

TPM AND LEAN MAINTENANCE – A CRITICAL REVIEW

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Abstract

In today's global economy an increasing search is on for methods and processes that drive improvements in quality, costs and productivity. TPM has been identified as a best in class manufacturing improvement process, along with the "LEAN" phenomenon that has allowed manufacturing industries to greatly increase their levels of profitability and productivity. Lean maintenance, combined with other initiatives, such as Total Productive Maintenance, has allowed these companies to focus on the efficiency of their production processes. However, Lean maintenance is neither a subset nor a spin-off of lean manufacturing; it is instead a prerequisite for success as a lean manufacturer that provides a holistic approach to the function of maintenance. Lean maintenance approach cannot just be a mirror image of a lean production approach because the business dynamics of asset maintenance and those of production are fundamentally different. This paper highlights this fact and discusses that to deliver "productivity without waste," or efficiency, in asset maintenance, there is a need of a different version of LEAN; one that takes into account the unique business dynamics of the area that the businesses work in.

Key Words: *Total Productive Maintenance, Lean Maintenance, Productivity without Waste*

1. Introduction

In today's global economy, the survival of companies depends on their ability to rapidly innovate and improve. As a result, an increasing search is on for methods and processes that drive improvements in quality, costs and productivity. In today's fast changing marketplace, slow, steady improvements in manufacturing operations will not guarantee profitability or survival. Companies must improve at a faster rate than their competition if they are to become or remain leaders in their industry.

Western products, practices and methods were long considered the best in the world. This perception is constantly changing as a result of new competition and economic pressures. Arrogance or self assurance has devastated specific sectors of western manufacturing base. For example, the Japanese now own the consumer electronics industry. Changes in the automotive industry are well documented, and for the first time Western dominated industry such as computers and aviation are facing serious challenges by foreign competitors. Other companies and cultures have proven they can compete successfully in the world marketplace with western manufacturing. To confront this challenge, enlightened company leaders are benchmarking their organizations' performance and improvement processes against domestic and international competitors. They are adopting and adapting best in class: manufacturing practices and improvement processes. As part of these benchmarking efforts Total Productive Maintenance (TPM) has been identified as a best in class manufacturing improvement process. TPM is a complex, Long term process which must be sold to the workforce as a legitimate

improvement methodology. For TPM to succeed in any industry, both management and the workforce must address issues strategically while operating in an environment of trust and organization. The improvement process must be recognized as benefiting both the company and the workers. The ultimate responsibility for success or failure of the TPM process rests more with management than the plant floor employees.

TPM took root in the automobile industry and rapidly became part of the corporate culture in companies such as Toyota, Nissan, and Mazda as well as their suppliers such as Nippondenso. It has also been introduced by other industries such as consumers, appliances, microelectronics, machine tools, plastics and many others. Having introduced Preventive Maintenance, the process industries then began to implement TPM. There have been a few studies done in the area of TPM to investigate the TPM relationship with manufacturing performance and business performance, for instance: Brah & Chong (2004); Seth & Tripathi (2005); Tsarouhas, 2007; Ahuja & Khamba, 2007; Ahuja & Kumar, 2009; Damiana & Ghirardo, 2010. Moreover, some studies have been done that deal with the TPM implementation issues; studies were related to the benchmarking of implementation practices to explore key areas (Damiana & Ghirardo, 2010), identification of critical factors (Seth & Tripathi, 2005); and strategies to support its implementation (Seng *et al.*, 2005); and organization's inability to obviate resistance to change (Ahuja & Khamba, 2008 b). The relationship of TPM with business performance has also been addressed in some studies (Bamber, Sharp & Hides, 1999; Cooke, 2000; Tsang & Chan, 2000; Jurice *et al.*, 2006).

Initially, corporate TPM activities were limited to departments directly involved with equipment such as production, however administrative and support departments, while actively supporting TPM in production, are now applying TPM to enhance the effectiveness of their own activities. TPM improvement methods and activities are also being adopted in product development and sales department. This last trend underlines the increasing tendency to consider production processes and equipment at the product development stage in an effort to simplify production, improve quality assurance and enhance and reduce the start-up period for new production. These issues are of particular concern most especially in the process industries today as product diversification continuous and product life cycle shortens. Interest in TPM outside Japan has also expanded throughout the recent years. Many companies in the United States, Europe, Asia and South America are planning to or are now actively pursuing TPM.

