: study results. World Academy of Science, Engineering and Technology. International Journal of Industrial Science and Engineering, Issue 82, October 2013 Barcelona, 3, str. 320-327. ICIEM 2013: International Conference on Industrial Engineering and Systems Management. Barcelona, Spain October 14-15, 2013.



Total Productive Maintenance (TPM) originated in Japan during the 1960s as a response to the increasing demands for quality, efficiency, and machine reliability in industrial environments. This approach evolved from traditional maintenance into a more comprehensive system that involves machine operators in preventive actions and daily maintenance. The goal was to reduce reliance on specialised maintenance departments, eliminate downtime, and improve efficiency and production quality. TPM is directly linked to the Toyota Production System (TPS), where Lean Manufacturing principles play a critical role.

Key Objectives of TPM at Its Inception

- Eliminate machine breakdowns.
- Minimise downtime and quality-related losses.
- Maximise machine efficiency.
- Engage all employees in maintenance activities.

Tokutaro Suzuki (1994). TPM in Process Industries. Portland: Productivity Press.

List of TPM Pillars

TPM is built on 8 main pillars that together form a comprehensive approach to managing maintenance and improving machine efficiency:

1. **Autonomous Maintenance**
2. **Planned Maintenance**
3. **Focused Improvement**
4. **Early Equipment Management**
5. **Quality Maintenance**
6. **Training and Education**
7. **Safety, Health, and Environment**
8. **Office TPM**

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The combined implementation of TPM pillars leads to the elimination of waste (Muda), increased productivity, improved quality, and reduced operational costs. TPM engages the entire organisation in preventive actions and continuous improvement.

- Involves engaging machine operators in basic maintenance tasks such as cleaning, lubrication, and visual inspection.
- The goal is to reduce dependence on the maintenance department and foster a sense of responsibility among operators.
- Autonomous Maintenance (AM) focuses on building operators' awareness of the technical condition of machines.

Goals of Autonomous Maintenance

- **Reduction of downtime and machine failures** – Operators can quickly detect and address minor issues before they escalate into major breakdowns.
- **Increased operator engagement** – Building responsibility and awareness about machine conditions enhances their efficiency.
- **Relief for the maintenance department** – Assigning simple maintenance tasks to operators allows specialists to focus on more advanced technical activities.
- **Improvement in production quality** – Regular maintenance and prompt responses to technical issues reduce the risk of defects.

Autonomous Maintenance empowers operators to take responsibility for their equipment, contributing to improved machine reliability, production efficiency, and overall workplace engagement.

1. Autonomous Maintenance

Key Activities in Autonomous Maintenance

- **Cleaning** – Regular cleaning of machines helps identify potential issues such as oil leaks, worn components, or loosened mechanisms.
- **Lubrication** – Operators ensure proper lubrication levels, preventing excessive wear of moving parts.
- **Visual inspection** – Operators learn to recognise signs of wear or damage, such as noise, vibrations, or deviations from normal machine operation.
- **Simple repairs** – Performing basic tasks such as replacing small parts, making adjustments, or tightening screws.
- **Standardisation** – Creating and using simple checklists that help systematically monitor the condition of machines.

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7 Steps to Implement Autonomous Maintenance

- **Initial Cleaning** – Introduce principles of regular cleaning and machine inspections.
- **Elimination of Contamination Sources** – Identify and eliminate the root causes of problems, such as leaks or loosened parts.
- **Establishing Cleaning and Inspection Standards** – Set regular schedules and methods for inspections and cleaning.
- **Operator Training** – Equip operators with the knowledge and skills needed to perform maintenance tasks.
- **Systematic Inspections** – Regularly monitor the condition of machines according to established procedures.
- **Process Standardisation** – Create clear procedures and documentation to support autonomous maintenance.
- **Continuous Improvement** – Conduct regular reviews of maintenance activities and implement improvements to the processes.

