



## **TOTAL PRODUCTIVE MAINTENANCE (TPM) AND PRACTICES IN A MANUFACTURING FACILITY**

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### **ABSTRACT**

*Total Productive Maintenance (TPM) concept evolved from breakdown maintenance and preventive maintenance concepts within time. In the conventional maintenance approach, maintenance and repair work is done only by the maintenance personnel/department. However in TPM operators who are close to machines conducts some minor maintenance jobs on their machines, called autonomous maintenance. In this study maintenance practices of a facility trying to implement TPM is examined. Steps were taken to implement Total Productive Maintenance, although TPM is not fully implemented at present, the positive effects are observed. Especially the training of operators, autonomous maintenance practices like daily cleaning of workbenches, lubrication etc., adoption of machines by operators, focus of the maintenance department on failures and periodic maintenance can be considered as a continuation of TPM practices. It can be said that Total Quality Management applications also developed some TPM practices.*

**Keywords:** Total Productive Maintenance, six big losses, overall equipment effectiveness

**Jel Codes:** M11, D24

## **TOPLAM VERİMLİ BAKIM (TVB) VE BİR İMALAT TESİSİNDE UYGULAMALARI**

### **ÖZ**

*Toplam Verimli Bakım (TVB) kavramı zaman içinde arıza bakım ve önleyici bakım kavramlarından evrilmiştir. Geleneksel bakım yaklaşımında bakım ve tamir işleri sadece bakım personeli / bölüüm tarafından yapılır. Fakat TVB’de makinelerle daha iç içe olan operatörle, otonom bakım denilen, makineleri üzerinde ufak bakım işlerini de yürütürler. Bu çalışmada TVB uygulamalarını yerleştirmeye çalışan bir tesisteki bakım uygulamaları incelenmiştir. Toplam Verimli Bakımı henüz tam olarak uygulanmamasına rağmen TVB anlayışını yerleştirmek için adımlar atılmıştır ve bunun olumlu etkileri gözlenmektedir. Özellikle operatörlerin eğitimi, tezgahların günlük temizlenmesi, yağlanması vs. gibi otonom bakım uygulamaları, operatörlerin tezgahlarını sahiplenmeleri, bakım departmanının hatalara ve periyodik bakıma odaklanması faaliyetleri TPM uygulamalarının bir uzantısı olarak görülebilmektedir. Tesisteki Toplam Kalite Yönetimi uygulamalarının da bazı TPM uygulamalarını geliştirdiği ifade edilebilir.*

**Anahtar Kelimeler:** Toplam Verimli Bakım, altı büyük kayıp, toplam ekipman etkinliği

**Jel Kodu:** M11, D24

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## **INTRODUCTION**

The history of maintenance began with the concept of "breakdown maintenance", which took place in the 1950s, when maintenance personnel were called in for failures in facilities and machines. In the following years, the concept evolved to protective maintenance, preventive maintenance, corrective maintenance and productive maintenance philosophy. Up to the 1950s, it is only in the case of that repairs were done when breakdowns arose. No maintenance activities were carried out until the machine and equipment failed. After the concept of protective maintenance has begun to be implemented, equipment failures have declined considerably. Over the years, the concept of corrective maintenance has emerged that reduces the likelihood that the same malfunction will occur again in the future. In addition, the concept of preventive maintenance has been developed which has included the design phase in an effort to manufacture better equipment and make it easier to maintain (Tok, 2007: 13). Now businesses had to change their understanding of maintenance and repair rather than "repair when breakdown occur". Thus, maintenance and repair concepts such as planned maintenance, preventive maintenance adopted. But these could not be enough for businesses. Because these perceptions were only limited by their application areas (İlbiz et al., 2007: 70).

Breakdown maintenance is an activity that can be applied in facilities and shopfloors that has relatively cheaper and redundant machines. If an unexpected failure occurs in a machine and if the machine does not have a backup, an unscheduled maintenance is required and this causes an interruption in production. Use of such a system may be appropriate only when the machine and/or equipment failure does not affect the production and there is no other cost beyond repair costs (Tok, 2007: 5). As a result of breakdown maintenance the overall situation of facility and machines is getting worse, causing further deterioration and problems. For this reason, the actual cost of breakdown maintenance is much more than the cost of maintenance resources and spare parts. In addition to repair costs, there are costs such as loss of production and disruption in the program (Chand and Shirvani, 2000: 150).

Preventive maintenance is the inspection, lubrication, renewal, revision of the equipment and the improvement of the usability period according to a specific program, regardless of the condition of failure. Such time based studies are called "planned maintenance" and the purpose is to minimize the maintenance needs that arise in an emergency situation. (Tok, 2007: 5-6).

