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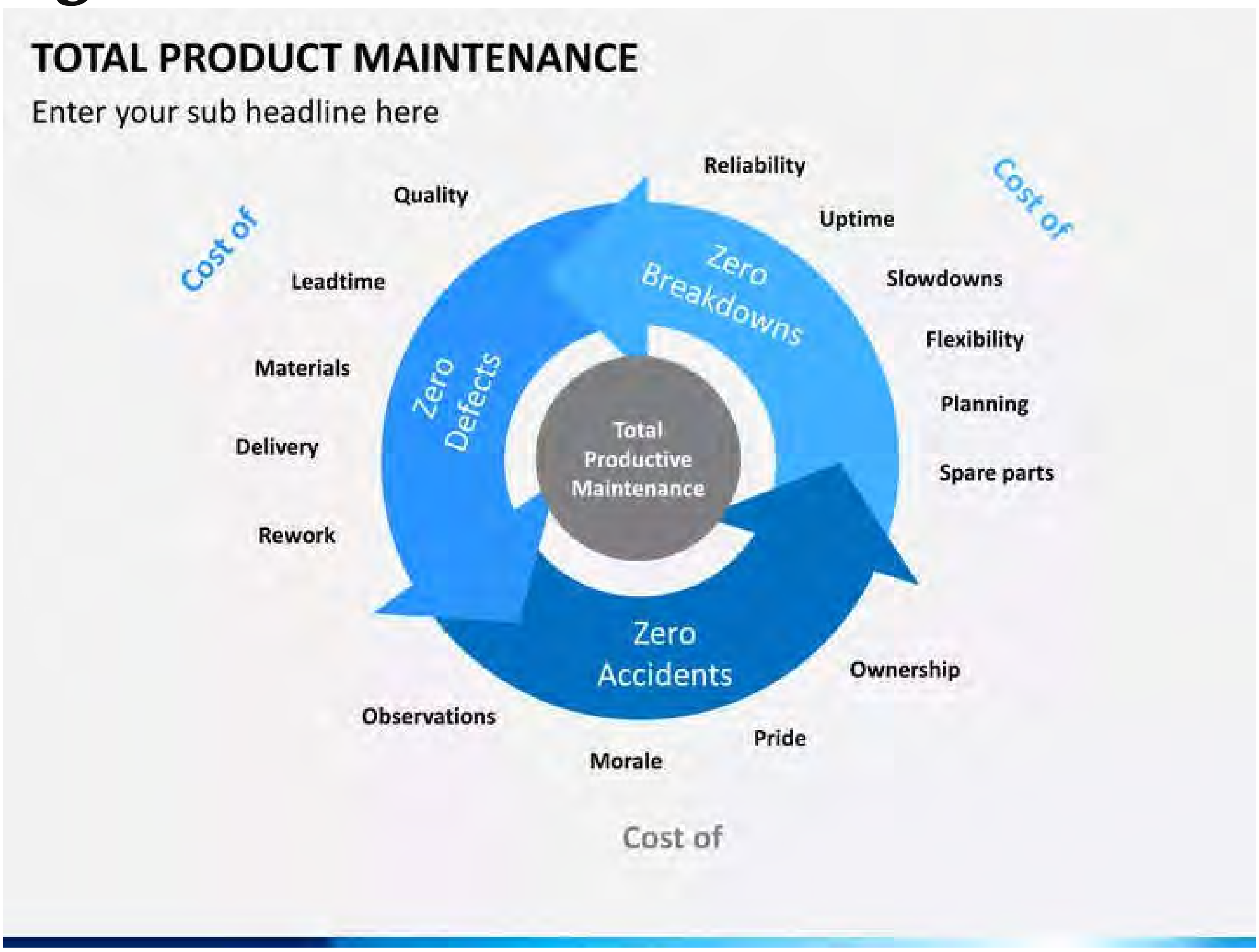
6S METHODOLOGY

TPM (Total Productive Maintenance) Explained By Gabriel Daniels PE. Lean Six Sigma Master Black Belt



TPM (Total Productive Maintenance) Explained By Gabriel Daniels PE. Lean Six Sigma Master Black Belt

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The Big Idea – Getting operators involved in maintaining their own equipment, and emphasizing proactive and preventive maintenance will lay a foundation for improved production (fewer breakdowns, stops, and defects).