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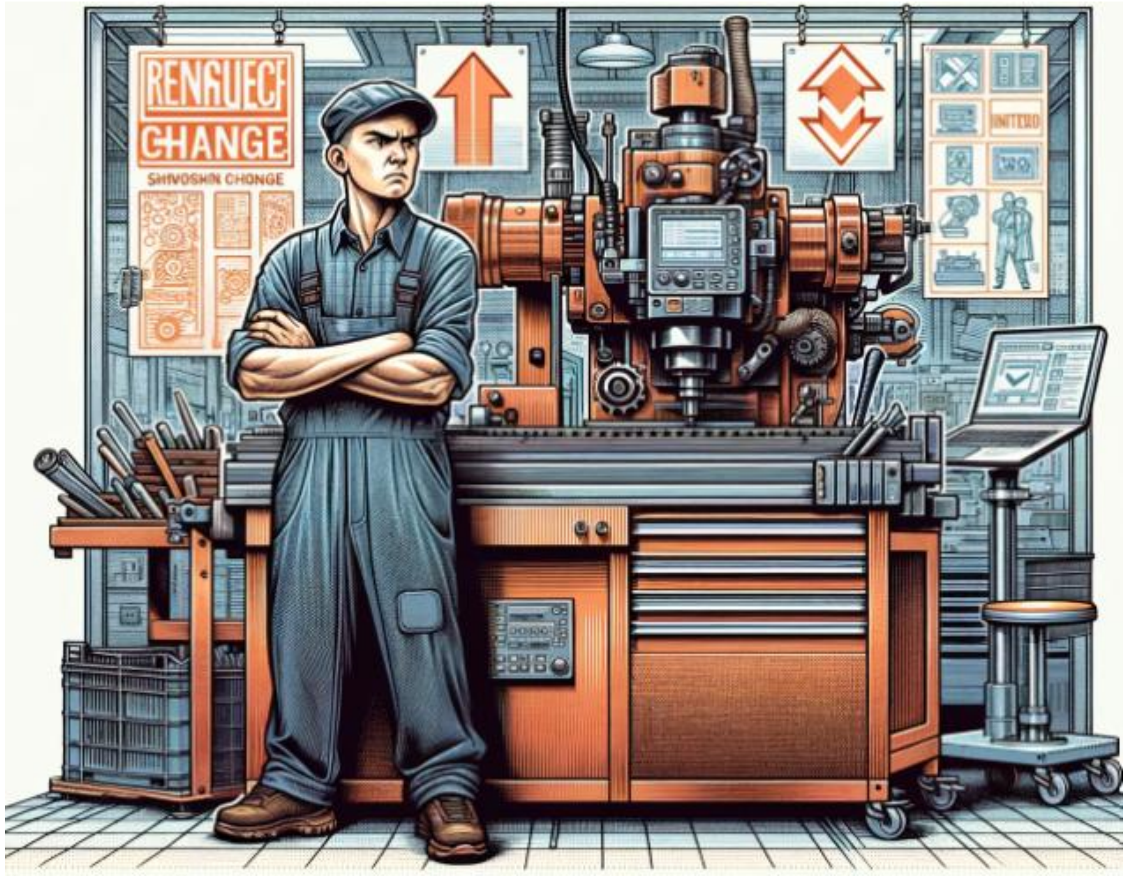
Challenges in Implementing Autonomous Maintenance

- **Resistance from employees to taking on new responsibilities** – Operators may be reluctant to adopt maintenance tasks outside their usual scope of work.
- **Lack of proper training or tools for conducting autonomous maintenance** – Without adequate support, operators may struggle to perform their tasks effectively.
- **The need to change organisational culture** – Creating an environment where operators feel responsible for machine condition requires a shift in mindset and engagement at all levels.



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2. Planned Maintenance

Planned Maintenance is related to regular scheduling of maintenance activities to prevent breakdowns and optimise resource utilisation.