Breakdown maintenance, protective maintenance and preventive maintenance approaches have been combined to form a new approach known as Productive Maintenance. In 1971, Japan Institute of Plant Maintenance (JIPM) recognized the name "Total Productive Maintenance" for all these repair and maintenance work, which was conducted in Japan in the 1970s, requiring autonomous maintenance and all employees to participate. According to this system operators become responsible for maintenance as well as maintenance and repair personnel (Tok, 2007: 14).

The rest of the study is organized as follows. In section 1 Total Productive Maintenance concept is discussed extensively. In section 2 maintenance practices in a manufacturing facility is examined. In section 3 the study is concluded with some discussions.

### **1. TOTAL PRODUCTIVE MAINTENANCE**

Total Productive Maintenance (TPM) combines the developing techniques of other maintenance activities creatively in the direction of design-product life cycle costing principles to provide reliability and ease of maintenance. TPM is implemented by protection equipment from breakdown, making inspection, easier repair and facilitation of use and assuring safety. Operators using equipment in TPM have two main tasks: to record the results of day-to-day checks and details of all failures, as well as to produce preventive ideas for failures and their causes. By looking at breakdown records and improvement ideas of operators', maintenance specialists and equipment designers work on recurring problems and develop machines to be less likely to fail, to be easier to maintain, and more regular (Tok, 2007: 7).

The philosophy of this system is to keep all the values such as people, machines and processes that production is connected in the best condition and use it in the most efficient way. TPM provides this with equivalent partnership of production and maintenance activities in gathering accurate

information, analysis and problem solving. In the simplest terms, it is an activity involving all the work carried out in order to increase the productivity or efficiency of the equipment used in a plant and to completely avoid the downtime and possible incidents caused by possible machine errors. TPM puts maintenance work at the focal point of business activities as an essential and crucial element of business, avoiding it as a profitless/costly activity, and the time spent on maintenance; as a complementary part of production time (Tok, 2007: 7-8). TPM considers maintenance as an essential and important part of work, not as a profit-free activity (Eti et al., 2004: 390).

TPM defines a synergistic relationship between all functions of the organization (Jostes and Helms, 1994: 18), between continuous improvement, operational efficiency, capacity utilization in general and production and maintenance in particular. It aims at eliminating failures that occur in unexpected times and maintenance of machines at certain times without any interruption of the production flow as much as possible and to implement all maintenance-repair concepts in an integrated way in the whole enterprise (İlbiz et al., 2007: 69). It is a proven successful procedure that transforms maintenance considerations into organizational activities. It requires operators and maintenance staff to work together as a team to reduce waste, minimize downtime, and improve final product quality (Eti et al., 2004: 388). It is carried out with small group work done to achieve the highest efficiency with the practices of production, maintenance and engineering departments and participation of all employees. In other words, it is a strategy adopted by all employees for realizing 'Zero Accident', "Zero Failure" and 'Zero Stop' in production (Tajiri and Gotoh, 1996: 15). It makes the employees specialists on their field by offering intensive technical training. It targets employees to use their skills on machines and maintenance in a crafty way (Yoluç et al., 2007: 336):

TPM considers equipment maintenance extensively, including the entire lifecycle of the equipment and all employees, from production and maintenance personnel to top management (McKone et al., 1999: 123). In order to optimize the general working conditions of an equipment or process, it is an approach that attempts to bring the losses to zero that may occur before, during and after the process (Saraç et al., 2007: 380). It tries to improve the efficiency and maximize the output of the equipment. It tries to reach and maintain the optimal equipment condition to prevent unexpected failures, speed losses and faulty products in the process. (Chand and Shirvani, 2000: 150). It supports the full participation of employees by combining the best features of efficient and preventive maintenance procedures with an innovative management strategy (Eti et al., 2004: 389).

The TPM concept has been introduced in the Japanese manufacturing industry to eliminate production losses in the Just-In-Time (JIT) production process. Nakajima described basic TPM concepts with the key concept of autonomous maintenance key, and observed the application procedures in hundreds of facilities in Japan (Eti et al., 2004: 389).

