The Lean Journey

Total Productive Manufacturing…the evolution of a maintenance based tool to a critical operational construct. By Gregg Messel, Robert Burke, and Patrick Lucansky

Traditionally, the role of maintenance has been to fix the equipment when it broke down. This "*reactive*" mode means that the machine always seems to be broke at the "worst possible time". Some companies truly have no time for maintenance (machine run time meets or exceeds available time) while most others have a perception of no time available to maintain. This perception is a false when in reality the time is being consumed by other non-value-adding activities. Moreover, time is rarely scheduled to perform normal maintenance activities; activities which would keep the equipment performing at designed specifications.

Many organizations began their corrective efforts by embracing Total Preventive Maintenance (where the focus was on the "6 Major-Losses") which evolved into Total Predictive Maintenance, where conditioned-based monitoring along with maintenance tracking software was utilized. These two maintenance philosophies helped management see the benefit of bringing manufacturing people into the process to assist with planned maintenance or Total Productive Maintenance. Ultimately, management realized the need to have operators responsible for day-to-day maintenance of monitoring, basic lubrication, adjusting and routine cleaning of equipment. Maintenance is now responsible for refining the predictive monitoring and trending performance of the equipment or Total Productive Manufacturing (see figure 1).

Figure 1

- ***Total Preventive Maintenance***
  Regularly scheduled maintenance following manufacturers guidelines. The lubrication, general care, and parts replacement by maintenance personnel, normally with little or no input from manufacturing.
- ***Total Predictive Maintenance***
  This form of maintenance evolved with the use of mean-time between failure (MTBF), mean time to repair (MTTR) and personal computers as a condition-based monitoring tool (temperature, vibration, etc.) along with maintaining accurate records of equipment repairs. This allowed maintenance personnel to predict and pre-plan equipment failures.
- ***Total Productive Maintenance***
  Total Productive Maintenance began with the utilization of production personnel in the daily maintenance of the equipment. During planned equipment shutdowns, production members clean, paint and lubricate the equipment. Maintenance personnel continue to perform the major repair and maintenance work.
- ***Total Productive Manufacturing***
  Total Productive Manufacturing utilizes manufacturing personnel as the front line to improve and maintain equipment. Operators write work orders, monitor their own equipment and are consulted prior to maintenance shutdown for input to the schedule. Additionally, operator's are involved in continuous improvement of equipment uptime-time and operation. Maintenance personnel train operators, receive input and discuss data generated by condition-based monitoring to ensure a thorough and effective maintenance operation is performed.

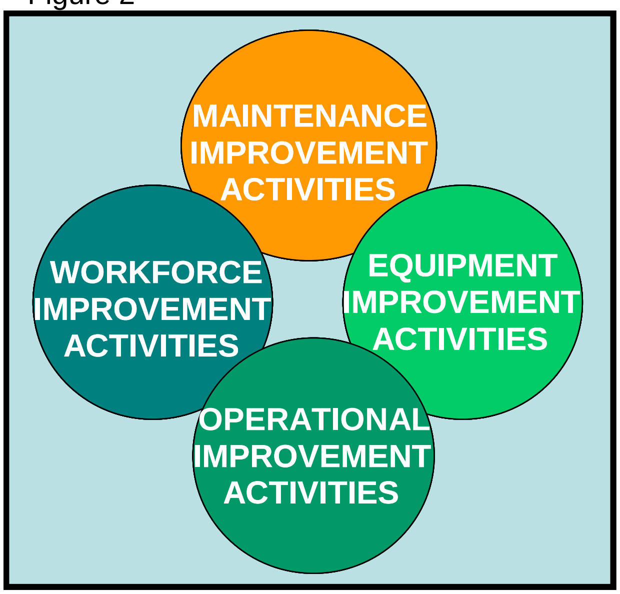
Historically, production divorced them selves from any responsibility for maintaining equipment; after all, their job was to run the equipment.

What is Total Productive Manufacturing?

