

## TOTAL PRODUCTIVE MAINTENANCE IN LAB SET UP OF EDUCATIONAL SYSTEM – CASE STUDY

**Panneerselvam Sivasankaran**

Department of Mechanical Engineering, Manakula Vinayagar Institute of Technology, Pondicherry – 605 107, India,  
sivasankaranmech@mvit.edu.in

**Keywords:** equipment effectiveness, Total Productive Maintenance (TPM), lab set up, daily maintenance.

**Abstract:** Total productive maintenance (TPM) is used to evaluate the performance of equipment used within the manufacturing facility, lab set up etc. TPM Concept used to improve the efficiency of machinery by undergoing serious maintenance activities every day based on the usages. Productivity is defined as maintaining the workplace and surrounding facilities neat and clean. Equipment used for performing work is said to be monitored every time continuously. Due to the continuous observation about the performance of the equipment will help us to note down the conditions of equipment also suitable remedies to further increase its effective usages. In this paper, an attempt has been made to use TPM concepts (Total Productive Maintenance) in the lab to set up the environment within the technical education institution in south India. The case study is conducted to study the quality and effectiveness of lab instruments with the help of TPM concepts used in real-time applications.

### 1 Introduction

TPM (Total Productive Maintenance) finds a good place for industrial implementation during the initial period. Then later TPM Concept was implemented in many different application areas like schools, colleges and higher level Research institutions. TPM concepts result to improve the overall equipment effectiveness that is termed as measuring the percentage utilization of machinery within the given facility or set up. TPM strives hard for continuous improvement in the workplace environment. In TPM culture, all peoples are equally involved together for the upliftment of standards maintained within the facility. TPM concepts focus on the reliability of equipment and its functions. The main discrimination between TPM and other concepts is described here as follows:

- a. In the TPM environment, workers are also involved in improving equipment effectiveness.
- b. Compared to other types of maintenance policies, TPM stands for proactive maintenance.

The goal of TPM is used to improve the overall equipment effectiveness of machinery by providing high precision results. TPM is said to be the innovative approach used in the workplace facility to minimize the elimination of several losses by increasing the reliability of equipment with fewer failures.

#### 1.1 Types of maintenance systems

Specific maintenance can be classified into various types as listed below:

1. Breakdown Maintenance.
2. Preventive Maintenance.
3. Total Productive Maintenance.
4. Condition-based Maintenance.

These are the above types of maintenance policies available as per the literature.

#### 1. Breakdown Maintenance:

The goal of breakdown maintenance is to do the maintenance activities after experiencing the problem in the later stage of equipment. Here in this type of maintenance system, failure is addressed only at the end after noticing the situation.

#### 2. Preventive Maintenance:

Preventive maintenance is regular in nature which is carried out daily before experiencing the failure in the equipment. Successful maintenance strategy requires careful planning and scheduling.

#### 3. Total Productive Maintenance:

Total Productive Maintenance uses everyday performance activity within the work place. TPM can be otherwise termed as total employee involvement system. TPM involves all peoples from levels of management to take necessary steps to foresee the various maintenance issues.

#### 4. Condition-based Maintenance:

This type of Maintenance strategy monitors the actual condition of asset based on that further decision can be taken what to be done in order to improve the performance. This type of maintenance strategy measures the real time performance of the asset and that tries to find out the suitable remedial measures for the equipment effectiveness.

## 1.2 Pillars of Total Productive Maintenance (TPM)

TPM (Total Productive Maintenance) is a lean management strategy which aims for zero breakdowns of

machinery, zero defects and zero accidents within the plant system.

The following are the 8 pillars (Figure 1) of TPM (Total Productive Maintenance):