Machine operators have unique knowledge about their equipment. Nobody knows that equipment better than the operator (Jostes and Helms, 1994: 19). With the teams to be established at the base of TPM, workers must do the first intervention in the face of a problem that may arise, and the interruption of production is tried to be minimized as much as possible. Even though operators have the ability to catch problems when they are small, they may ignore these minor problems and lead to major problems because they are hesitant for reaction of the managers (İlbiz et al., 2007: 70). With the participation of all the employees of the TPM, a new culture is created systematically that eliminates all losses in production, continuously increases the efficiency of equipment and human power, prevents product faults from occurring, and creates a new culture with "Zero Defects", "Zero Stop" and "Zero Accident" slogan to reach the best (Saraç et al., 2007: 380).

TPM generally provides a comprehensive company-wide approach to maintenance management, which is divided into short-term and long-term. The short term focuses on autonomous maintenance for the production department, planned maintenance for the maintenance department, and talent development for production and maintenance personnel. In the long term, it focuses on the design of new equipment and the eliminating reasons of losses (McKone et al., 1999: 125).

According to Nakajima, the concept of TPM includes the following five elements (Chand and Shirvani, 2000: 151):

- Maximizing equipment efficiency.
- Constitutes a planned preventive maintenance system covering the entire life span of the equipment.
- It is implemented with the participation of various departments on the company (engineering, production, maintenance).
- It encompasses all employees from the top management level to the bottom level.
- Encourage preventive maintenance with motivation management involving small group activities.

The word "total" in TPM describes three main characteristics (Blanchard, 1997: 73):

- Total effectiveness: refers to the TPM's pursuit of economic effectiveness and profitability.
- Total maintenance system: Includes maintenance prevention and maintenance development with preventive maintenance.
- Total attendance of all employees: It includes autonomous maintenance carried out by operators with small group activities.

The three main components of the concept are (i) optimum equipment effectiveness, (ii) autonomous-operator maintenance, and (iii) small group activities. It is an approach that requires high-level participation of workers. The concept of TPM involves long-term planning with the participation of top management. TPM starts as an application from the top to bottom, but successful implementation is only possible with from bottom to top participation. The main aims of TPM are to realize zero failure, zero error and production increase by means of the following (Eti et al., 2004: 389):

- Increase the involvement of the operator and ownership of the process.
- Improve problem solving through teamwork.
- Organizing preventive and predictive maintenance activities.
- Focus on reliability and durability.
- To upgrade the skills of each operator.

In TPM, machine operators need to change their minds. With the start of the application, they are no longer just operators, they also prepare the machine, clean it, lubricate it and do minor repairs. They must be willing to own the machine. At the same time they should be willing to take on traditional responsibilities of training and maintenance (Jostes and Helms, 1994: 19).

TPM does not provide a quick or easy solution. Often it takes time-consuming changes in the attitude and values of the employee. This requires long-term thinking and careful planning. Rapid, company-wide performance increases are not anticipated in the initial stages. In these early stages, senior management should demonstrate full involvement in TPM by allocating the necessary resources to create and maintain the necessary cultural changes to ensure that appropriate training is provided for employees to apply autonomous maintenance (Eti et al., 2004: 393).

In the TPM method, the concept of prevention of failures is based on the following three principles (Tok, 2007: 17).

- Continuity of normal conditions: In order to maintain normal operating conditions, the operators are required to clean, inspect, lubricate, bolt, it should try to prevent disturbances that may occur in the future by squeezing the fastening elements appropriately.
- Early detection of anomalies: Operators should use their own intuition and measuring instruments to detect when abnormal conditions occur. Maintenance personnel also need to perform tests to prevent malfunctions that may occur periodically using special tools.
- Instant intervention: Operators and maintenance personnel must intervene on anomalies in time.

Errors that occur in businesses can be examined in three classes: small, medium, and large errors. Traditional approach in business management generally underestimate small errors. On the TPM philosophy, on the contrary of the traditional approach, there is the assumption that small errors will accumulate leading to moderate, even bigger errors. Minor errors in TPM are tried to be removed, so

that large and medium faults will be removed from the beginning, so the journey to reach zero stop starts (Tok, 2007: 24-25).

TPM organizes maintenance activities by implementing the following (Eti et al., 2004: 390):

- Apply autonomous maintenance to enable an operator to have a sense of ownership. The operator takes responsibility for his / her area. This task includes cleaning, routine inspection, lubrication, adjustment, simple repairs.
- Creates cross-functional teams of operators, maintenance personnel, engineers, and managers to improve employee and equipment performance.
- Creates an optimal cleaning and preventive maintenance schedule to maximize work time and expand the living space of the facility.