Goals of Planned Maintenance

- **Preventing breakdowns** – Regular maintenance activities minimise the risk of major technical issues.
- **Increasing machine availability** – Reducing downtime caused by unexpected breakdowns.
- **Cost optimisation** – Performing scheduled maintenance avoids costly repairs and losses caused by production interruptions.
- **Improving safety** – W ell-maintained machines reduce the risk of workplace accidents.

Key Activities in Planned Maintenance

- **Developing maintenance schedules** – Regular inspections and check-ups are established based on historical data and machine manufacturer specifications.
- **Monitoring maintenance proces –** MTBF (Mean Time Between Failures) and MTTR (Mean Time to Repair).
- **Preventive replacement of components** – Replacing parts that may wear out before the end of their lifecycle to prevent failures.
- **Predictive diagnostics** – Using advanced technologies like thermography or vibration analysis to predict potential breakdowns.

MTBF (Mean Time Between Failures)

MTBF is a metric that represents the average time between failures of a machine, system, or device during a specific period of operation. It is a key parameter used to evaluate equipment reliability.

$$MTBF = \frac{\text{Total operating time of the equipment}}{\text{Number of failures in a given period}}$$

Importance of MTBF:

- A higher MTBF indicates greater equipment reliability.
- It is used to plan preventive maintenance and minimise downtime.

MTTR (Mean Time To Repair)

MTTR is a metric that represents the average time required to repair a machine, system, or device after a failure. It measures the efficiency of repair processes.

$$MTTR = \frac{\text{Total repair time}}{\text{Number of failures in a given period}}$$

Importance of MTTR:

- A lower MTTR indicates quicker and more efficient repairs.
- It is used to optimise repair processes and evaluate the performance of the maintenance team.

Stages of Implementing Planned Maintenance

- **Assessment of Current Machine Condition** – Identify the equipment most prone to failures.
- **Creating Maintenance Schedules** – Determine the frequency of maintenance activities based on machine usage data.
- **Training Personnel** – Ensure that employees responsible for maintenance have the necessary technical qualifications.
- **Setting Priorities** – Focus on machines that are critical to maintaining production continuity.
- **Monitoring and Optimisation** – Regularly review the effectiveness of implemented actions and adjust them to meet changing needs.

Gather Historical Data
↓
Conduct Machine Inspections
↓
Analyse Key Metrics (MTBF, MTTR, OEE)
↓
Engage Operators and Maintenance Teams
↓
Prioritise Based on Criticality
↓
Use Diagnostic Tools and Technologies
↓
Develop a Risk Matrix
↓
Document Findings

2. Planned Maintenance

Gather Historical Data
- Maintenance Records (breakdowns, repairs, and recurring issues)
- Production Data (downtime records, delays, impacts on production)
- Failure Reports (components or systems with the highest failure rates)

Conduct Machine Inspections
- visible signs of wear, damage, improper functioning
- anomalies: unusual noises, vibrations, leaks during operation

Analyse Key Metrics (MTBF, MTTR, OEE)

Engage Operators and Maintenance Teams
- Operator Feedback

Prioritise Based on Criticality
- Impact on Production, Safety Risks, Replacement Costs

Use Diagnostic Tools and Technologies
- Vibration Analysis, Thermal Imaging, Ultrasound Detection

Develop a Risk Matrix

Document Findings

Overall Equipment Effectiveness - OEE

OEE = Availability × Performance × Quality

- OEE is a key performance indicator used to measure the efficiency of equipment in a production environment.
- It evaluates how effectively a machine or process is utilised by considering three factors: **Availability**, **Performance**, and **Quality**.

$$\text{Availability} = \frac{\text{Net Production Time}}{\text{Planned Production Time}}$$

$$\text{Performance} = \frac{\text{Actual Output}}{\text{Theoretical Output}}$$

$$\text{Quality} = \frac{\text{Good Units}}{\text{Total Produced Units}}$$

- **Availability** measures the proportion of time a machine is available for production compared to the planned production time.
- **Performance** evaluates whether the machine operates at its maximum speed relative to its theoretical capacity.
- **Quality** measures the percentage of produced items that meet quality standards.

