

UNIT III

STATISTICAL PROCESS CONTROL

Meaning and significance of statistical process control (SPC) – construction of control charts for variables and attributes. Process capability – Meaning, significance and measurement – Six sigma - concepts of process capability. Reliability concepts – Definitions, reliability in series and parallel, product life characteristics curve. Total productive maintenance (TMP), Tero Technology.

TOTAL PRODUCTIVE MAINTENANCE

Total Productive Maintenance (TPM) is a holistic approach to equipment maintenance that integrates the efforts of all departments within a company to maximize the performance of production equipment throughout their entire life cycle.

Key elements:

- **Total** — everyone is involved in the process: from operators to top management, from production to the office.
- **Productive** — focus on maximizing equipment effectiveness, eliminating all types of waste.
- **Maintenance** — proactive maintenance, preventing failures rather than reacting to them.

Total productive maintenance isn't just a repair schedule. It's a philosophy where the machine operator becomes its first "guardian": daily inspections, cleaning, lubricating and noticing even the slightest deviations. Maintenance personnel focus on complex tasks, while the routine tasks are handled by those who work with the machine every day.

Total preventive maintenance is often confused with total productive maintenance, but they are different concepts. Preventive maintenance is only one of the pillars of TPM, while the system itself encompasses culture, training, process improvement and much more.

Pillars of TPM

TPM is built on eight interconnected pillars. Each pillar is responsible for its own area of work, but together they create a coherent system as part of a comprehensive TPM programme.

1. Autonomous Maintenance

Autonomous maintenance delegates basic equipment maintenance tasks to operators. Instead of waiting for a mechanic every time a line gets dirty or experiences a minor issue, equipment operators perform the following tasks themselves:

- Daily cleaning and visual inspection

- Lubrication of accessible components
- Tightening fasteners
- Detecting anomalies (noise, vibration, leaks). Restoration to basic conditions is the first step in autonomous maintenance. The team literally “brings the machine back to life”: cleaning away years of accumulated dirt, restoring markings and tidying up every component. This process teaches operators how the equipment works and identifies hidden defects.

The autonomous maintenance plan includes gradual skill development so operators can maintain their own equipment in prime operating condition.

Example: At a packaging plant, operators used to call a mechanic at the slightest contamination on the line. After implementing the autonomous maintenance program, they started cleaning the conveyors themselves every shift using an autonomous maintenance checklist. As a result, minor downtime was reduced and mechanics were able to focus on serious modernization tasks.

2. Focused Improvement (Kaizen)

Focused improvement uses kaizen methodology to eliminate major losses. Small cross-functional groups (operators, technicians, engineers) gather to address a specific problem: frequent component breakdowns, long setup times, chronic defects.

Tools:

- 5 Whys Analysis
- Fishbone Diagram
- PDCA (Plan-Do-Check-Act) Cycle

Small-group activities are the heart of this pillar. Regular short meetings (15-30 minutes) allow for quick idea generation, hypothesis testing and consolidation of changes to achieve sustainable improvement.

Example: A team of three noticed that one press was stopping 4-5 times per shift due to jammed workpieces. After a week of kaizen activities, they installed an additional sensor and modified the guides. Downtime due to this issue completely disappeared.

3. Planned Maintenance

Planned maintenance shifts repair from “if it breaks, we fix it” to “know when it’s going to break, we replace it in advance”. The system is based on:

- Component reliability data (MTBF – mean time between failures) supporting equipment reliability.

- Consumable and component replacement schedules — planned maintenance schedule.
- Failure histories and wear trends — maintenance history.

Instead of waiting for a bearing to seize up in the middle of a shift, you replace it according to the schedule — during the scheduled maintenance intervals, when the line is down anyway. This approach uses the baseline replacement interval to optimize maintenance planning.

Service Type	Trigger	Downtime	Cost
Emergency repairs	Breaking	Unplanned, long	High (urgent parts, overtime)
Planned maintenance	Calendar/counter	Controlled, short	Average (purchase in advance)

4. Quality Maintenance

Quality maintenance focuses on defect prevention through process control. The idea is simple: defects don't occur randomly — they are caused by variations in equipment operation (temperature, pressure, speed, tool wear).

Key practices:

- Identifying critical process parameters.
- Implementing poka-yoke (error-proofing) devices that physically prevent defects.
- Root-cause analysis of each defect to eliminate quality defects.

Example: Underfills were occurring periodically on a bottling line. The quality maintenance team discovered that vibration from a nearby compressor was shifting the calibration of a level sensor. The solution: anti-vibration mounts and daily sensor calibration. The underfill rate dropped significantly, moving closer to the goal of zero defects.

5. Early Equipment Management

Early equipment management integrates operating experience into the design of new lines. When engineers purchase or design equipment, they consider:

- Ease of access to components for maintenance.
- Spare parts standardization (to reduce inventory).
- Minimization of changeover time.
- Built-in diagnostics and protection against incorrect operation.

