OpusWorks

Online Student Guide

Total Productive Maintenance

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Comments

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Learning Objectives

Upon completion of this course, student will be able to:

- Describe the primary benefits gained from Total Productive Maintenance (TPM)
- Identify four major categories of maintenance
- Define Overall Equipment Effectiveness

Introduction

Meeting Customer Demand

Let's begin with a simple truth: to be successful, manufacturing companies must produce their products at a rate that meets customer demand. But what do manufacturing companies do when they run up against problems that affect their output capacity? Often, they seek to increase overtime, add shifts, or purchase new equipment. These investments may result in short-term fixes, but they rarely get to the root cause of the problem.

Companies can resolve output issues more effectively by optimizing the performance of their existing equipment to increase machine availability, improve machine performance, and improve output quality. When a machine in a process breaks down, it can create bottlenecks that affect many other steps in the process. If the equipment operates without breakdowns and works well consistently, the entire process will run more smoothly, everyone's work will be easier, and the company will be more profitable.

Production equipment performance problems can be traced to six major losses. These include breakdown loss, setup and adjustment loss, cycle time loss, machine stoppage due to parts shortages, startup rejects, and defect loss.

Unplanned Downtime

Unplanned machine downtime can account for as much as 40% of lost production capacity and can consume as much as 30% of a company's maintenance budget.

In a typical manufacturing process, machines are required to run close to 100% of the time they are available in order to make a production schedule. This leaves no time for preventive maintenance and causes wear and tear on the machines, which in turn leads to many more problems. Resulting problems can include poor quality and defects, variation in delivery of parts to downstream operations, bottlenecks, and accumulation of inventory in the factory.

TPM Definition & Goals

Total Productive Maintenance (or TPM), a team and shop floor-based initiative, is a proactive process that focuses on optimizing the effectiveness of manufacturing equipment.

The goals of TPM include: preventing equipment breakdowns through planning; preventing product defects and rejects based on equipment issues; improving equipment effectiveness and efficiency; involving and training operators in equipment maintenance and basic repair; improving equipment to minimize maintenance and/or make the maintenance and repair easier; and reducing costs, including the money and space tied up with spare parts inventory.

Types of Maintenance

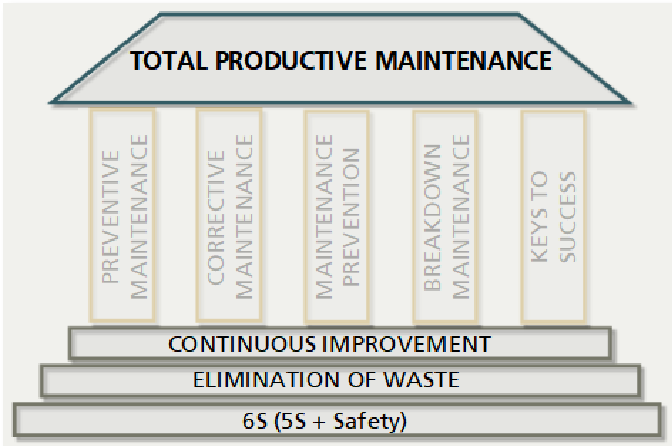
You have just learned the definition of TPM and the goals it seeks to achieve. Now let's look at how TPM works.

TPM includes four main types of maintenance. Preventive maintenance focuses on proactive maintenance to prevent breakdowns. Corrective maintenance focuses on equipment improvements or modifications to prevent breakdowns or make maintenance easier. Maintenance prevention focuses on minimizing required maintenance based on equipment design and/or installation. Breakdown maintenance focuses on repairing breakdowns.

TPM Architecture

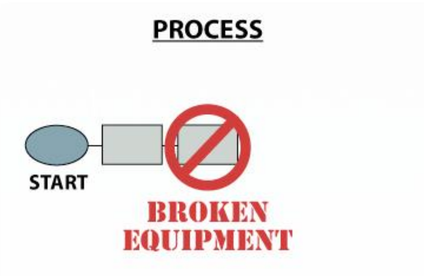
We will describe the four maintenance categories in more detail soon. But first, let's look at the overall architecture of TPM.

TPM starts with 6S. Problems cannot be seen clearly when the workplace is disorganized. Following the 6S process and organizing the workplace will help the team uncover problems that might otherwise be overlooked. Think of 6S as the first layer of the foundation needed to support TPM. The other foundational parts upon which TPM is built are the elimination of waste and continuous improvement. These are the principles which must be in place to support the pillars or components of TPM. As you can see in the model shown here, the main pillars of TPM include the four types of maintenance along with "keys to success." We'll talk about "keys to success" later in this module.