OEE Interpretation

- ≥85% OEE
  World-class performance – highly efficient with minimal losses.
- 60-85% OEE
  Average performance – potential for improvement in some areas.
- <60% OEE
  Below average – significant inefficiencies requiring corrective actions.

Stadnicka D., Antosz K. (2018) Overall Equipment Effectiveness: Analysis of Different Ways of Calculations and Improvements. In: Hamrol A., Ciszak O., Legutko S., Jurczyk M. (eds) Advances in Manufacturing. Lecture Notes in Mechanical Engineering. Springer, Cham, pp. 45-55. DOI: 10.1007/978-3-319-68619-6_5

De Ron, A. J., & Rooda, J. E. (2006). OEE and equipment effectiveness: an evaluation. International Journal of Production Research, 44(23), 4987-5003.

Rahayu, P. C., & Wicaksono, K. A. (2024, May). Real time OEE monitoring for intelligent manufacture technology. In 2024 15th International Conference on Mechanical and Intelligent Manufacturing Technologies (ICMIMT) (pp. 80-83). IEEE.

Diagnostic Tools for Maintenance Technicians

- **Pyrometers** – Devices for non-contact, point-based temperature measurement, operating on the principle of detecting thermal radiation. Ideal for measuring hard-to-reach surfaces (https://www.youtube.com/watch?v=CcBPy9tQeYc&t=9s).
- **Thermal Imaging Cameras** – Equipment that enables the diagnosis of faulty components by imaging areas with varying temperatures, even in challenging lighting conditions (https://www.youtube.com/watch?v=AeFXmIgxk1M&t=1s).
- **Industrial Thermometers** – Robust instruments used for measuring ambient and liquid temperatures ranging from -200°C to +700°C, utilising methods such as gas excitation or thermal expansion.
- **Hygrometers (Moisture Meters)** – Devices for measuring air humidity content, based on changes in the properties of materials due to moisture. Commonly used for climate control in industrial spaces.
- **Decibel Meters (Sound Level Meters)** – Instruments for measuring sound intensity in various environments, particularly useful for assessing machine noise levels and providing precise readings of noise exposure.
- **Vibrometers (Vibration Meters)** – Tools that measure the speed, acceleration, and displacement of machine vibrations, helping evaluate equipment for misalignment, imbalance, or loosened components.

https://qrmaint.pl/blog/12-narzedzi-dla-technika-utrzymania-ruchu/

Diagnostic Tools for Maintenance Technicians

- **Technical Endoscopes** – Inspection cameras for examining hard-to-access areas, comprising a camera with a recorder, a long cable, and a monitor. Used to check the condition of engines, tanks, or the interior of pipes.
- **Tachometers (Speed Meters)** – Devices for non-invasive measurement of rotational speed of shafts and other rotating elements, aiding in monitoring machine performance.
- **Electricity Meters** – Instruments for diagnosing issues related to power quality, used for monitoring parameters of energy distribution networks and power supply systems in industrial plants.
- **Cable Locators** – Tools for detecting cables and wires and tracing their routes, capable of identifying faults such as breaks or short circuits, as well as tracking water or heating pipe routes.
- **Pressure Meters (Manometers)** – Devices measuring the pressure of gases and liquids, useful in diagnosing hydraulic and pneumatic systems.
- **CMMS Systems (Computerized Maintenance Management Systems)** – Software that supports maintenance teams by automating tasks such as failure notifications, maintenance scheduling, inventory management, and reporting.