2. TPM

Total Productive Maintenance as the name suggests consists of three words: Total signifies to consider every aspect and involving everybody from top to bottom; Productive emphasizes on trying to do it while production goes on and minimize troubles for production; Maintenance means keeping equipment, autonomously by production operators, in good condition – repair, clean, grease, and accept to spend necessary time on it. Nakajima (1989), a major contributor of TPM, has defined TPM as an innovative approach to maintenance that optimizes equipment effectiveness, eliminates breakdowns, and promotes autonomous maintenance by operators through day-to-day activities involving the total workforce. According to Chaneski (2002), TPM is a maintenance management program with the objective of eliminating equipment downtime. However, TPM is not a maintenance- specific policy; it is a culture, a philosophy, and a new attitude toward maintenance.

TPM describes a relationship between production and maintenance, for continuous improvement of product quality, operational efficiency, capacity, assurance and safety (Nakajima, 1988); it is an aggressive strategy that focuses on actually improving the function and design of the production equipment (Swanson, 2001). TPM has been accepted as the most promising strategy for improving maintenance performance in order to succeed in a highly demanding market arena (Nakajima, 1988). Ahuja *et al.*, (2006) report that TPM implementation can significantly contribute towards improvement in organizational behavior in the manufacturing enterprises; leading to world class competitiveness; it is also considered to be an effective strategic improvement initiative for improving quality in maintenance engineering activities (Ollila & Malmipuro, 1999; Pramod *et al.*, 2007). Another strategic outcome of TPM implementations is the reduced occurrence of unexpected machine breakdowns that disrupt production and lead to losses, which can exceed millions of dollars annually (Gosavi, 2006). There are three ultimate goals of TPM: zero defects, zero accident, and zero breakdowns (Willmott, 1994; Noon *et al.*, 2000).

Since the deficiencies of the RCM and TPM maintenance strategies became apparent in the 1990s, lean maintenance strategy emerged as an affective maintenance strategy. However, lean maintenance is neither a subset nor a spin-off of lean manufacturing. It is instead a prerequisite for success as a lean manufacturer that provides a holistic approach to the function of maintenance. As lean concept has been taking hold in the manufacturing sector, there is an increasing realization that maintenance must not be viewed only in narrow operational context dealing with equipment failures and their consequences. Rather, maintenance must be viewed in the long-term strategic context and must integrate the different technical and commercial issues in an effective manner.

The six key elements of TPM include: Improving equipment effectiveness by targeting the major losses; Involving operators in the daily, routine maintenance of their equipment; Improving maintenance efficiency and effectiveness; Training for everyone involved; Life-cycle equipment management and maintenance prevention design; and Winning with teamwork focused on common goals. The result of these six elements working together to improve equipment performance and reliability is TPM in a nutshell. No one element, removed from its partners, can create the effects achievable by this strategy, nor will any combination missing even one element. The six elements are interrelated and designed to support each other. It is perhaps the lack of this comprehensive approach that has resulted in 50% of TPM initiatives being abandoned since it was introduced to U.S. in 1986, Williamson, 2001.

The logic behind TPM can be grasped more easily by having an understanding of the Toyota Production System, the tradition behind it. But, until recently, a working definition of the Toyota Production System has been hard to pin down. This is because the Toyota Production System is the accumulated result of a trial and error process over the course of five decades and has never been written down. Fortunately, two Harvard researchers, H. Kent Bowen and Steven Spear, spent four years studying this system, and have published their findings. In their article "Decoding the DNA of the Toyota Production System," the authors isolate the following four rules that govern the system: All work shall be highly specified as to content, sequence, timing, and outcome; Every customer-supplier connection must be direct, and there must be an unambiguous yes-no way to send requests and receive responses; The pathway for every product and service must be simple and direct; and Any improvement must be made in accordance with the scientific method, under the guidance of a teacher, at the lowest possible level in the organization, Bowen & Spear, 1999.