Unscheduled Downtime

TPM is concerned with reducing unscheduled downtime of production equipment. But why is unscheduled downtime so important? What is its real impact on cycle time, and how does it interfere with Lean?

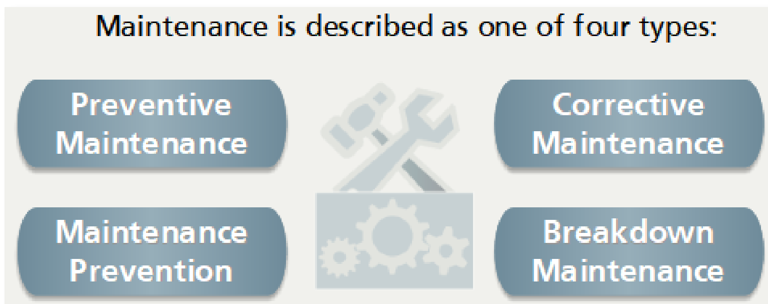


Consider this: Manufacturing companies cannot produce if the necessary equipment is down or not available. Further, time and energy are required to make adjustments and repairs to the equipment. Inefficient equipment can result in less product or slower than projected production. Unscheduled breakdowns, machine malfunctions, and component breakages can generate bad product and result in wasted time for reprocessing.

So, what can manufacturing companies do to clear the roadblock caused by unscheduled downtime? They can establish processes to ensure production equipment is available when needed, and perform maintenance and upkeep proactively versus reactively.

Types of Maintenance

As you now know, TPM focuses on four types of maintenance: preventive maintenance, corrective maintenance, maintenance prevention, and breakdown maintenance. Let's take a closer look at each of these types.

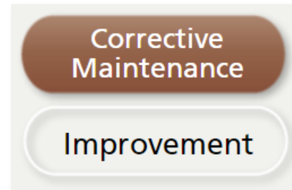


Preventive Maintenance

Preventive maintenance focuses on proactive maintenance activities, such as daily or weekly cleaning, inspecting, oiling, and other minor work to keep equipment in healthy condition. To ensure early detection of changes in condition that require work, many of these activities are carried out by operators. A form of preventive maintenance called autonomous maintenance is the concept that the people who operate a machine should maintain the machine, the degree of which depends on their level of training and experience. Because machine operators are usually the first ones to know when something has changed, they are in the best position to perform maintenance or seek help.

The goal of preventive maintenance is to prevent equipment failure and extend machine life in order to minimize unscheduled downtime, costs, and negative impact on operations. Equipment listings, historic performance, and predictions are used to plan, schedule, and perform the necessary maintenance activities. To successfully carry-out this type of maintenance, a schedule and commitment of time are required. In times of strong demand and tight schedules, this can become difficult, but the commitment is a must!

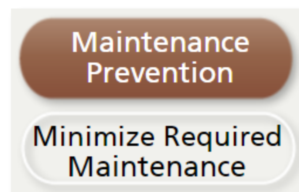
Corrective Maintenance



The focus of corrective maintenance is to improve equipment or components so that preventive maintenance can be carried out more easily. The ideas for improvement are generally based on input and suggestions from operation-based teams and other staff as they become involved in TPM. By making maintenance easier and more accessible, corrective maintenance serves to improve reliability and prevent breakdowns. Machine modifications and design changes are signs of corrective maintenance in action.

Corrective maintenance requires creativity and varying levels of flexibility. Some investment of time and money may be necessary to make the needed changes to equipment. These costs are justified by balancing investment with the expected returns in reliability, uptime, and ease of maintenance.

Maintenance Prevention



Maintenance prevention is based on actions and modifications that minimize required maintenance. As with corrective maintenance, many of these ideas come from the TPM operation-based teams. Maintenance prevention reduces costs and makes equipment more available for productive use. Maintenance prevention is often accomplished through changes to design and/or installation. Challenges of maintenance prevention may include an investment of time and money and a need for creativity and flexibility.

Breakdown Maintenance

The focus of breakdown maintenance is to repair machines and equipment when they break. As much as possible, these repairs are carried out by operators, with all necessary tools and parts readily available (think 5S).