Total Productive Manufacturing (TPM) is the marriage between maintenance and production, two dissimilar groups who work together everyday but who often times may have different and even opposing goals and objectives. In its simplest form, maintenance maintains the equipment and manufacturing runs the equipment. TPM is about total participation by the operators, maintenance personnel, management, and engineering. TPM is not solely about maintenance (see figure 1 for a distinction between ideologies). It incorporates a customer-focused approach aimed at satisfying the needs of both the customer and the company. In essence, TPM has four main objectives, (1) fundamentally change the culture, (2) optimization of processes and equipment effectiveness, (3) involvement of all employees in the process and (4) a proactive process to operations and equipment maintenance. The key concepts to making TPM a sustainable tool is to find *optimal* rather than *acceptable* conditions where actions are focused on understanding machine principles and mechanisms, taking all losses seriously, measuring performance accurately and tracking results.

In a Total Productive Manufacturing environment productions' responsibility is to produce product at the correct quantity, quality, cost and price. On the other hand, the responsibility of maintenance is to ensure the equipment is available to run at optimum levels of productivity, quality and quantity with minimal planned and unplanned downtime. This marriage ensures having a common goal (Figure 2) of meeting customer demand where optimization of equipment, materials and employees is crucial.

Figure 2



By uniting production and maintenance with a common goal, companies are realizing increased cooperation, productivity and quality, lower costs, cleanliness, and ultimately a team approach to maintaining equipment. By having the two groups working together there is an increased effort to not only repair and maintain equipment but to improve its capability. It is a partnership aimed at improving or eliminating the nine major categories of equipment losses (Figure 3). Traditional TPM programs identified six losses (1) unexpected breakdowns (2) set-up and adjustments (3) minor stoppages (4) speed loss (5) defects and rework and (6) yield. Total Productive Manufacturing adds (7) Planned Down-time, (8) Idle Time and (9) Engineering/Validation loss.

Why Total Productive Manufacturing?

Traditionally, when a machine breaks down the impact is rarely felt up or downstream in the near term since upstream operations have space to store components and downstream operations have high levels of in-process material to run from stock. However, as the downtime lengthens upstream processes run out of space to store material and eventually shut down. In regulated industries this may mean split lots or spoiled work. Similarly, downstream processes starve due to lack of parts and are forced to shut down.

As companies move toward lean enterprise, works cells and flow manufacturing, a single breakdown has an immediate impact of stopping the entire process and affects the entire system's performance immediately. In a lean enterprise, operations generally cannot be moved to another machine and there is no inventory to keep other machines in the cell running. This forces the operation to deal with the breakdown immediately and put measures in place to prevent a reoccurrence.

Figure 3

- **Unplanned Downtime:** equipment breakdown which requires repair, waiting for maintenance, parts and ends when equipment is ready to run
- **Planned Downtime:** any scheduled maintenance activity, including cleaning, inspection, preventive maintenance, equipment upgrade, all wait times and ends when equipment is ready to run
- **Set-up time:** time spent changing over to the next product, process or recipe and includes the time from the last good product produced to the first good piece of the next product produced
- **Minor stoppages:** stoppages that can be resolved by the operator within 6 minutes
- **Idle Time:** occurs when there is no work, no operator available on bottlenecked equipment
- **Speed Loss:** the difference between the optimal running speed and the current running speed
- **Engineering or Validation Runs:** includes all non-productive activity which includes the time from the last good piece from the prior production run to the first good piece of the next product run
- **Rework and Scrap:** expressed in equivalent time to produce all units requiring rework or scrapped, includes all downstream activities impacted by the rework or scrap
- **Quality Time Loss:** the time the process is stopped to correct non-compliant issues, inspecting and accepting non-compliant product produced

Equipment performance is especially critical to pharmaceutical and medical device manufacturers where products have been validated on specific equipment and cannot simply be shifted to another machine. Variations in equipment performance may adversely affect the finished product in meeting its predetermined specifications and quality attributes. Poor equipment performance may require re-validation or at a minimum re-verification of the process. Major equipment breakdowns will require re-validation to ensure that the process or product will meet all functional and safety requirements of the design specifications. TPM now becomes mandatory in supporting the organization and lean enterprise.