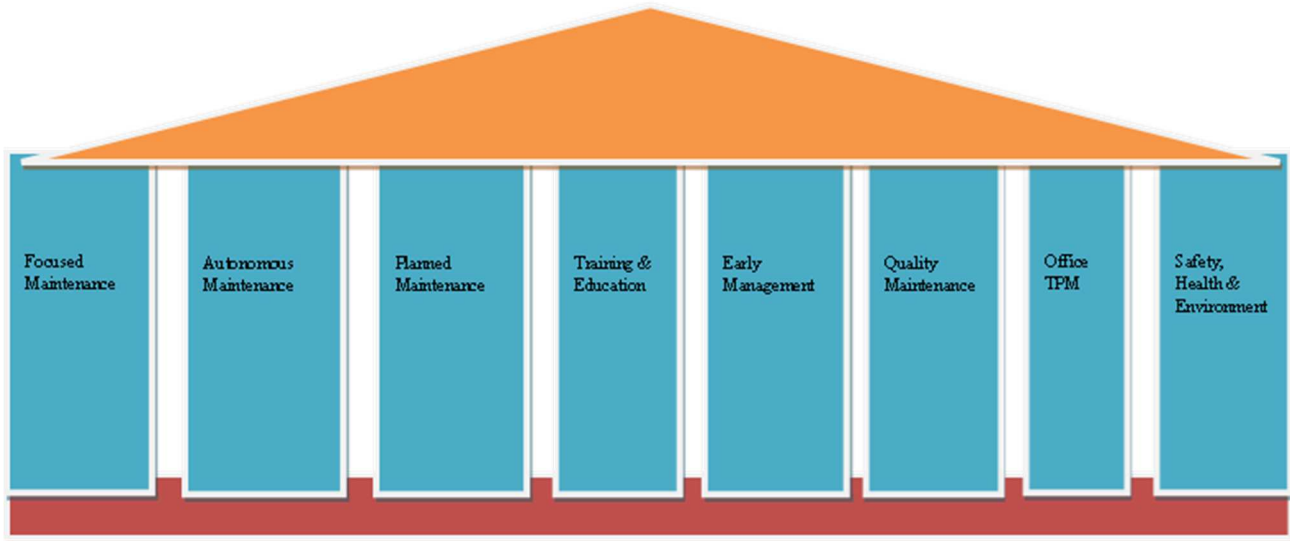


Figure 1 8 Pillars of TPM Framework

1. Focused Maintenance,
2. Autonomous Maintenance,
3. Planned Maintenance,
4. Training & Education,
5. Early Management,
6. Quality Maintenance,
7. Office TPM,
8. Safety, Health & Environment.

### 1. Focused Maintenance:

Focused maintenance is otherwise termed as continuous improvement the main goal is to improve the effectiveness of maintenance program.

TPM focuses on losses in equipment as listed below:

1. Unplanned or unexpected machine stop
2. Shutdown losses
3. Speed losses

These are the various losses in TPM. In this strategy the aim is to avoid losses of equipment, tools and energy etc the whole team has to be proactive in nature.

### 2. Autonomous Maintenance:

This is the second pillar in TPM hierarchy in this type of maintenance system every team will act as individual person or autonomous agent. Everyone has the responsibility to clean, inspect and contribute with various assets of organization. In autonomous maintenance everyone are involved in improving the quality of equipment functioning and its usages. All are responsible for their work that's why TPM is said to be total employee culture. This type of method improves safety of equipment by reducing accidents.

### 3. Planned Maintenance:

According to TPM planned maintenance minimizes the breakdown by controlling the downtime.

In this type of maintenance system proper shutdown of machineries must be done to recover the failures.

### 4. Training and Education:

TPM believes on training and education otherwise every employee will not trust each other.

Training is the only possible way of education to enlighten the knowledge of technicians or workers about the use and functions of machines. So, training and education act as main hub to sharpen the minds of worker about the functions of machines.

### 5. Early Maintenance:

The main objective of early maintenance is to improve the effectiveness of machineries well in advance before the failure occurs. Early maintenance means careful assessment and conditional analysis of equipment based on the everyday usages.

### 6. Quality Maintenance:

It is focused towards the customer satisfaction by delivering high quality products. Through focused improvement defects are eliminated from the process through effective maintenance procedures.

### 7. Office TPM:

Office TPM aims to improve the administrative functions or processes more effectively. This includes process and procedures that can be automated. The

documents are maintained with proper labeling mechanism, sorting the files within the rack as per the standards etc. Office TPM aims for improving the standard office work culture in order to maintain the documents frequent usages.

### 8. Safety, Health & Environment:

The aim is to improve the safety by proper education and training provided to the workers every now and then. Safety maintenance of equipment's must be regulated every now and then for the concern of workers.