The first three rules illustrate the actual processes of TPM and what roles each person involved in maintenance must play. The fourth rule expands this structure to comment on how to solve problems and improve overall performance. With that in mind, the first rule, "all work shall be highly specified as to content, sequence, timing, and outcome", dictates that anything done to maintain and improve equipment must be documented in procedures that every employee follows. This documentation should include detailed information on the parts used, labor hours involved, descriptions of the problems that arose, the estimated root causes of the problems and the corrective measures taken to solve the problem. It also means that maintenance work is governed by planned maintenance routines and that frequent joint production/maintenance planning and status meetings are scheduled to keep efforts focused.

The second rule, "every customer-supplier connection must be direct, and there must be an unambiguous yes-no way to send requests and receive responses", means that proper maintenance tools, parts, and supplies be made available, as they are needed. It also means that spare parts are adequately maintained and that maintenance requests are sent and acknowledged promptly. Visual systems and signals can be used to eliminate long drawn-out explanations and reading. Lastly, when proper repairs or improvements are made, those who requested them should sign off on them.

The third rule, which states that the "pathway for every product and service must be simple and direct" requires every equipment operator to know exactly where to go for help with an equipment problem. By extension, this means that every maintenance person knows on what equipment he is qualified to work and where he or she can get help when a problem exceeds their expertise. Finally, this rule necessitates that the documentation for specific equipment remain accessible to those who need it.

The fourth rule, "any improvement must be made in accordance with the scientific method, under the guidance of a teacher, at the lowest possible level in the organization" indicates that data should be collected, analyzed, and made available to make the improvements more efficient and effective. Additionally, informed people closest to the problem should work out possible solutions and conduct experiments to determine the workability of their solutions. Applying the logic of this rule also requires that formally experienced and trained problem solvers lead improvement effort and that changes are made in the equipment and supporting work processes and people are trained in the new methods.

As one can see, a great amount of discipline is required in the workplace to sustain the application of TPM strategies. Fields as diverse as aircraft assembly, petroleum exploration and even racecar equipment maintenance have successfully put TPM strategies into use, their only commonality being the high degree of discipline that each of these callings demand. The four rules described above define the disciplined approach that Total Productive Maintenance requires to produce the optimum results. Implementing TPM means striving

toward a vision of the ideal manufacturing situation: a vision that encompasses; zero breakdowns, zero abnormalities, zero defects, and zero accidents. These three main categories of equipment-related losses: downtime, speed loss, and defect or quality loss—are also the main ingredients for determining the overall equipment effectiveness, OEE.

3. Lean Maintenance: Lean Manufacturing and Lean Maintenance

Lean Manufacturing started as the Toyota Production System (TPS), developed in the 1940's and beyond, primarily by Shigeo Shingo (1989) and Taiichi Ohno (1988), at Toyoda (now Toyota) Motor Car Company. Toyoda started by the manufacturing of looms for manufacturing cloth, and then branched into bicycles before WWII. In time, Toyoda (now Toyota) started to manufacture engines, small delivery vehicles, trucks, and cars. Poor management decisions almost put the company into bankruptcy. Losing face, the Sr. Management resigned, and/or changed their ways. They changed the name of the company (Toyoda to Toyota), granted workers life-long employment, and went on an aggressive improvement program to try and work their way back from near oblivion. The motivations for TPS were now established. Soon the tools and techniques started to emerge that eased the frustrations with the old, inefficient ways, and allowed Toyota to achieve its TPS goals.

Toyota's engineers looked to Henry Ford - inventor of the assembly line, Taylor - inventor of "Modern Management techniques and Industrial Engineering", and Dr. W. Edwards Deming – "Father of Modern Quality Management". Based on these early beginnings, the techniques were refined, honed, and improved in all areas. With the invasion of the North American market by Volkswagen in the 1960's, and Toyota in the 1970's, and a world-wide recession, the American automotive industry was in for major changes and de-stabilization. North American automotive watchdogs were looking for an explanation as to how Toyota could manufacture a car, ship it to North America, and sell it faster and cheaper than domestically made vehicles. Huge import tariffs and import restrictions didn't stop the flow of these cheap, desirable cars. Over time, the quality of the vehicles, as defined by their reliability and longevity on the road, increased at a rapid rate. The Japanese vehicles innovated at an extremely rapid rate, while N. American designed and built vehicles tended to change at a very slow rate.