Instead of struggling with an inconvenient machine for three years, you immediately purchase or design equipment that is easy to maintain and rarely breaks down.

6. Training and Education

Training and education are the pillars without which all others will collapse. The TPM program requires new skills from operators (basic diagnostics, schematic reading) and technicians (statistical analysis, data manipulation).

The training system includes:

- Competency matrices (who knows what, who needs to learn what).
- Practical training on real equipment — developing practical knowledge.
- One-Point Lesson standards — brief instructions for a single task.
- Skill certification (e.g., “Level 1 AM” means an operator can perform basic cleaning and lubrication independently).

Example: A pharmaceutical company launched an “AM Champions” program: 20% of operators completed in-depth mechanical and electrical training. Now, each shift has someone capable of fixing equipment — handling 80% of minor issues without calling a technician. Average response time to a problem has been reduced from 45 minutes to 5.

7. Safety, Health and Environment (SHE)

Safety, Health and Environment integrate occupational health and safety and environmental requirements into daily TPM practices. Equipment in good condition is safer: no oil leaks, broken wires, or unexpected mechanical movements.

Practices:

- Risk assessment for each routine task.
- Lockout/Tagout of hazardous energy (LOTO) before any intervention.
- Emission control, waste management, and energy efficiency as part of improvements.

8. Administrative TPM

Office TPM applies these principles to office processes: procurement, logistics, HR and IT. The idea is the same: eliminate waste, standardize and engage everyone

Examples:

- Faster order processing (like changeover in manufacturing).
- Automating routine tasks (like operator-led activities).
- Better data quality (like quality maintenance).

Six Big Losses

TPM categorizes all types of productivity losses into six categories — the Six Big Losses. This is the foundation for a loss-driven implementation roadmap.

Loss Category	Description	Impact on OEE
1. Breakdowns	Unscheduled stops due to failures	Reduces availability
2. Reconfigurations and adjustments	Time to switch from one product to another	Reduces availability
3. Minor downtime and idle running	Short-term stops (jamming, sensor activation)	Reduces performance
4. Reduce speed	Work is slower than planned performance levels due to wear and tear	Reduces productivity
5. Defects during launch	Defects at the beginning of the batch while the process is stabilizing	Reduces quality
6. Manufacturing defect	Defects in stable mode	Reduces quality

Major losses are analyzed through the lens of equipment performance and target equipment to focus improvements. Poor maintenance is often the root cause of major losses.

Benefits of Total Productive Maintenance

A properly implemented TPM system delivers a range of business outcomes that support greater productivity, efficiency and revenue potential. The operational impact of total productive maintenance includes the following:

- **Decreased breakdowns and production delays:** Proactive maintenance reduces the frequency of equipment failures and unplanned outages for your machinery. Greater equipment uptime decreases the loss created by production delays and work stoppages.
- **Reduced operational and maintenance costs:** Preventing a repair is always less costly — in terms of material expense and productivity loss — than responding to an equipment failure. TPM enables equipment efficiencies that can reduce the total cost of ownership for your assets.
- **Better overall asset performance:** Equipment not only suffers fewer failures, but it's able to operate with greater speed, efficiency and longevity.
- **Standardizing work to industry best practices:** In addition to potentially supporting regulatory compliance, TPM brings your manufacturing operations in line with the leading best practices for sustainability, safety and efficiency.

- **Safer equipment:** Your employees are less exposed to potential hazards, preserving their health while reducing the risk of accidents that could force a work stoppage.

Disadvantages of TPM

While businesses can realize significant benefits by implementing a TPM system, this approach isn't a foolproof method for addressing productivity loss — especially when its implementation isn't supported with appropriate resourcing and stakeholder buy-in.

The disadvantages of total productive maintenance can include:

- **The need to create a detailed plan with clear goals and milestones:** Developing this long-term strategy and checklists can be difficult, especially when stakeholders have different views on what those goals should be. Implementing TPM requires a significant commitment to shifting the organization's goals around maintenance.
- **Everyone in the organization must buy into this approach:** If operators and other key personnel aren't committing to supporting TPM, this system has a high risk of failure.
- **Upfront costs for employee training and maintenance:** While you can achieve TPM implementation through strategic and administrative changes, it requires some resourcing to set up employees for success in their roles.

Learning from Toyota's Example as a TPM Pioneer

Thanks to the pioneering efforts of Seiichi Nakajima at Nippon Denso (now Denso), an auto parts manufacturer in Japan, Toyota became one of the leading global brands embracing total productive maintenance to improve the quality and cost efficiency of its auto manufacturing processes.

Toyota prioritized proper training for all of its manufacturing workers as it implemented TPM into its manufacturing processes. The company then used the TPM methodology to support lean manufacturing processes that experienced minimal disruptions and stoppages. This brought stability to manufacturing processes designed for maximum cost-efficiency and quality assurance.

Today, TPM remains a core element of Toyota's manufacturing processes, and it has helped inform the company's mission of creating "good products at affordable prices."