### **1.1. Six Major Losses**

TPM accepts that if 100% potential of the equipment can not be used, it is based on some physical conditions that can be identified, controlled, reduced and eliminated. These physical conditions are described as six major losses in TPM (McCharty and Rich, 2004: 33). The following six major losses that reduce equipment effectiveness can be eliminated on a businesswide basis, minimizing the lifecycle cost by maximizing equipment efficiency (Chand and Shirvani, 2000: 151):

- Downtime losses
  - Failures
  - Setup and adjustments
- Speed losses
  - Idling and minor stoppages
  - Reduced speed
- Defect losses
  - Defects in process
  - Reduced yield

The main goal of the TPM can be described as decreasing six major losses to the lowest level. By this way a measurable improvement in the productivity of all machines can be achieved (Tok, 2007: 17).

The main causes of this losses are (McCharty and Rich, 2004: 33):

- Equipment condition is poor
- Human error / lack of motivation
- Lack of understanding of how to achieve optimum conditions

Six major losses are in fact not directly related to maintenance performance. Production losses are only one of many effects of the maintenance policy. They constitute a useful analysis of a part of the problem (Sherwin, 2000: 158). The six major losses are briefly explained below (Tok, 2007: 31-37).

**Failures:** Failures are the largest of the six major losses. Many of the major failures stems from loose screws, wear and pollutants. The effects that accumulate as a result of neglecting these factors will eventually lead to a reduction in equipment efficiency. Therefore, many small failures that contribute to big trouble are also important in TPM.

**Setup and Adjustments:** The setup and adjustment period is the time interval between the completion of a product and production of the next product in a standart quality. This loss is caused by the stoppages for setup and adjustment.

**Idling and minor stoppages:** In contrast to usual failures, idling and minor stoppage losses come into play due to temporary problems with the equipment. For example, a workpiece may be jammed in the duct or a quality control sensor may temporarily stop the equipment. When someone removes this jammed workpiece or reconfigures the sensor, the machine starts working normally

again. Because idle work and minor stoppage can be eliminated fairly easily, they are often ignored and are not considered as lost.

**Reduced Speed:** The difference between the speed at which a machine is designed and the actual speed brings about reduced speed loss. This loss can be caused by mechanical problems, unbalanced lines, quality failures. Reduced speed losses are often either neglected or not considered.

**Defects in Process:** This type of loss is exposed due to quality errors in the product and reprocessing or repair that must be done to correct these errors. The loss caused by the reprocessing or repair of the defective product has a great effect on the yield of the equipment, therefore the most important activity that must be carried out in the effort reduce six major losses is this kind of loss.

**Reduced yield:** These losses are caused by the fact that the amount of production is low during the time it takes for the equipment to reach the normal operating level from the start of production. The first products produced in this period can not achieve the expected quality level.

## **1.2. Overall Equipment Effectiveness**

Measuring the effectiveness of a maintenance program is complicated because it involves multiple interactions. For this reason, separate states of maintenance performance are generally measured. Commonly used maintenance performance indicators are (Eti et al., 2004: 392):

- Equipment performance measures such as availability, reliability and total equipment effectiveness
- Process performance measures such as fulfilled / planned work, program fit
- Cost performance measures such as labor and material cost of maintenance

Overall Equipment Effectiveness (OEE) is a simple TPM criterion used to measure the effectiveness of machinery / equipment used by enterprises and is widely used in the manufacturing sector because it points to key areas that require improvement. The benefits of determining the OEE value of any equipment can be summarized as follows (Saraç et al., 2007: 380):

- According to the OEE value, managers can take precautions to prevent these losses by determining the causes of time losses.
- The initial OEE value is compared with the next OEE value to determine the level of performance increase. The trend of change in OEE can be used as the basis for improvement.
- OEE of a machine/equipment can be compared with other machine/equipment to detect low performance.
- Depending on the OEE values of existing equipment, it may be decided whether additional equipment should be purchased or not.

The purpose of the TPM is to increase the efficiency of the equipment so that each part of the equipment can operate at full capacity and can be maintained at this level. It is important to recognize, measure and mitigate the losses in order to increase the effectiveness. Overall Equipment Effectiveness (OEE) is a measure of the value added by the equipment and is a function of that the machine availability, performance efficiency and rate of quality (Chand and Shirvani, 2000: 151).

$$\text{OEE} = \text{Availability} \times \text{Performance Efficiency} \times \text{Quality Rate}$$

Availability is related with breakdown and setup and adjustment losses. Performance efficiency is associated with idling and minor stoppages and reduced speed losses. Quality ratio is related to quality defect and rework and startup losses (Chand and Shirvani, 2000: 152).

$$\text{Availability (Breakdown Losses)} = \text{Run Time} / \text{Net Time}$$

$$\text{Performance Effectiveness (Speed Losses)} = \text{Net Run Time} / \text{Run Time}$$

$$= \text{Actual Production Amount} / \text{Target Production Amount}$$

$$\text{Quality Ratio (Quality Losses)} = \text{Fully Productive Time} / \text{Net Working Time}$$

$$= \text{Good Product Quantity} / \text{Total Production Quantity}$$

Before TPM, OEE is usually around 50-60%, after which it has to reach 85% (Jostes and Helms, 1994: 19).