Change Required for Total Productive Manufacturing Thinking

In order for a company to move from a preventive to a productive program, the focus should be on identifying the causes for the high frequency of breakdowns (i.e. equipment dependability, see figure 4) and the reasons for long repair times (i.e. maintainability).

Two indicators of equipment performance) widely used are Mean Time Between Failure (MTBF) and Mean Time To Repair (MTTR). MTBF indicates the dependability of the equipment. The more dependable the equipment, the longer the time it runs between failures. MTTR indicates the maintainability of the equipment. Equipment with better maintainability is easier to repair and requires less time for repairs.

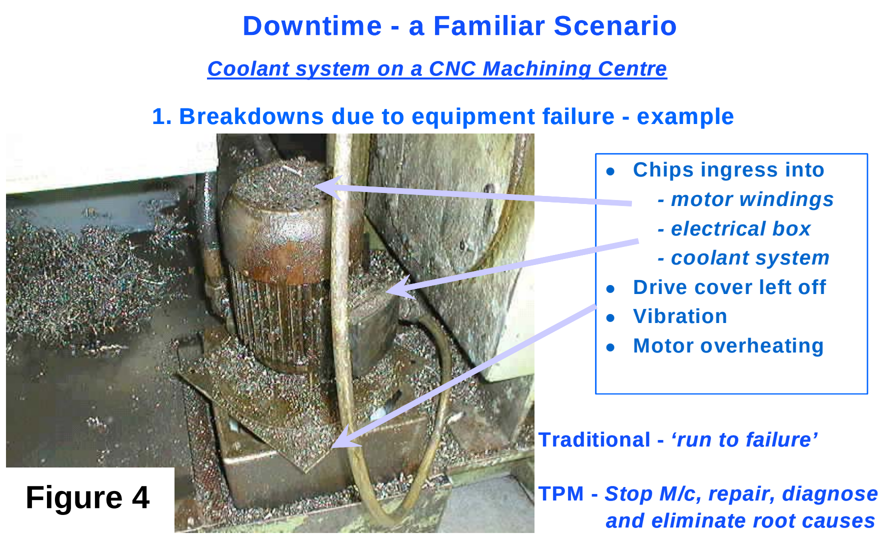


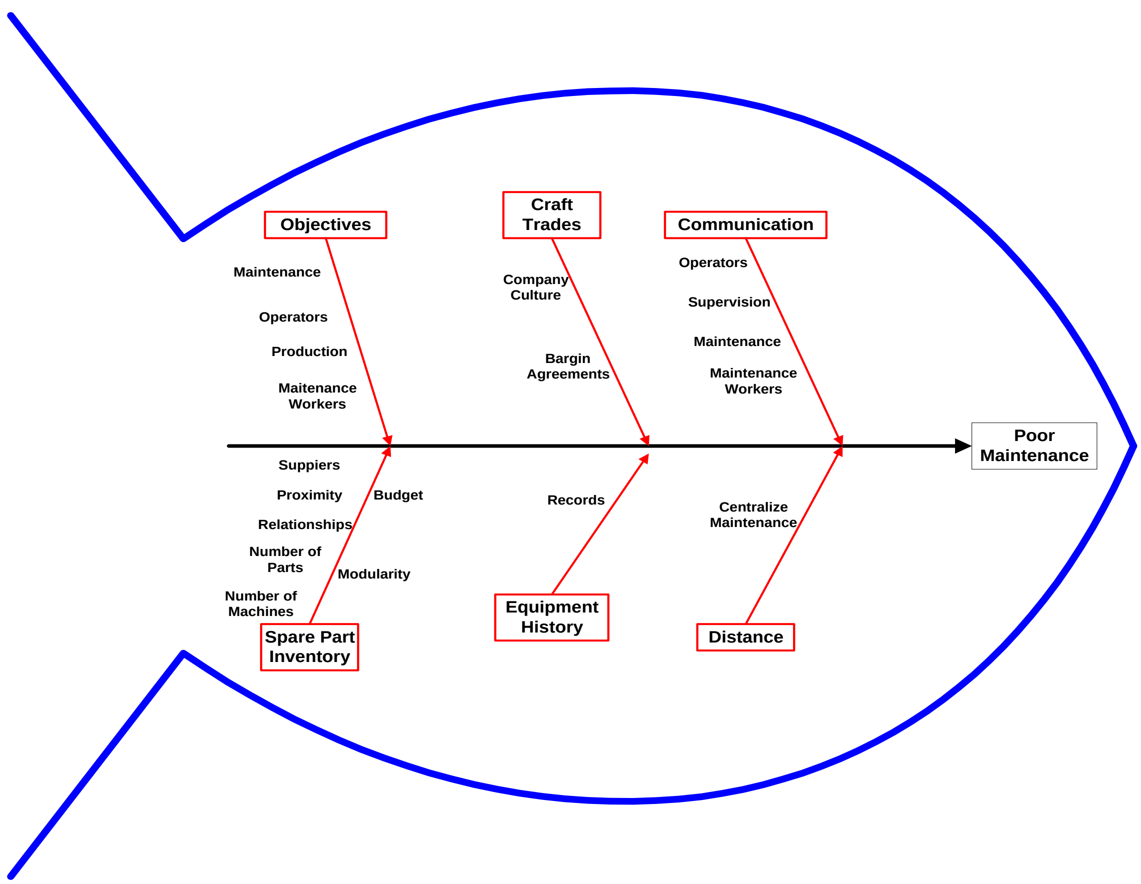
Figure 4

There are four main categories for high frequency of equipment breakdowns: 1) the way the equipment is used, 2) the level of maintenance, 3) equipment complexity, and 4) equipment design.

1. *The way equipment is used.* Equipment used above or out-of manufacture's specifications can be attributed to the frequency of breakdowns. It is not uncommon to see production requirements causing equipment to be used outside its specified designed characteristics. Equipment that is used beyond specified limits must be monitored more closely than those used normally.
2. *The level of maintenance.* Many organizations still believe it is better to wait until components break down before replacing them. When equipment is regularly lubricated and parts (such as bearings and other components subject to wear) are changed on a timely basis, equipment stoppages are can be significantly reduced.
3. *The complexity of the equipment.* Equipment composed of hundreds or thousands of components are more likely to break down than simple machines with fewer components. This does not mean that higher breakdown rates occur from increased automation, but rather from the higher level of complexity. The integration of numerous complex components into a single system increases the risk of failure.