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Risk Matrix	Potential impact				
Likelihood of occurring	**Insignificant (1)**	**Minor (2)**	**Moderate (3)**	**Major (4)**	**Catastrophic (5)**
Rare (1)	Low	Low	Low	Medium	Medium
Unlikely (2)	Low	Low	Medium	Medium	High
Possible (3)	Low	Medium	Medium	High	High
Likely (4)	Medium	Medium	High	High	Critical
Almost Certain (5)	Medium	High	High	Critical	Critical

Likelihood of occurring:

- **Rare (1)**: Extremely unlikely to happen.
- **Unlikely (2)**: May happen occasionally.
- **Possible (3)**: Could happen, but not frequently.
- **Likely (4)**: Will probably happen in most circumstances.
- **Almost Certain (5)**: Expected to happen.

Potential impact:

- **Insignificant (1)**: Minimal impact, no disruption.
- **Minor (2)**: Low impact, minor disruption.
- **Moderate (3)**: Moderate impact, noticeable disruption.
- **Major (4)**: High impact, significant disruption.
- **Catastrophic (5)**: Severe impact, complete disruption.

Risk level:

- **Low**: Monitor, no immediate action required.
- **Medium**: Plan for mitigation and closely monitor.
- **High**: Implement mitigation strategies as a priority.
- **Critical**: Immediate action required to reduce or eliminate the risk.

Low	Low	Low	Medium	Medium
Low	Low	Medium	Medium	High
Low	Medium	Medium	High	High
Medium	Medium	High	High	Critical
Medium	High	High	Critical	Critical

Potential risks or hazards in the process or project	Likelihood of occurring	Potential impact	Risk level	Mitigation strategy

4. Early Equipment Management

- Improving machine and process designs during the planning stage.
- Incorporates feedback from operators and technicians to design machines that are easier to maintain.

Stages of Implementing Early Equipment Management

- **Analysis of Production Needs** – Define the requirements for new equipment, such as performance, reliability, ease of operation, and operational costs.
- **Involvement of End Users** – Operators and technicians participate in the selection and testing of machine prototypes, enabling early detection of potential issues.
- **Maintenance-Friendly Design** – Incorporate features like easy access to key components, visual markings, and modular construction to simplify repairs and maintenance.
- **Testing and Optimisation** – Conduct real-world tests and make necessary adjustments before full implementation to ensure optimal performance.
- **Standardisation and Documentation** – Develop technical documentation, user manuals, and maintenance schedules to support the long-term operation of the equipment.

Early Equipment Management Fundamentals

- Preventing defects by identifying and addressing root causes of quality issues.
- Involves monitoring key machine parameters to ensure processes meet quality requirements.

Key Activities in Quality Maintenance

- **Identification of Critical Control Points (CCP)** – In production processes, identify points where product quality is most at risk, such as assembly, welding, or moulding stages.
- **Monitoring and Measurements** – Regularly record production process data to quickly detect deviations from established standards.
- **Root Cause Analysis (RCA)** – When an issue is identified, conduct an analysis to determine its root cause and implement measures to prevent recurrence.
- **Implementation of Poka-Yoke Systems** – Employ error-proofing systems, such as sensors, locks, or visual indicators, to prevent defects from occurring.
- **Employee Training** – Train operators to identify non-conformities and respond effectively to deviations in processes.
- **Continuous Improvement** – Regularly review processes and implement enhancements based on quality data and customer feedback.

- Enhancing employee skills to enable them to effectively manage machines, identify issues, and implement improvements.
- Applies to both operators and maintenance personnel.

Goals of Training and Education in TPM

- **Skill Development** – Provide employees with the technical and operational skills required for their roles, including equipment operation, maintenance, and troubleshooting.
- **Building Ownership** – Empower workers to take responsibility for the condition and performance of the equipment they use.
- **Knowledge Sharing** – Foster collaboration between departments by sharing expertise, such as maintenance best practices or operational techniques.
- **Eliminating Skill Gaps** – Identify and address gaps in employee skills to ensure uniform competence across the workforce.
- **Promoting Continuous Improvement** – Encourage a culture where employees regularly seek ways to enhance processes and performance.