A 5 year, \$5 million research project by MIT (Massachusetts Institute of Technology) was started so as to analyze the world-wide automotive industry in 14 countries (design, markets, and manufacturing). In "The Machine that Changed the World" Dr. Womack and his International Motor Vehicle Program (IMVP) group at MIT, identified the key differences between Toyota's TPS, European auto industry, and North America's traditional systems. In short, N. American and European had assumed and accepted the mass production theory and honed it to perfection. Japan and Toyota had used mass production as a starting point and evolved it further to TPS. Womack coined the phrase "Lean Manufacturing" so as to encourage its adoption of TPS methods everywhere (for competitors to admit they were borrowing from Toyota was not feasible, nor politically possible; the old "Not Invented Here" syndrome), Womack *et al.*, 1990. Unfortunately, most didn't realize that Toyota had borrowed heavily from Henry Ford's principles of the 1930's. Henry Ford's book was a best seller in Japan well past when the existence of Ford's book was already forgotten in North America.

Today Lean Thinking (re-coined again so as to signal that the same techniques can be used in banks, service organizations, hospitals, and all manner of business systems) is being used world-wide in a growing number of organizations. It is applied at the point of contact with customers, as well as back room work. It applies to Engineering & Design offices, as well as traffic flow in urban centers. Though best known for its tools, Lean Manufacturing is first and foremost a philosophy and a way of life. It is a commitment to continuous improvement and customer satisfaction founded in planned, controlled, and measured change. Lean Manufacturing is a system that strives for perfection. Commonly defined targets are a reduction in lead time and costs while providing on-time delivery of quality goods and services to customers. It is NOT, as many derisively describe it, simply a euphemism for pushing inventory back on the supplier. Lean Manufacturing is a company-wide, supply-chain-long commitment to: elimination of all waste; customer service; and continual improvement.

Many companies focus on the tools: Five S, Standardize Work, Kaizen (continuous improvement), Kanban (signal), Poka-Yoke (mistake proofing), SMED (single-minute exchange of die), and TPM. The tools themselves, however, are not the point, nor the purpose of Lean. The tools are merely a means to an end, and a clear understanding of the end is crucial to success with Lean. Because many people like "silver bullet" solutions, however, use of the tools is often confused with actually being Lean. A company transitioning to lean manufacturing will not have a sound basis of maintenance support without first implementing necessary and fundamental changes in the maintenance operation. The foundation elements, in particular TPM must be in place before an organization can effectively build on the maintenance management pyramid with elements such

as autonomous maintenance and before it can sustain continuous improvement. Lean maintenance is a prerequisite for success as a lean manufacturer, Mather (2005). Lean maintenance is defined as a proactive maintenance operation employing planned and scheduled maintenance activities TPM practices using maintenance strategies developed through application of reliability centered maintenance (RCM) decision logic and practiced by empowered (self-directed) action teams using the 5S process, weekly Kaizen improvement events, and autonomous maintenance together with multi-skilled, maintenance technician-performed maintenance through the committed use of their work order system and their computer managed maintenance system (CMMS) or enterprise asset management (EAM) system. They are supported by a distributed, lean maintenance/MRO (Maintenance, Repairs, Operations) storeroom that provides parts and materials on a just-in-time (JIT) basis and backed by maintenance and reliability engineering group that performs root cause failure analysis (RCFA), failed part analysis, maintenance procedure effectiveness analysis, predictive maintenance (PdM) analysis, and trending and analysis of condition monitoring results. That is lean maintenance in a nutshell.

During the past decade, the “LEAN” phenomenon has allowed manufacturing industries to greatly increase their levels of profitability and productivity. Lean, combined with other initiatives, such as TPM, has allowed these companies to focus on the efficiency of their production processes; efficiency as being “productive without waste.” Recently, we have seen many consultancies and companies starting to talk about terms such as “Lean Maintenance,” an attempt to bring the same efficiency improvement approach into the world of physical asset management.

The thinking behind this is laudable, and many companies have been able to benefit greatly from the waste elimination focus that LEAN fosters. The problem is that the same fundamental principles have been brought directly from the production environment into the asset maintenance environment. The same seven areas of waste, the same initiatives such as just-in-time inventory management, and the same sort of focus on the day-to-day without including a longer term focus. The reason why a lean maintenance approach cannot just be a mirror image of a lean production approach is because the business dynamics of asset maintenance and those of production are fundamentally different. Some of the differences noted below will help to understand; why LEAN maintenance needs a different focus than that of LEAN production and what it should be?