WHAT IS TPM?

TPM (Total Productive Maintenance) is a holistic approach to equipment maintenance that strives to achieve perfect production:

- No Breakdowns
- No Small Stops or Slow Running
- No Defects

In addition, it values a safe working environment:

- No Accidents

TPM emphasizes proactive and preventative maintenance to maximize the operational efficiency of equipment. It blurs the distinction between the roles of production and maintenance by placing a strong emphasis on empowering operators to help maintain their equipment.

The implementation of a TPM program creates a shared responsibility for equipment that encourages greater involvement by plant floor workers. In the right environment, this can be very effective in improving productivity (increasing up time, reducing cycle times, and eliminating defects).

TRADITIONAL TPM

The traditional approach to TPM was developed in the 1960s and consists of 5S as a foundation and eight supporting activities (sometimes referred to as pillars).

The traditional TPM model consists of a 5S foundation (Sort, Set in Order, Shine, Standardize, and Sustain) and eight supporting activities.

The 5S Foundation

The goal of 5S is to create a work environment that is clean and well-organized. It consists of five elements:

- Sort (eliminate anything that is not truly needed in the work area)
- Set in Order (organize the remaining items)
- Shine (clean and inspect the work area)
- Standardize (create standards for performing the above three activities)
- Sustain (ensure the standards are regularly applied)

It should be reasonably intuitive how 5S creates a foundation for well-running equipment. For example, in a clean and well-organized work environment, tools and parts are much easier to find, and it is much easier to spot emerging issues such as fluid leaks, material spills, metal shavings from unexpected wear, hairline cracks in mechanisms, etc.

The Eight Pillars

The eight pillars of TPM are mostly focused on proactive and preventative techniques for improving equipment reliability.

Pillar	What Is It?	How Does It Help?
Autonomous Maintenance	Places responsibility for routine maintenance, such as cleaning, lubricating, and inspection, in the hands of operators.	• Gives operators greater "ownership" of their equipment. • Increases operators' knowledge of their equipment. • Ensures equipment is well-cleaned and lubricated. • Identifies emergent issues before they become failures. • Frees maintenance personnel for higher-level tasks.
Planned Maintenance	Schedules maintenance tasks based on predicted and/or measured failure rates.	• Significantly reduces instances of unplanned stop time. • Enables most maintenance to be planned for times when equipment is not scheduled for production. • Reduces inventory through better control of wear-prone and failure-prone parts.

Pillar	What Is It?	How Does It Help?
Quality Maintenance	Design error detection and prevention into production processes. Apply Root Cause Analysis to eliminate recurring sources of quality defects.	• Specifically targets quality issues with improvement projects focused on removing root sources of defects. • Reduces the number of defects. • Reduces cost by catching defects early (it is expensive and unreliable to find defects through inspection).
Focused Improvement	Have small groups of employees work together proactively to achieve regular, incremental improvements in equipment operation.	• Recurring problems are identified and resolved by cross-functional teams. • Combines the collective talents of a company to create an engine for continuous improvement.
Early Equipment Management	Directs practical knowledge and understanding of manufacturing equipment gained through TPM towards improving the design of new equipment.	• New equipment reaches planned performance levels much faster due to fewer startup issues. • Maintenance is simpler and more robust due to practical review and employee involvement prior to installation.