### **1.3. Benefits of TPM**

One of the most important benefits of TPM is the planning and control of maintenance costs. This alone is a significant advantage. Maintenance costs in a facility with traditionally maintenance are between 15-40% of the total cost of production. In general, the pre-tax profit is 5%. This means that the avoidable maintenance cost will directly increase pre-tax profit. Another benefit is the reduction in the need for maintenance personnel. By transferring preventive maintenance activities to the production staff (operators), they can be saved from maintenance staff who are already interested in preventive maintenance. Although less measurable, there are also a number of other benefits (Jostes and Helms, 1994: 20):

- As the participation of the employees increases, the relations among the employees will also develop. Operators will be considered as the contributors to the company with their thoughts.
- As the quality of the product increases, customer satisfaction will also increase. The customer expects a stable and reliable product and TPM will contribute to realize this.
- As operators are more familiar with the tools and techniques in the problem-solving process, the solving rate of problems will increase.
- As equipment becomes more reliable and processes become more repeatable, scheduling the workflow will be easier. The safety stock and semi-finished stock will decrease. Products will flow faster from the system, which will allow less investment to the inventory.

Many TPM operators have made great strides in the following situations (Eti et al., 2004: 390):

- To improve the performance of critical equipment and determine the causes of performance degradation.
- Better understand the criticality of the equipment and where and when worth to develop it.
- More collaborative team work, better agreement between production and maintenance workers.
- Improved procedures; (i) in replacement and setups, (ii) in carrying out maintenance activities, (iii) in the training of operators and maintenance personnel; All of this will result in lower unit cost of production and better service.
- Increase in the enthusiasm, commitment and participation of the workforce.

### **1.4. Transition to TPM**

In the course of the transition to total productive maintenance practices in operation, the overall implementation steps under the topic General Approach to the Implementation of Total Productive Maintenance Activities are stated as follows (Demirci, 2002: 34):

- Initial Cleaning
- Precautions against sources of pollution
- Cleaning and Lubrication Standards
- Comprehensive Inspection
- User Maintenance Standards
- Process Quality Reliability
- User Control

Initial Cleaning: Initial cleaning is intended to completely destroy foreign materials such as dirt, dust, grease, sawdust and scrap that adhere to equipment, molds, tools and equipment at the beginning of user maintenance work. This is a thorough cleaning up to the complete removal of the equipment from the pollutants. During cleaning, everyone touches all the pieces on the equipment and every corner takes a peek. This approach increases the chance of detecting hidden faults, noises, vibrations, smells and warmth. Since failures can be easily detected in the cleaned equipment, corrective and preventive actions are applied quickly without significant faults.

**Precautions against sources of pollution:** In order to easily maintain the condition of the machines which are cleaned in the initial cleaning, the contamination sources should be eliminated. If it is not possible to remove the source, it should at least be prevented from spreading the pollution to the equipment with appropriate modifications. Excessive difficulty in initial cleaning ensures that operators do not allow the equipment to become polluted again. Even after the equipment is cleaned, even the presence of a simple pollution begins to disturb the operators. At this stage, operators will also learn about the basic work and movement patterns of machines while carefully observing how they are formed at the sources of foreign materials in preparation for countermeasures. The aim of precautions taken against pollution sources is not only to eliminate foreign substances and to reduce the cleaning time but also to observe the pollution phenomenon in detail and to learn the working patterns and movements of the machines.

**Cleaning and Lubrication Standards:** Although there are occasional and significant losses due to insufficient lubrication, generally no one is interested in lubrication. In step 1 the operators completely eliminate the pollution that has been neglected and accumulated for a long time. The pollution sources and difficult cleaning zones that prevent the maintenance of the cleanliness achieved are improved in step 2. The equipment is clean enough to look fresh, and employees keep these conditions by following the cleaning standards that they specify. In step 3, all lubrication points and surfaces are handled for inspection to identify and cure failures that have arisen from the lack of lubricant, particularly in difficult lubrication areas. As a result of the remedial work carried out, appropriate and reliable lubrication methods are carried out. When operators establish cleaning and lubrication standards themselves, they make it easy to follow and to facilitate convenient working conditions. They understand the necessity and importance of following standards.