Breakdown maintenance is only appropriate for equipment in need of immediate repair or for equipment that does not significantly affect the operation or generate much loss other than repair costs. For this type of maintenance to be successful, companies must identify equipment that fits this category; train operators and floor-based teams to do the repairs; and ensure necessary tools and parts are available.

Level of Stop:	Duration:	Repaired by:
Minor Stoppage	5 min	Operator
Minor Breakdown	30 min	Process expert or lead worker
Breakdown	30 min - 3 hrs	Maintenance
Major Breakdown	Over 3 hrs	Maintenance or machine field technician

A key challenge is to avoid using breakdown maintenance when preventive maintenance is the better choice. Too often, breakdown maintenance is incorrectly used as the default method, causing major delays and increases in cost.

Breakdown maintenance can be classified based on the duration and complexity of the repair. For example, minor stoppages can be repaired by the operator according to work instructions and visual aids. Minor breakdowns would require assistance from a process expert or a lead worker. More difficult breakdowns would require a maintenance person and major breakdowns could require outside assistance from a field technician.

OEE Details

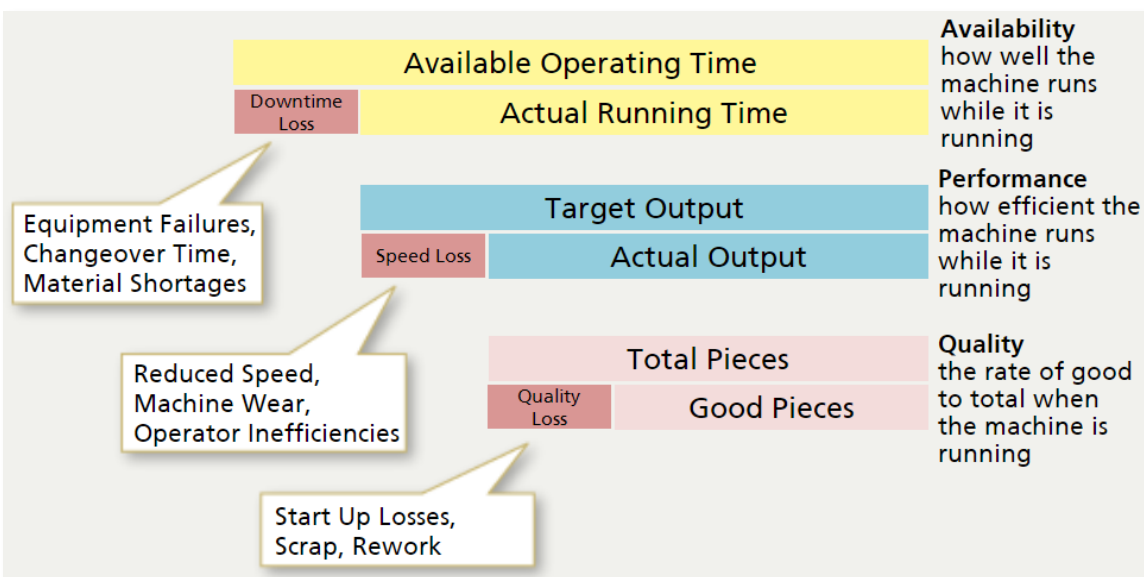
Overall Equipment Effectiveness (OEE) is a process used to characterize the overall performance of a single piece of equipment or even an entire factory.

A key metric associated with TPM, OEE was designed to highlight areas for focused improvement and to measure and communicate the effectiveness of improvements.

OEE is calculated by multiplying Availability by Performance rate and Quality rate. Let's look at this calculation in more detail:

Available operating time is the total amount of time available for a machine to run after accounting for planned downtime such as lunch breaks. When you subtract downtime losses due to equipment failures, changeover time, and material shortages, you're left with the actual running time. Actual running time becomes the target output and is affected by speed losses such as reduced speed, machine wear, and operator inefficiencies. The actual output can be expressed in terms of the total pieces to be produced and is affected by startup losses, scrap, and rework.

Availability is the ratio between actual running time and the available operating time; performance is a ratio between actual output and target output; and quality is a ratio between good pieces and total pieces. These three ratios multiplied together (Availability times Performance times Quality) equal OEE.



OEE Worksheet

Using a spreadsheet to calculate OEE makes the job a bit easier. This is a typical spreadsheet, but companies can create their own to meet their needs.