Pillar	What Is It?	How Does It Help?
Training and Education	Fill in knowledge gaps necessary to achieve TPM goals. Applies to operators, maintenance personnel, and managers.	• Operators develop skills to routinely maintain equipment and identify emerging problems. • Maintenance personnel learn techniques for proactive and preventative maintenance. • Managers are trained on TPM principles as well as on employee coaching and development.
Safety, Health, Environment	Maintain a safe and healthy working environment.	• Eliminates potential health and safety risks, resulting in a safer workplace. • Specifically targets the goal of an accident-free workplace.
TPM in Administration	Apply TPM techniques to administrative functions.	• Extends TPM benefits beyond the plant floor by addressing waste in administrative functions. • Supports production through improved administrative operations (e.g. order processing, procurement, and scheduling).

OEE AND THE SIX BIG LOSSES

Introduction to OEE

OEE (Overall Equipment Effectiveness) is a metric that identifies the percentage of planned production time that is truly productive. It was developed to support TPM initiatives by accurately tracking progress towards achieving "perfect production".

- An OEE score of 100% is perfect production.
- An OEE score of 85% is world class for discrete manufacturers.
- An OEE score of 60% is fairly typical for discrete manufacturers.
- An OEE score of 40% is not uncommon for manufacturers without TPM and/or lean programs.

OEE consists of three underlying components, each of which maps to one of the TPM goals set out at the beginning of this topic, and each of which takes into account a different type of productivity loss.

Component	TPM Goal	Type of Productivity Loss
Availability	No Stops	Availability takes into account **Availability Loss**, which includes all events that stop planned production for an appreciable length of time (typically several minutes or longer). Examples include Unplanned Stops (such as breakdowns and other down events) and Planned Stops (such as changeovers).
Performance	No Small Stops or Slow Running	Performance takes into account **Performance Loss**, which includes all factors that cause production to operate at less than the maximum possible speed when running. Examples include both Slow Cycles and Small Stops.
Quality	No Defects	Quality takes into account **Quality Loss**, which factors out manufactured pieces that do not meet quality standards, including pieces that require reworking. Examples include Production Rejects and Reduced Yield on startup.
OEE	Perfect Production	OEE takes into account all losses (Availability Loss, Performance Loss, and Quality Loss), resulting in a measure of truly productive manufacturing time.

As can be seen from the above table, OEE is tightly coupled to the TPM goals of No Breakdowns (measured by Availability), No Small Stops or Slow Running (measured by

Performance), and No Defects (measured by Quality).

It is extremely important to measure OEE in order to expose and quantify productivity losses, and in order to measure and track improvements resulting from TPM initiatives.

Benefits of Automated OEE Tracking

Manually calculating OEE is a great way to start. It can be done with pencil and paper or with a simple spreadsheet, and only five pieces of data are needed (Planned Production Time, Stop Time, Ideal Cycle Time, Total Count, and Good Count). Performing manual OEE calculations helps reinforce the underlying concepts and provides a deeper understanding of OEE. However, there are also very strong benefits to quickly moving to automated OEE data collection:

Item	Benefit
Stop Time	The accuracy of manual unplanned stop time tracking is typically in the range of 60 to 80% (based on real-world experience across many companies). With automatic Run/Down detection, this accuracy can approach 100%.
Small Stops and Slow Cycles	For most equipment it is impossible to manually track slow cycles and small stops. This means that a great deal of potentially useful information, such as time-based and event-based loss patterns, is not available.
Operator Focus	With automated data collection the operator spends more time focused directly on the equipment (versus spending time on paperwork).
Real-Time Results	Automated data collection provides results in real-time, enabling improvement techniques such as SIC (Short Interval Control).

Creating a “Best of the Best” OEE Goal

An interesting question is how to set an effective “stretch” goal for OEE. As it happens, there is an excellent technique for doing so-called “Best of the Best”. Here is how it works:

1. Track OEE (including Availability, Performance, and Quality) for the target equipment for one month. Make sure to compile the results by shift.
2. Review every shift result, keeping track of the best individual result for Availability, Performance, and Quality across all shifts (i.e. the highest Availability score across

all shifts, the highest Performance score across all shifts, etc.).