**Comprehensive Inspection:** Operators with insufficient knowledge and skill can not make an effective inspection. It is important to train the staff who can carry out the actual examination in the enterprise. From this point of view, training of critical, intuitive, and knowledgeable operators based on technical considerations by providing appropriate training and experience is essential. After achieving the necessary skills with such training, the operators prepare their own control forms. Sufficient inspection can then be achieved with operators reaching the ability to formulate daily inspection rules.

**User Maintenance Standards:** The workings made up to this step considerably reduce the stoppages on the machine. This step is intended to be carried out under normal or appropriate conditions, with the aim of carrying out a regular operation in which small gauges can be detected at a glance. The cleaning and lubrication standards in step 3 and the temporary inspection standards prepared in accordance with each inspection category in step 4 are combined in this step. Both standards are combined as "user maintenance standards" that describe the daily cleaning, lubrication and inspection tasks carried out by the operators. Operators follow these standards and clean, lubricate and inspect all installed equipment. After that, they learn how to obtain and use data related to stoppages and quality failures in the process, taking into account the time and intervals given to daily tasks.

**Process Quality Reliability:** All activities completed from step 1 to step 5 are focused on equipment and zero stop. In this step, user maintenance activities are directed towards zero defect. Quality products are realized by clearly specifying the quality of the process and by protecting the relevant quality conditions. In terms of process reliability, this step is aimed not only for the equipment but also for a regular operation of the entire plant. The remedial measures in quality problems are more difficult than the remedial measures in equipment postures.

**User Control:** In this step, knowledgeable operators execute user maintenance. Operators steadily maintain basic equipment conditions and replace wear parts. On the other hand, the maintenance personnel provide highly planned maintenance by applying predictive maintenance studies on critical machines. As expected, zero accidents, zero defects, zero stops are achieved. If user maintenance is not applied steadily, TPM system has a danger of slow but continuous deterioration. Therefore, all employees should protect and develop the applied TPM level. Operators and maintenance personnel collaborate with each other to protect the TPM level achieved in the previous



steps of the TPM development program. For the maintenance of basic equipment conditions, the operators inspect equipment wear and make improvement. Simultaneously, the maintenance personnel make efforts to improve the maintenance skills of the operators. As specified in daily and periodic maintenance plans, operators and maintenance personnel must perform the tasks assigned to them. In this way, periods of optimal cleaning service, such as cleaning, lubrication, inspection, monitoring of operating conditions, replacement of parts, repair of equipment, etc., are established within a few years. All useful information obtained in these maintenance activities is sent to the engineering department as preventive maintenance information so that future business development can be used in engineering and planning work.

### **1.5. Relationship between TPM, TQM and Lean Manufacturing**

A complete TPM application program is very similar to a Total Quality Management (TQM) or quality improvement program, with an emphasis on maintenance. TPM applications will be better in an enterprise if TQM is also applied. If a quality improvement program is followed, the TPM program will be better. The small group activities of employees will not proceed in the absence of any form of TQM and management involvement. If quality circles are implemented in TQM, then there is no need to recreate quality circles for TPM, and since maintenance will affect quality, quality circles will also deal with problems in maintenance. In fact, many quality circle recommendations already overlap with better maintenance practices (Sherwin, 2000: 158). Both TQM and TPM are processes that try to make the enterprise more competitive. TPM is an important subset of TQM (Jostes and Helms, 1994: 18).

TPM is thought of as applying TQM concepts to equipment for zero failure and minimum production loss. TQM and TPM share some concepts like participation of employees, continuous improvement, etc. These two complementary concepts are applied together in many companies to create synergy (Seth and Tripathi, 2005: 257).

In a survey that examines the effect of TQM and TPM applications on firm performance, the performances of companies that implement TQM, implement TPM, and implement both are compared. As a result, leadership, strategic planning, process management and training factors in the performance topic have come forward in all three applications. Apart from that, information infrastructure and equipment management factors come forward in firms applying TPM; Customer satisfaction, employee involvement and empowerment factors come forward in firms implementing TQM, while information infrastructure and performance measurement system factors come forward in firms implementing both (Seth and Tripathi, 2005).