The motto of this pillar is to achieve zero defects and zero accidents within the shop or workplace.

### 1.3 Concept of overall equipment effectiveness

Overall equipment effectiveness is a common standard for measuring productivity of the organization. This concept tries to define the percentage of manufacturing time maintained to be truly productive. OEE aims to benchmark the performance of the machineries compared with standards. OEE helps to improve the productivity of the manufacturing equipment.

The physical relationship of OEE (1) can be expressed as given below:

$$OEE = Availability * Performance * Quality \quad (1)$$

Where:

Availability = It measures the percentage of usage of the equipment throughout the time.

Performance = It describes the operating characteristics of the equipment subject to repair and other losses

Quality = It expresses the percentage of both good and bad part produced together

## 2 Literature review

This section describes the brief literature survey collected on TPM concepts as shown:

**Ranteshwar Singh, Ashish M Gohil, Dhaval B Shah, & Sanjay Desai [1]** - In this article authors have focused the difference between quality and manufacturing which are closely connected to the organization. Over a period of certain time these two have emerged into TPM (Total Productive Maintenance) and TQM (Total Quality Management) respectively. In this paper author described the importance of TPM (Total Productive Maintenance) and its significant features. The concept was implemented in auto component manufacturing industry. Also, authors have suggested the concept of OEE for successful implementation of TPM.

**Dip Kumar Patel & Prashant Singh Tomar [2]** - The proposed article describes the efforts to minimize the machine downtime at manufacturing unit of switch gear situated in north Indian states. The problem focused primarily is idle time due to machine break down. In order

to reduce the machine breakdown time TPM (Total Productive Maintenance) is carried out to improve the quality of equipment functioning. In addition to that the authors have described about the various pillars of TPM and OEE concepts.

**Sivakumar Annamalai, Suresh D. [3]** - The present article focuses about the self-directed maintenance namely TPM. TPM concept is incorporated with Overall Equipment Effectiveness (OEE) for enhancing the productivity of equipment. In the proposed work OEE concept is applied to measure the effectiveness of machines and equipment's with respect to the daily use. OEE stands as benchmark reference for all companies in order to maintain the tools and machineries with good working conditions.

**Wan Hasrulnizam et al. [4]** - In present article the main focus is made on the use of office TPM for Lecturer room in the faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka. Selected as primary source for data gathering, Observation and Interview techniques used in this work. In the present work the main respondents considered are staffs and students. For the enhancement of Office TPM lecturer room was selected for further implementation using 5S concept. The results obtained from 5S concepts created a positive impression to all staffs and students of the university in Malaysia.

**Jignasha P. Acharya & Maharshi J. Bhatt [5]** - The entire work focused on the implementation of TPM and its various pillars to solve the manufacturing problem within the organization. Also in this paper focus on OEE concepts improves the success of industry by maintaining the factory machines with high working standards.

**Wasim S. Hangad & S. Sanjay Kumar [6]** - In this work authors have focused on medium sized industry for TPM implementation. Depending on the size industries are classified into three types namely small, medium and large sized industries. In this existing work deep focus is made on TPM challenges and implementation and its significant importance.

**Rahul V. Dandage, Prasad K. Hajare, Manoj V. Dhebe, Amitraj U. Lad, Santosh S. Pinjari [7]** - In this article authors have made key focus on laboratories available in technical institutions in India particularly they considered engineering institutions. In every technical institution there are various laboratories equipped with all latest instruments but the thing is how these instruments going to serve the need in future use. In this work TPM concept is focused for improving the quality and use of lab instruments for effective demonstration. Also in this work authors have given suggestion to use preventive maintenance in order to keep the equipment in good working condition.

**Vigneshwaran, Maran & Manikanadan [8]** - The main purpose of this article is to improve the effectiveness of equipment using concept named TPM ( Total Productive Maintenance) . In this paper both tangible and Intangible measures are discussed briefly to analyze the importance and implementation of TPM in many several applications such as Educational Institutions and Industries. In this present work authors conducted review by collecting several sources on Total productive maintenance and its applications. The literature focuses on TPM by enhancing Overall Equipment Effectiveness as well as Employee Morale.