3. Multiply the best individual results together to calculate a "Best of the Best" OEE score.

This newly calculated "Best of the Best" OEE score represents the stretch goal – derived from the best results actually achieved across the month for Availability, Performance, and Quality.

Understanding the Six Big Losses

OEE loss categories (Availability Loss, Performance Loss, and Quality Loss) can be further broken down into what is commonly referred to as the Six Big Losses – the most common causes of lost productivity in manufacturing. The Six Big Losses are extremely important because they are nearly universal in application for discrete manufacturing, and they provide a great starting framework for thinking about, identifying, and attacking waste (i.e. productivity loss).

Six Big Losses	OEE Category	Examples	Comments
Unplanned Stops	Availability Loss	Tooling Failure, Unplanned Maintenance, Overheated Bearing, Motor Failure	There is flexibility on where to set the threshold between an Unplanned Stop (Availability Loss) and a Small Stop (Performance Loss).
Setup and Adjustments	Availability Loss	Setup/Changeover, Material Shortage, Operator Shortage, Major Adjustment, Warm-Up Time	This loss is often addressed through setup time reduction programs such as SMED (Single-Minute Exchange of Die).
Small Stops	Performance Loss	Component Jam, Minor Adjustment, Sensor Blocked, Delivery Blocked, Cleaning/Checking	Typically only includes stops that are less than five minutes and that do not require maintenance personnel.
Slow Running	Performance Loss	Incorrect Setting, Equipment Wear, Alignment Problem	Anything that keeps the equipment from running at its theoretical maximum speed.
Production Defects	Quality Loss	Scrap, Rework	Rejects during steady-state production.

Six Big Losses	OEE Category	Examples	Comments
Reduced Yield	Quality Loss	Scrap, Rework	Rejects during warm-up, startup or other early production.

SIMPLIFIED ROADMAP

An excellent way to get a deeper understanding of TPM is to walk through an implementation example. This section provides a step-by-step roadmap for a simple and practical TPM implementation.

Step One – Identify Pilot Area

In this step, the target equipment for the pilot TPM program is selected. There are three logical ways to approach this selection.

Which Equipment?	Pros	Cons
Easiest to Improve	• Best opportunity for a "quick win". • More forgiving of limited TPM experience.	• Less payback than improving constraint equipment. • Does not "test" the TPM process as strongly as the other options.
Constraint/Bottleneck	• Immediately increases total output. • Provides the fastest payback.	• Working on a critical asset as a trial project is a higher risk option. • May result in equipment being offline more than desired as it is improved.

Which Equipment?	Pros	Cons
Most Problematic	• Improving this equipment will be well-supported by operators. • Solving well-known problems will strengthen support for the TPM project.	• Less payback than improving constraint equipment. • Unsolved problems are often unsolved for a reason – it may be challenging to get good results.

Here are some additional guidelines:

- For a company with limited TPM experience and/or support (whether through internal staff or external consultants) the best choice is usually the Easiest to Improve equipment.
- For a company with moderate or strong TPM experience and/or support (whether through internal staff or external consultants) the best choice is almost always the Constraint/Bottleneck equipment. The key is to minimize potential risk by building temporary stock and otherwise ensuring that unanticipated stop time can be tolerated.
- Teams often gravitate to selecting the Most Problematic equipment. This, however, is rarely the best choice (unless it happens to also be the Constraint/Bottleneck).

In order to create a wide base of support for the TPM project, make sure to include the full spectrum of associated employees (operators, maintenance personnel, and managers) in the selection process, and work hard to create a consensus within the group as to the equipment selection choice.

Once the pilot area has been selected, create a local visual focus for the project (e.g. a project board) where plans and progress updates can be posted.