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Key Areas of Focus in Training and Education

- **Basic Equipment Knowledge** – Teach operators the fundamental principles of how machines work and the importance of proper maintenance.
- **Problem-Solving Skills** – Train employees in methodologies like Root Cause Analysis (RCA) and 5 Whys to identify and resolve issues efficiently.
- **Maintenance Skills** – Educate operators on basic maintenance tasks, such as cleaning, lubrication, and visual inspection, as part of Autonomous Maintenance.
- **Safety Training** – Emphasise workplace safety by teaching employees to recognise potential hazards and adhere to safety protocols.
- **Advanced Diagnostics** – Provide specialised training for maintenance teams to use diagnostic tools like vibration analysers, thermal imaging cameras, or ultrasonic detectors.
- **Standardisation** – Train employees on standard operating procedures (SOPs) to ensure consistency and minimise errors.

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7. Safety, Health, and Environment

- Creating a safe working environment by eliminating risks and hazards associated with machine operation.
- Ensures compliance with safety regulations and considers environmental factors.

Improved Safety

- **Hazard Prevention** – Regular maintenance reduces risks of equipment malfunctions, such as leaks, fires, or structural failures, which could lead to workplace accidents.
- **Safer Work Practices** – Training employees in proper machine handling and maintenance fosters a culture of safety awareness.
- **Elimination of Unsafe Conditions** – TPM encourages proactive identification and mitigation of safety hazards during routine inspections.

Enhanced Employee Health

- **Reduced Physical Strain** – Improved ergonomics in machine design, maintenance tasks, and workflows minimise physical stress on workers.
- **Lower Exposure to Hazards** – Regular checks prevent leaks of hazardous substances, reducing exposure to harmful chemicals, noise, and vibrations.
- **Stress Reduction** – Reliable equipment and processes lower the stress associated with frequent breakdowns or emergencies.

Environmental Benefits

- **Minimised Waste** – TPM reduces material waste by ensuring equipment operates efficiently and producing fewer defective products.
- **Energy Efficiency** – Well-maintained machines consume less energy, lowering the organisation's carbon footprint.
- **Pollution Control** – Preventive measures, such as sealing leaks and monitoring emissions, reduce environmental contamination.

IT Equipment Maintenance:
- Regular maintenance of computers, servers, printers, and other IT infrastructure to ensure reliability.
  - Operating system updates.
  - Regular data backups.
  - Monitoring system performance and security.

Telecommunication Systems Management:
- Ensuring the efficient operation of telephone networks, video conferencing systems, and internet connectivity to support effective communication.

Office Equipment Management:
- Regular inspections and repairs of devices such as copiers, scanners, projectors, and coffee machines to minimise downtime and maintain productivity.

Office Space Management:
- Lighting, HVAC Maintenance – Maintaining lighting, air conditioning, heating, and ventilation systems.
- Ergonomic Workstation Arrangement **–** Managing ergonomic setups for workstations to enhance employee comfort and health.

Infrastructure Safety:
- Regular testing of alarm systems, fire protection systems, and video surveillance.
- Ensuring compliance with safety and health regulations (e.g., OSHA standards).

Operational Continuity:
- Developing contingency plans for office equipment or IT infrastructure failures.
- Implementing solutions such as uninterruptible power supplies (UPS) or backup IT systems to ensure uninterrupted operations.

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Challenges in Implementing and Sustaining TPM

Resistance to Change

- Employees may fear new responsibilities and changes in established processes.
- Lack of acceptance for new methods and tools.

Lack of Leadership Commitment

- Insufficient support or lack of active involvement from leaders in implementing TPM.
- Treating TPM as an additional project rather than an integral part of the strategy.

Insufficient Employee Training

- Lack of knowledge and skills among operators and maintenance teams.
- Limited availability of training programs.