Availability		**Actual Availability**		
A	Total Scheduled Time (min)	480		per shift
B	Planned Downtime	60		(Lunch + Breaks + Meetings)
C	Total Available Time	420		(A - B)
	Changeover Time	80		Downtime for set-up change
	Unplanned Breakdowns	20		
	Other Stoppages	30		out of material
D	Downtime Losses	130		Changeover + Unplanned + Other
E	Operating Time	290		(C - D)
F	Availability	**69.0%**		(E / C)
Performance Efficiency		**Actual Performance**		
G	Total Parts Run	450	parts	per day
H	Ideal Cycle Time	0.5	minutes	per part
I	Ideal Output	580	parts/shift	(E /H) (based on Ideal Cycle Time)
J	Performance Efficiency	**77.6 %**		(G /I)
Quality Rate		**Actual Quality**		
K	Total Parts Produced	450	parts	(explanation required if different than G)
L	Total Defective	32	parts	(Rejects, Rework, Reruns, and Scrap)
M	Good Parts	418	parts	(K - L)
N	Quality Rate	**92.9%**		(M / K)
Overall Equipment Effectiveness		**Actual OEE**		
O	Overall Equipment Effectiveness	**49.8%**		(F x J x N)

Components of the Six Big Losses

One of the major goals of using OEE as part of TPM is to reduce and/or eliminate the Six Big Losses, the most common causes of efficiency loss in manufacturing. They include: breakdown loss, setup and adjustment loss, cycle time loss, stoppage due to shortages, startup rejects, and defect loss.

This table shows the relationship between each loss in the OEE category. Data can be collected on each of these causes of loss to serve as a basis for corrective action. Kaizen Events can then be defined to correct and/or eliminate the problems.

Breakdown loss	Availability	Unplanned Maintenance Equipment Failure Tooling Failures
Setup and adjustment loss	Availability	Changeover Time Major Adjustments Warm-Up Time
Cycle time loss	Performance	Rough Running Under the Design Capacity Equipment Wear
Stoppage due to shortages	Performance	Part Outages Improper Process Balance Backlog or Changing Priorities
Startup rejects	Quality	Scrap and Rework In-process Damage Test Runs to Verify Setup
Defect loss	Quality	Scrap and Rework In-process Damage Defective Parts from Previous Operations

Equipment Reliability Metrics

"If it ain't broke, don't fix it!"

Unfortunately, many maintenance operations still operate on the principle, "if it ain't broke, don't fix it!" Preventing breakdowns from happening in the first place is a much better approach. Reliability metrics, which are used to measure and understand equipment performance and maintenance requirements, are key components of preventive maintenance.

Equipment reliability metrics are derived from three basic measures: schedule hours (the number of hours scheduled for the equipment per week); number of breakdowns (the number of failures that occur per week); and repair time (the amount of time it takes to repair each breakdown). Let's look at an example:

During a one week period, a process runs for two shifts of 40-hours each. During the week, there are four breakdowns, which are repaired in 115 minutes, 110 minutes, 40 minutes, and 135 minutes, for a total repair time of 400 minutes. This information can be used to calculate several equipment reliability metrics.

Failure Rate

Failure rate is one of the simplest and most useful metrics used to determine equipment performance. It can be approximated using any convenient time interval, such as one week, one month, etcetera. Failure rate is designated by the Greek letter lambda and is equal to the number of failures during the designated time period divided by the total operating hours. As you can see from this calculation, the failure rate for our example is .063 breakdowns per week.

Failure Rate Is the rate at which equipment breakdowns occur, and is designated by the Greek letter lambda.

λ lambda

$$\lambda = \frac{\text{Number of failures}}{\text{Total available operating hours - downtime}} = \frac{\text{4 breakdowns}}{\text{70 - 6.67 hrs}} = \text{.063 breakdowns per hour}$$

Another simple reliability metric, meantime between failure (or MTBF), is used to determine the average amount of time between failures. This is a useful metric for long periods of time, but is not suitable for daily or weekly monitoring. This is because if there are no breakdowns in a given time period, the MTBF cannot be mathematically defined. For this example, let's assume the time period is one month (rather than the one week period used in the previous example). As you can see, MTBF is easily calculated using the same measures used to determine failure rate, but with the data inverted. In this case, MTBF is 15.83 hours.