Step Two – Restore Equipment to Prime Operating Condition

In this step, the equipment will be cleaned up and otherwise prepped for improved operation. Two key TPM concepts will be introduced:

- 5S
- Autonomous Maintenance

First, a 5S program should be initiated (including both operators and maintenance personnel).

Item	Description
Photograph	Take photographs that capture the initial state of the equipment and post them on the project board.
Clear Area	Clear the area of debris, unused tools and components, and any other items that are not needed.
Organize	remaining tools and components onto shadow boards (boards containing outlines as visual cues).
Clean Up	Thoroughly clean the equipment and surrounding area (including residue from any leaks or spills).
Photograph	Take photographs that capture the improved state of the equipment and post them on the project board.
Checklist	Create a simple 5S checklist for the area (creating Standardized Work for the 5S process).
Audit	Schedule a periodic audit (first daily, then weekly) to verify that the 5S checklist is being followed. During the audit, update the checklist as needed to keep it current and relevant. Keep audits positive and motivational (treat them as a training exercise).

Next, an Autonomous Maintenance program should be initiated. Strive to build a consensus between operators and maintenance personnel on which recurring tasks can be productively performed by operators. In many cases, light training will be required to bring up the skill level of operators.

Item	Description
Inspection Points	Identify and document key inspection points (all wear parts should be included). Consider creating a map of inspection points as a visual aid.
Visibility	Replace opaque guarding with transparent guarding in cases where inspection points are obscured (where feasible and safe to do so).

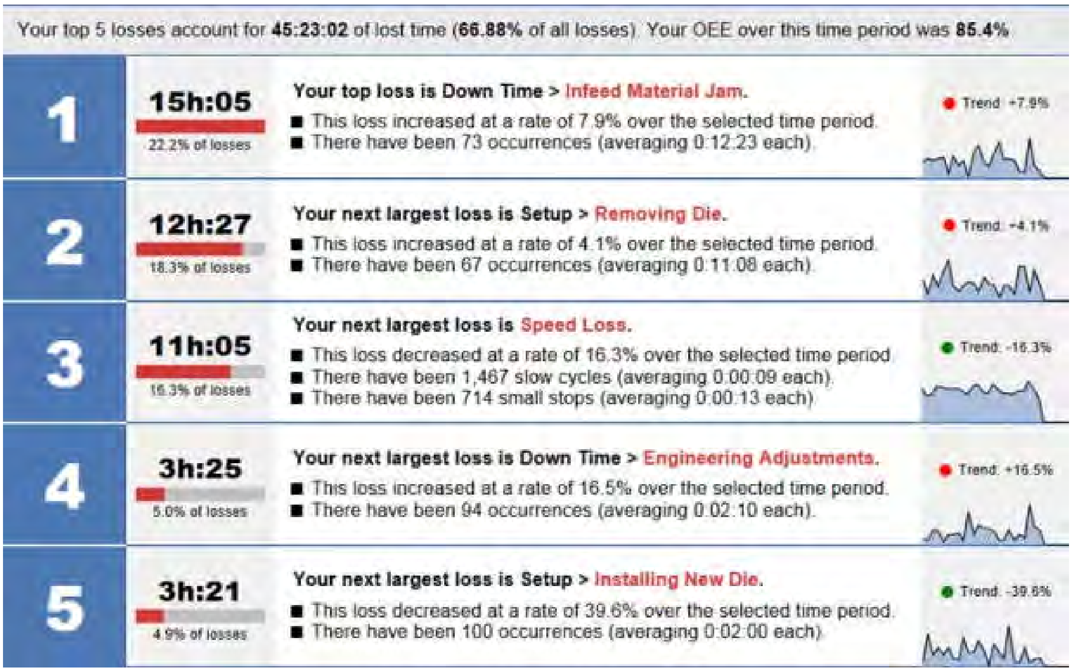
Item	Description
Set Points	Identify and document all set points and their associated settings. Consider indicating settings directly on the equipment as a visual aid for inspection and auditing.
Lubrication Points	Identify and document all lubrication points. Schedule lubrication to occur during changeovers or other planned stops (in other words, avoid creating new sources of unplanned stop time). Consider externalizing lubrication points that are difficult to access or that require stopping the equipment (where feasible and safe to do so).
Operator Training	Train operators to bring any anomalies or emerging conditions to the attention of the line supervisor.
Create Checklist	Create a simple Autonomous Maintenance checklist for all inspection, set point, lubrication, and other operator-controlled maintenance tasks (creating Standardized Work for the Autonomous Maintenance process).
Audit	Schedule a periodic audit (first daily, then weekly) to verify that the Autonomous Maintenance checklist is being followed. During the audit, update the checklist as needed to keep it current and relevant. Keep audits positive and motivational (treat them as a training exercise).