TPM is based on the concepts of just-in-time (JIT), lean manufacturing, total quality management (TQM) (Eti et al., 2004: 388). TPM is aimed at solving the main problems in JIT production. Because it is possible that the next order (Kanban) will arrive at JIT at any time, it is not possible to plan maintenance that requires the machine to be dismantled. The TPM is based on the fact that the deterioration of the machine has increased due to the lack of simple maintenance such as wear and tear, poor operation and operator-made lubrication. Operator efforts may delay the need for preventive maintenance, but if simple maintenance is not done, costly failures may occur. TPM does not exclude or even defend preventive maintenance, but there is no specific strategy that makes it possible to plan preventive maintenance and can be overlooked when the factory is very busy. Depending on the maintenance of the operator, serious reductions in failure rates can be achieved, especially when treated as condition monitors (Sherwin, 2000: 157).

Since automated plants require higher investment costs, the results of a failure or non-operation are much more costly than traditional plants. It is important that the machines operate with high capacity utilization rates; it is necessary to operate the machines at the limit as much as possible to ensure high efficiency. Today, in the face of rising competition, successful TPM is one of the factors that determine the survival of many organizations (Eti et al., 2004: 391).

At TPM, Lean Manufacturing also highlights points that have been considered hidden wastes. Despite their different origins, the development of both depends on recognizing the behaviors and practices that cause waste, paying particular attention to these issues, and seeing that each employee sees wastes as an abnormal condition and takes the necessary precautions. Companies that implement

TPM are channeled to increase efficiency in order to increase customer value, but the lean idea tries to strengthen the definition of "value". Lean thoughts consistently seek reliable processes, but TPM provides a road map for zero failure and continuous improvement in equipment optimization. The relationship between TPM, TQM and lean production is shown in Figure 1 (McCharty and Rich, 2004: 24).

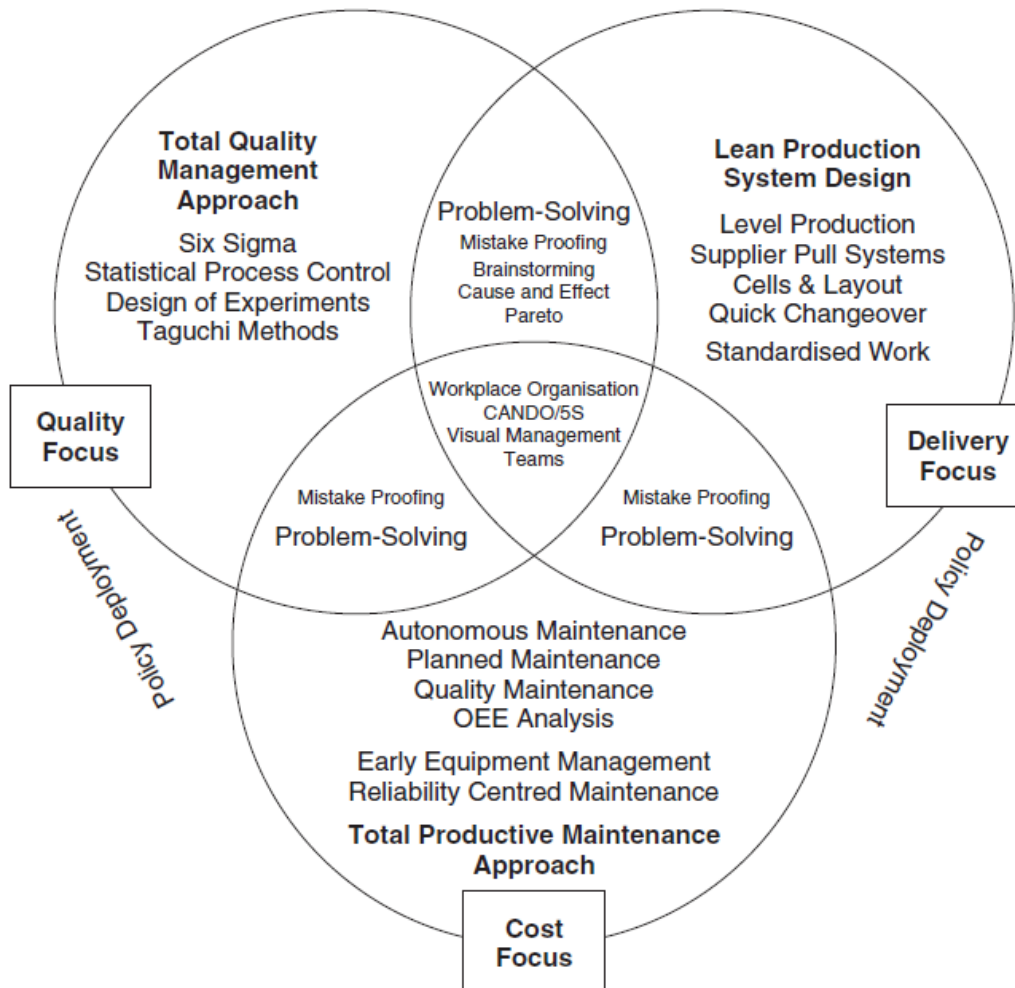


Figure 1: Relationship Between TPM, TQM and Lean

Source: McCharty ve Rich (2004). *Lean TPM, A Blueprint for Change*, Elsevier: Oxford, 17.