Mean Time Between Failure (MTBF) Is the average amount of time between failures and is the inverse of lambda. MTBF is a meaningful metric for longer periods of time but not suitable for daily or weekly monitoring.

$$\text{MTBF} = \frac{\text{Total available operating hrs - downtime}}{\text{Number of breakdowns}} = \frac{\text{70 - 6.67 hrs}}{\text{4 breakdowns}} = \text{15.83 hrs}$$

Reliability Metrics

Mean time to repair (or MTTR) is a reliability metric that can be derived from just two of our three basic measures: number of breakdowns and repair time. A useful metric for maintenance, it reflects both the severity of the breakdowns and the effectiveness of the repairs. MTTR is equal to the sum of the repair times, divided by the number of breakdowns. In our example, MTTR is 100 minutes (or 1.67 hours) per breakdown.

Mean Time to Repair (MTTR) is another useful metric for maintenance. It reflects both the severity of the breakdowns and the effectiveness of the repairs.

$$\text{MTTR} = \frac{\text{Sum of repair times}}{\text{Number of breakdowns}} = \frac{400 \text{ min}}{4 \text{ breakdowns}} = 100 \text{ min} = \text{1.67 hours per breakdown}$$

Reliability R(t) is the probability that a machine will run for "t" hours without breakdown, e = 2.71828 and the failure rate (λ) = .063.

$$R(t) = e^{-\lambda t}$$

The probability that the machine will run for 8 hours without breakdown is:

$$R(8) = e^{-.063*8} = 0.60$$

Reliability rate is a metric used to show the probability that a machine will run for a certain number of hours without breakdown. To calculate this metric, we use the formula "R(t) = e to the negative lambda t." In this formula, 't' represents the designated number of hours, and as you recall, "e" is a constant equal to 2.71828 and lambda represents failure rate which, as we saw earlier, is equal to .063 breakdowns per hour. Therefore, in our example, the probability that the machine will run for 8 hours without breakdown is point 60 (or 60 percent).

TPM Metrics Summary

A summary of the OEE and reliability metrics for our example shows several areas for improvement. For instance, it shows that the machine is only available to operate 69% of the time, and when it does operate, it only performs at 75% of its capacity. This summary also shows a high machine failure rate, with only a 60% chance the machine will run 8 hours without a failure. Tracking these metrics as improvement projects are completed and implemented will help determine whether the improvements are working.

Overall Equipment Effectiveness	
Availability	69.0%
Performance	77.6%
Quality	92.9%
OEE	49.8%

Machine Reliability	
0.063	Failure Rate (breakdowns per hour)
15.83	MTBF - hrs
1.67	MTTR - hrs
0.60	P(t) running without breakdown for t = 8.00 hrs

The Final Pillar

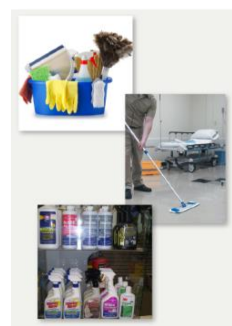
As you learned at the beginning of this module, the four types of maintenance are pillars that support TPM. The final pillar of TPM, keys to success, encompasses several things. First, management at all levels must understand that in TPM, the role of maintenance changes from troubleshooting and repairing to preventing failure. Leadership at all levels is also essential. Top management support, middle management buy-in and leadership, and good communications are also keys to success. Good training, including awareness training at the beginning of the program and detailed training at all levels of the organization, is another important factor of a project's success. Additionally, a good preventive maintenance system must be in place, and information on machine performance and maintenance history must be available.

Everyone involved in a TPM project must be committed to its implementation, and a full-time person should be dedicated to the task. Many companies fail, especially in the early stages, when the team leader has to split time with other tasks. Follow up is the final key to success. Once an area or a piece of machinery is ready to launch TPM, the task has just begun. 99% of its success will depend on

communication between the coordinator, management, and machine operators. Good follow-up is necessary to build confidence for the TPM project and to achieve the maximum benefit.

TPM in the Office

TPM focuses on machines and equipment that produce products for customers. While machines and equipment, such as computers, telephones, printers, and copiers are used in an office environment, the equipment is not primarily responsible for producing the product. Rather, the equipment supports the services that are provided. For this reason, TPM is not suggested for service and other related industries.



5S is better suited to the office environment than TPM, and it offers similar benefits and focuses on many of the same activities. For example, in both 5S and TPM, teams focus on clean work areas and equipment; look for items in need of repair; and put supplies and other necessary items in order. In 5S, as in TPM, it is also important to train all team members in basic equipment maintenance (paper replenishment, replacement of toner and ink cartridges, etc.), and to assign ongoing 5S activities to team members.