Cultural Change

- The need to shift the organisational mindset from reactive to proactive.
- Challenges in fostering a sense of responsibility for machine conditions among employees.

Lack of Data and Monitoring Tools

- Limited data on machine condition, performance, and downtimes.
- Key metrics such as MTTR (Mean Time to Repair), MTBF (Mean Time Between Failures), and OEE (Overall Equipment Effectiveness) are not calculated.

Financial Constraints

- High initial costs associated with TPM implementation.
- Budget limitations, particularly for smaller organisations.

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Challenges in Implementing and Sustaining TPM

Insufficient Time Resources

- Conflict between daily production demands and the time required to implement TPM.
- Lack of dedicated TPM leaders to drive the initiative.

Sustaining the Implementation

- Risk of reverting to old habits after the initial implementation phase.
- Difficulty in maintaining discipline and motivation for TPM activities.

Cross-Departmental Coordination

- Inadequate communication and collaboration between production, quality, and maintenance teams.
- Lack of shared understanding of TPM goals across departments.

Pressure for Short-Term Results

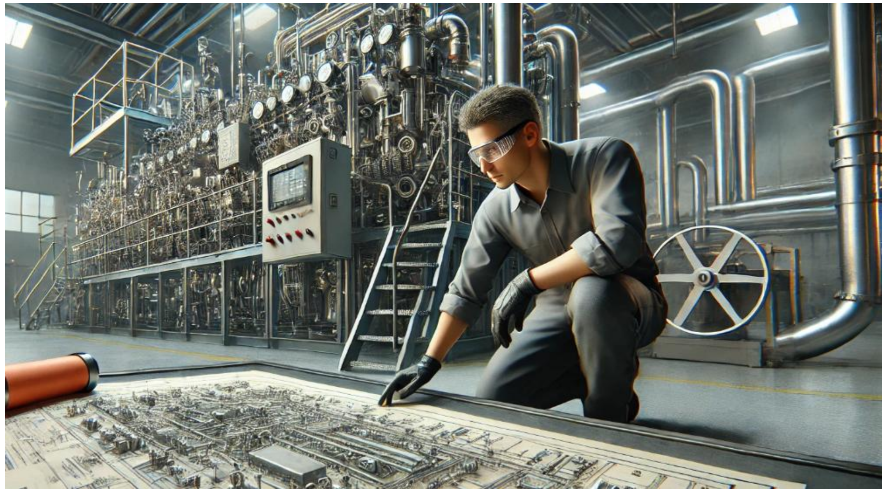
- Challenges in balancing the need for time and resource investment in TPM with the pressure for immediate production outcomes.

Technical Complexity

- Managing diverse equipment with varying levels of technological advancement.
- Need for advanced diagnostic skills and tools.

Lack of Standards

- Absence of defined procedures and guidelines for maintenance actions.



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Q&A

What is the main goal of TPM?
a) Increasing the number of employees responsible for maintenance
b) Maximising equipment efficiency and eliminating failures
c) Increasing production speed at the expense of quality

Which TPM pillar focuses on involving operators in basic maintenance activities?
a) Planned Maintenance
b) Autonomous Maintenance
c) Office Management

Which metrics are key for monitoring performance in TPM?
a) ROI and ROE
b) MTTR, MTBF, and OEE
c) NPV and IRR

What does the OEE indicator in TPM measure?
a) Evaluation of environmental emissions
b) Machine utilisation efficiency
c) Total cost of equipment maintenance

Which TPM pillar focuses on optimising processes at the machine and equipment design stage?
a) Planned Maintenance
b) Early Equipment Management
c) Focused Improvement

Which of the following activities is key in Autonomous Maintenance?
a) Regular inspections carried out by the maintenance department
b) Self-directed cleaning, lubrication, and inspection of machines by operators
c) Implementation of CMMS systems

Q&A

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