## 2. MAINTENANCE PRACTICES IN A MANUFACTURING FACILITY

The facility which is examined in terms of maintenance practices in the study is located in Kayseri, Turkey. The facility has a kind of process layout. It has 40 different workshops and 1100 employees. The company produces 4000 kinds of products every year.

### 2.1. Maintenance of Workbenches

There are about 40 CNC machines and 30 NC machines in various types of operation. While the utilization rate of CNC machines is approximately 95% for 8 hours working day, this situation reaches only 65% for other machines.

There are 8 staff members for the maintenance in this facility. However, these personnel spend about 40% of the labor hour for the production and repair work of other products, except for the machine maintenance service. The service provided by the machine maintenance service is divided into two parts, mechanical and electrical/electronics.

Two staff members were assigned to the machine maintenance service for the maintenance of the CNC workbenches. All kinds of electronic card maintenance / repair operations of CNC machines

are fulfilled by these two personnel. Very rarely (1%) there is market support for the repair of parts that they can not repair.

Maintenance and repair service periodically maintains CNC machines considering working hours. Periodic maintenance studies have been determined as a result of TPM studies. The maintenance carried out on each workbench is filled out the data form. Until 1995, the maintenance and repair history of each bench kept manually was not held due to automation in 1995. In the automation system, only the breakdown times and defective counter numbers of the failure are entered and no other information.

Periodic maintenance of the workbenches is attempted to be carried out especially during the annual leave periods or when the workbenches are empty. This is achieved through the coordination of planning and production. All of the machines have backups, except for 8-10 machines, so in the case of a breakdown, interruption of production is rarely seen. However, close to 60% of the machines must have filled their economic life, and this is affecting the number of breakdowns and their duration day by day. This situation is more evident in double or triple shift applications.

Failures are reported with a form to the maintenance department. Some of the spare parts to be used in the maintenance are manufactured in the enterprise and some of them are purchased outside.

Particular emphasis is given to the training of personnel working in CNC machines (CNC operators), as they are costly, convenient to mass production and have large contribution to production. Operators are not employed on the workbench without their training about the machine, autonomous maintenance and etc. That is, each operator is qualified for the workbench. In addition operators are also trained on programming logic, all kinds of technical drawing reading and so on.

It is observed that the operators own and adopt their workbench, since they are trained for a certain type of bench and working on the same workbench for a long time unless an important change occur. The operators also carries out daily maintenance / cleaning work of their workbench. Every operator is doing the work that can be described as small maintenance such as oil change, lubrication, test, adjustment. The application of autonomous maintenance is observed in the enterprise.

### **3. CONCLUSION**

In the conventional maintenance approach, maintenance and repair work is done only by the maintenance department. It is impossible to achieve success in reaching a zero failure or zero defect level, since operators who are close to the main machine are not taken into account in the maintenance and repair section. In total productive maintenance, participation and cooperation of every employee starting from the top management to the lowest levels, is necessary. Maintenance activities are not left to only maintenance department. Operators who are closest to the machine and who understand most of their language take care of minor maintenance tasks with autonomous maintenance, and they have an opportunity to intervene early if they feel an abnormality in the machine.

In this study maintenance practices of a facility trying to implement TPM is examined. Steps were taken to implement Total Productive Maintenance however, some applications have not been able to continue for various reasons. Although TPM is not fully implemented at present, the positive effects are observed. Especially the training of operators, autonomous maintenance practices like daily cleaning of workbenches, lubrication etc., adoption of machines by operators, focus of the maintenance department on failures and periodic maintenance can be considered as a continuation of TPM practices. It can be said that Total Quality Management applications also developed some TPM practices. It is stated that administrative and organizational factors such as TQM and JIT affect TPM application level (McKone et al., 1999).

However, due to the fact that the with the automation system and loss of some details of the failure records, it is impossible to carry out such tasks as forward predictive maintenance. In addition, many of the workbenches have an alternative, which causes an inertia about keeping records in detail and make forward-looking predictions. It is important to emphasize that it is not possible to know what the current situation is and to make progress in the future without detailed data.

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