4. *The robustness of equipment design.* How well does the equipment perform under extreme conditions? It is important to know the extent of the conditions and ranges the equipment was designed to perform under. Operating outside of these ranges increases risk of malfunction.

Repair times are also affected by equipment design, accessibility to parts, and ease of disassembly and reassembly of components. However, the major contributor to long repair times is poorly organized maintenance activities. The use a fishbone diagram can dramatically reduce the causes of long repair times (See Figure 5).

Figure 5



The six key elements of the fishbone diagram are:

Communications. Poor communications between operations and maintenance results in longer than required repair times. Typically, it is not uncommon to see several waves of people converge on a machine after a report or observation of a breakdown before a qualified maintenance personnel are notified. Supervisors are notified and operators cannot direct call the maintenance department. This only prevents a fast diagnosis and resolution to problems.

Craft Trades. Rigid craft classifications (like union job classifications) prevent maintenance flexibility and lengthen repair times. Most breakdowns that occur routinely are not complex and do not require specialized knowledge they do however require a good knowledge base in every field.

Objectives. Between maintenance and operations, goals and objectives are not always in alignment and often are contrary to meeting customer needs. Many companies still operate in functional silos. Production workers are not encouraged to prevent breakdowns. Maintenance personnel do not feel the need to consider production priorities and are not encourage to speed up the repairing of critical equipment.

Distance. Locations of parts are often not co-located where needed most. Maintenance workers can waste a lot of time traveling back and forth between machines and the maintenance base resulting in long repair times.