1. Production plans are driven by sales forecasts and in the near term by sales orders. This means they are driven by an exact schedule of works. Asset maintenance, on the other hand, is driven in part by a schedule of routine work and in part by the likelihood of failure of the assets under management. This means that initiatives such as JIT inventory management have only a limited ability to assist the efficiency of the maintenance process. Issues such as just-in-case inventory management are far more important. This has implications not only within the area of operations, but throughout the entire supply chain. Often the improvement of a supply chain is based on “how we buy,” the probabilistic nature of asset maintenance means also that we need to be thinking about “why we buy.”
2. Production efficiency is gained almost entirely through present operations. So to be “productive without waste” is thought of in terms of the day-to-day activities involved in managing the production processes - and rightly so. Asset maintenance being “productive without waste” has an additional time perspective. A large part of any asset maintenance spent over time relates to asset replacement and refurbishment intervals. Depending on the type of plant these are often very large scale costs on par with the initial equipment purchase in terms of magnitude. So “productive without waste” means not replacing these too early, and often in not allowing them to fail completely before replacement. In order to be truly efficient management needs to control a range of issues related to asset use, type, expected life and other issues. This is significant and reaches outside of the maintenance function itself. For example – a machine that is subject to regular overload situations is likely to have a shortened life expectancy, meaning that capital will need to be spent on it at an earlier stage than previously thought.
3. The last issue to explore here is that of data management and collection. Improvement of production processes can often be made through recording and acting upon dynamic operational information. Data management and collection is also useful in asset maintenance but management also need to be able to confidently forecast spending in the future and how that is affected by current activities. This requires data other than the dynamic operational data. It also requires static data on equipment type, location and age; as well as a range of data regarding failure rates, asset condition and other areas. While this seems straight forward, when this task is not correctly managed it can be a tremendous strain on the resources of the asset maintenance department.

Here is a list of some of the wasteful activities where waste in maintenance occurs that Lean maintenance needs to focus on:

- I. Unproductive work – Efficiently doing work that doesn't need to be done!
- II. Delays in motion – Waiting times, delays waiting for parts, machinery, people, etc.
- III. Unnecessary motion – Un-needed travel, trips to tool stores or workshops, looking for items, moving mobile work stations around without good reason.
- IV. Poor management of inventory – Not able to have the right parts at the right time. A complex area that can cause many of the other areas of waste on this list.
- V. Rework – Having to repeat tasks, or do additional tasks, as a result of poor workmanship.
- VI. Underutilization of people – Using people to the limits of their qualifications, not to the limits of their abilities!
- VII. Ineffective data management – Collecting data that is of no use, or failure to collect data which is vital.
- VIII. Misapplication of machinery – Incorrect operation or deliberate operational strategies leading to maintenance work being done when it needn't be.

4. Conclusion

Lean manufacturing, lean enterprise, or lean production, or often simply, "Lean", is a production practice that considers the expenditure of resources for any goal other than the creation of value for the end customer to be wasteful, and thus a target for elimination; "value" is defined as any action or process that a customer would be willing to pay for.

For many, Lean is the set of "tools" that assist in the identification and steady elimination of waste. As waste is eliminated quality improves while production time and cost are reduced. Lean maintenance is used to drive waste out of the manufacturing process by reducing or eliminating production time lost to machine failures. Lean Maintenance is a prerequisite for success as a lean manufacturer that provides a holistic approach to the function of maintenance. As lean concept has been taking hold in the manufacturing sector, there is an increasing realization that maintenance must not be viewed only in narrow operational context dealing with equipment failures and their consequences. Rather, maintenance must be viewed in the long-term strategic context and must integrate the different technical and commercial issues in an effective manner. However, Lean Maintenance approach cannot just be a mirror image of a lean production approach because the business dynamics of asset maintenance and those of production are fundamentally different. In order to deliver "productivity without waste," or efficiency, in asset maintenance, there is a need of a different version of "Lean"; one that takes into account the unique business dynamics of the area that the businesses work in.

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