Step Three – Start Measuring OEE

In this step, a system is put into place to track OEE for the target equipment. This system can be manual (refer to www.oee.com for detailed information about performing manual OEE calculations)

For most equipment, the largest losses are a result of unplanned stop time. Therefore, it is strongly recommended to categorize each unplanned stop event to get a clear picture of where productive time is being lost. It is also recommended to include a category for "unallocated" stop time (i.e. stop time where the cause is unknown). Providing a category for unallocated stop time is especially important with manually tracked OEE. It improves accuracy by providing operators with a safe option when the stop time reason is not clear.

Data should be gathered for a minimum of two weeks to identify recurring reasons for equipment unplanned stop time, and to identify the impact of small stops and slow cycles. Review the data during each shift to ensure that it is accurate and to verify that the true causes of unplanned stop time are being captured.



A Top Loss chart is an excellent way to visualize the reasons for lost production. In this example, the top loss is an unplanned stop event called "Infeed Material Jam".

Step Four – Address Major Losses

In this step, the most significant sources of lost productive time are addressed. The TPM concept of Focused Improvement (also known as kaizen) is introduced.

Item	Description
Select Loss	Based on equipment-specific OEE and stop time data, select one major loss to address. In most cases, the major loss that is selected should be the largest source of unplanned stop time.
Create Team	Create a cross-functional team to address the problem. This team should include four to six employees (operators, maintenance personnel, and supervisors) with the best equipment knowledge and experience…and that are likely to work well together.
Collect Information	Collect detailed information on symptoms of the problem, including observations, physical evidence, and photographic evidence. Consider using an Ishikawa (fishbone) diagram at the equipment to collect observations.
Organize	Organize a structured problem solving session to: a) identify probable causes of the problem, b) evaluate probable causes against the gathered information, and c) identify the most effective fixes.
Schedule	Schedule planned stop time to implement the proposed fixes. If there is an existing change control process, be sure to utilize that process when implementing fixes.

Item	Description
Restart	Restart production and determine the effectiveness of the fixes over an appropriate time period. If sufficiently effective, document any changes to procedures and move on to the next major loss. Otherwise, collect additional information and organize another structured problem solving session.

During this step, OEE data should continue to be carefully reviewed each shift to monitor the status of losses that have already been addressed, as well as to monitor overall improvements in productivity.

Step Five – Introduce Proactive Maintenance Techniques

In this step, proactive maintenance techniques are integrated into the maintenance program (thus introducing the TPM concept of Planned Maintenance).

First, identify all components that are candidates for proactive maintenance:

Item	Description
Components that Wear	Identify and document all components that undergo wear (these should have been established as inspection points in Step Two). Consider replacing wear components with low-wear or no-wear versions.
Components that Fail	Identify and document all components that are known to regularly fail.
Stress Points	Consider utilizing thermography and/or vibration analysis to provide additional insights as to equipment stress points.