Equipment history. Not keeping equipment records increases breakdown rates and repair times. As a result, when maintenance is called to repair a machine, they often have no idea what the frequency of that problem is, who last repaired the machine, last service dates and/or scheduled maintenance which is especially crucial in multi-shift companies. It is critical to keep good records of equipment breakdowns, changed parts, last check-up dates, MTBF, MTTR, PM operations and other events.

Spare part inventory. Critical parts inventory are often not stocked in-house due to financial constraints. Furthermore, since they are specific to each machine their ability to interchange is minimal. Equipment purchasing and availability of spare parts have can have a negative impact on repair times. Since it is not unusual for companies to have a large number of machines with low-modularity that are purchased from a wide-variety of OEM's, the ability to interchange parts is limited at best. Typically, maintenance budgets allow storing of only the barest minimum of spare parts and vendors can't be relied upon for rush delivery. When buying equipment, companies rarely consider a vendor's location or a distributor's efficiency of delivery.

The New TPM Organization

The new organization serves two major purposes: (1) to optimize the maintenance response time when equipment breaks down, and (2) to increase the level of cooperation and trust between operators and maintenance personnel. Two key aspects emerge with the new organization: (1) specialized maintenance workers by craft trades is reduced or eliminated and (2) equipment maintenance operations are decentralized.

As Total Productive Manufacturing takes hold, organizations can expect to see common goals and objectives across departments, more focus on customer needs, and a coordinated effort. Their efforts should relate to reducing any of the nine losses identified in figure 3. Maintenance and manufacturing personnel are now willing to share, listen, and support improvement suggestions and ideas. Operators are now held responsible for maintaining their equipment and begin to take ownership in it's' performance. Spare time is now used for cleaning and improving the work area and attention is focused on anticipating problems. What is missing is the usual finger pointing and blame-oriented culture.

TPM is not just for the shop floor. The methodology can be applied in all areas of the company including quality laboratories, engineering departments, research labs and the general office. Any area where equipment such as, copiers, measuring instruments, computers, and telecommunications equipment is used lend itself to improvements with TPM.

Continuing the Change and Sustaining the Gain

As operators are given more responsibility in maintaining the equipment, they are also given the opportunities to improve the way maintenance operations are performed and suggest equipment modifications that will facilitate maintenance. Operators and maintenance personnel work together to identify ways to continually improve existing equipment performance.

For this program to survive, a cultural change must occur. Production and maintenance must think as a team with one true purpose, meeting customer demand profitably. Moreover, sustainability will occur when everyone believes in the program, realizes the benefits and takes ownership of the process. Key performance Indicators (KPI's) are a useful tool to monitor progress and continually remind everyone what is at stake.

Benefits

TPM programs provide organizations with four broad benefits (1) focused management (maintenance and operations), (2) training systems, (3) audit and diagnosis tools, and (4) reduced process variability. Companies can realize these benefits through incorporating a disciplined Corrective Action Preventive Action (CAPA) program into their SOP's, ISO and GMP's. On a micro-level, TPM provides for enhanced equipment performance resulting in lead-time reductions, increased flexibility and proactive centered-maintenance. Operators know their equipment / process and use root-cause analysis to identify and resolve issues (See figure 6.)

Category	Examples of TPM Effectiveness
Productivity	AVERAGE 30% ↑
Defects/Rework	AVERAGE 70% ↓
Cost	AVERAGE 30% ↓
Output	AVERAGE 30% ↑
Breakdowns	AVERAGE 80% ↓
Morale	SUBSTANTIAL ↑

Figure 6

Summary

Total Productive Manufacturing is a larger concept than its predecessors where the focus is now on the customer, the organization and people. TPM is a way to involve the whole organization in identifying, resolving and preventing issues, which ultimately impact the customer. The four main objectives of culture change, optimized processed and equipment, employee involvement and proactive processes provide organizations the essential basics to reduce the biggest company loss…human loss. Organizations need to involve, engage and respect their workforce, give them a reason not to leave, instill "ownership" and "mutual accountability" of equipment and processes and finally they need to listen to their suggestions and respond. It is a journey taking years to implement fully and effectively. It requires additional training for the machine operators and maintenance mechanics. This will be a win-win situation for the customer, the company and the employees.

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