Next, establish initial proactive maintenance intervals:

Item	Description
Wear Based	For wear components, establish the current wear level and a baseline replacement interval (in some cases replacement may be triggered early by an Autonomous Maintenance inspection as established in Step Two).
Predicted Failure Based	For failure-prone components, establish a baseline (predicted) failure interval.
Time Based	Create a baseline Planned Maintenance Schedule that schedules proactive replacement of all wear and failure-prone components. Consider using "Run Time" rather than "Calendar Time" as the interval time base.

Item	Description
Work Order Based	Create a standard process for generating Work Orders based on the Planned Maintenance Schedule.

Next, create a feedback system for optimizing the maintenance intervals:

Item	Description
Component Log	Create a Component Log sheet for each wear and failure-prone component. Record every instance of replacement, along with information about the component condition at the time of replacement (e.g. wear amount, "component failed", "no observable issues", etc.).
Monthly Audit	Perform a monthly Planned Maintenance audit: a) verify that the Planned Maintenance Schedule is being followed, b) verify that the Component Log sheets are being maintained, and c) review all new entries in the Component Log and adjust maintenance intervals where appropriate. Keep audits positive and motivational (treat them as a training exercise).
Maintenance Interval Adjustments	Anytime there is an unscheduled component replacement, consider adjusting the maintenance interval. If the component is not on the Planned Maintenance Schedule, consider adding it.
Component Analysis	Consider plotting data over time from thermography and vibration analysis to expose emerging problems and issues.

ADDITIONAL TPM ACTIVITIES

The Simplified Roadmap is optimized to provide an incremental, step-by-step approach to implementing TPM. So, what comes next in the TPM journey?

There are an additional four TPM activities that are not within the scope of the Simplified Roadmap. The question then becomes, when should these activities be introduced? In keeping with the incremental, step-by-step approach, selection of new activities should be prioritized based on whatever is the most pressing and urgent need.

TPM Activity	Introduce When…
Quality Maintenance	Quality is at the forefront of issues facing the company. This may be a result of a) significant customer issues being raised over quality or b) significant internal concerns being raised over quality (e.g. unsatisfactory first-pass yield).

TPM Activity	Introduce When…
Early Equipment Management	New equipment is being designed or installed in a constraint/bottleneck area.
Safety, Health, Environment	The company a) has no substantive Safety, Health, Environment program, or b) the existing program would significantly benefit from being linked into existing TPM activities.
TPM in Administration	Administrative issues (e.g. delays in processing customer orders or invoices, issues with part procurement) are one of the largest impediments to smoothly running production.

SUSTAINABLE IMPROVEMENT

One of the greatest challenges at any company is how to achieve sustainable improvement. This includes both a) achieving short-term success and b) maintaining that success over the long-term. This section outlines four techniques for achieving sustainable improvement.

- Engaging Employees
- Succeeding Early
- Providing Active Leadership
- Evolving the Initiative

Engaging employees is important for both short-term and long-term success of initiatives. A powerful technique for engaging employees is creating a shared vision of the future "improved" state of the company – and clearly outlining how it will benefit employees. This will create a strong, broad-ranging motivation to succeed. Another powerful technique is recognizing and rewarding desired behavior. In the context of TPM, this may include providing a monthly rotating trophy for the Best 5S Area or awarding gift certificates each month for the Biggest Kaizen Improvement.

Succeeding early helps to ensure long-term success by building momentum behind the initiative. By way of contrast, if an initiative is perceived as having been tried and failed, it will be much harder to successfully implement that initiative in the future.

Providing active leadership is one of the primary responsibilities of senior management (up to and including the Plant Manager). It means regularly demonstrating the importance of TPM activities through words and actions. Active leadership combats the natural tendency of employees to drift back into old patterns of behavior and old ways of working. It continually feeds new energy into the initiative, which over time is absorbed by employees in the form of new engrained behaviors.

Evolving the initiative applies continuous improvement techniques to ensure that it does not become stale and that employees do not become complacent. The goal is to keep the initiative fresh and interesting. Evolving the initiative also helps to ensure that it thrives over the long-term by constantly adapting it to a changing environment.

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