**Hemlata Vivek Gaikwad [9]** - The article discuss about the purpose of Jishu Hozen one among the pillar of TPM activity aims to focus on zero defects, Zero accidents, Zero breakdowns and Zero wastages. There are three phases in the study namely planning, Observing and Analyzing. Organization formed a research team to do necessary analysis and experiments using the Jishu Hozen pillar of TPM. By implementing the TPM concept in industries employee can able to achieve the target of more than 85 % as per world class standards.

**Yash Parik & Pranav Mahamuni [10]** -In this paper the detailed research is carried on the various methods and processes to improve the quality and maintenance. TPM helps to improve the productivity of the manufacturing operations. TPM Pillars serves as effective guidance and support for successful implementation. In this article attempt has been made to TPM objectives, benefits and Overall equipment effectiveness.

**I.P.S. Ahuja and J.S. Khamba [11]** - The main purpose of this article is to conduct detail review on TPM and its implementation challenges.This paper focuses on Importance of TPM, Basic framework and its applications in machine maintenance in shop floor. Detailed survey is conducted by questionnaire technique.

**Ravishankar V. Korgal & Anil S. Badiger [12]** -In the fast-growing competitive environment TPM is the best focused philosophy used in all manufacturing enterprises in order to improve the productivity of the resources. The main role of this work is to review the concept of TPM in engineering educational Institutions. In this paper suitable effort has been made to implement the TPM practices in normal applications. This article strives for finding out the possible areas to implement TPM and its roles in Technical Institutions.

**A. Sivanatham & N.M. Sivaram [13]** - The present article focuses on the review about TPM concepts and applications. This article represents the basic origins of TPM, process guidelines and Case studies.According to the Total Productive Maintenance it is observed from the fact

that TPM is most widely used concept in many countries.Therefore, TPM is considered to be world class strategy.

**Muhammad Zubair et al. [14]** – This article primarily focus on OEE (Overall Equipment Effectiveness). Since equipment is the main key important element in the production its quality must be fixed higher in order to perform much better. In this work evaluation of OEE (Overall Equipment Effectiveness) is carried out in local pharmaceutical industry situated in Pakistan. In OEE concepts there are three main parameters considered namely availability, Performance & Quality. OEE concepts will try to identify the area for identifying the bottlenecks in production line.

**Lisbeth del Carmen Ng Corrales et al. [15]** - This paper tells about the status of research carried out by the various authors on OEE concepts practiced in TPM implementation for machine as well as equipment maintenance . Authors have reviewed 862 articles out of that they took references of about 182 articles from highly indexed journals on TPM concept. Based on the review of literature following are the three key results noted by the authors. 1. The academic Interest in TPM has increased a lot in last few decades 2. Many no of authors developed model based on OEE concepts in TPM. 3. OEE is the emerging topic in the area of logistics operations and services. Moreover this research serves as base for future literature studies.

**V. Ramakrishnan & S. Nallusamy [16]** - In this present work the main aim is to implement the lean technique in TPM methodology in order to reduce the machine breakdown time within the shop floor unit. This study was conducted in foundry shop in a leading manufacturing industry situated in south Tamil Nadu. Also from the results of analysis it is confirmed that breakdown failure happens due to flaws observed in casting operation. After careful study suggestion has been given to reduce the overall lead time and breakdown time. Based on the result it is found that 20 percentage savings done in improving the breakdown time to minimal after incorporating the lean technique in TPM work culture.

**G. Pinto et al. [17]** - The present article describes the importance of maintenance in Industrial Sector. Even though there are many strategies used to tackle various productivity issues. This work was implemented in the industrial context. The methodology chosen here is Total Productive Maintenance (TPM). TPM uses maintenance activities which are derived from preventive maintenance. Based on the results it is observed that there was a decrease in breakdown due to failure by 38% this leads to increase in machine availability and Overall Equipment effectiveness.

**Melesse workneh Wakijra et al. [18]** - The main objective of this work is to review the contributions of TPM in various dimensions within the organization. In this work significant importance is studied and evaluated by measuring the performance improvements. In the present work various factors like top management support and leadership, traditional maintenance policies and various initiatives taken during the implementation process of TPM.

**A.Y. Ali [19]** - The problem encountered in this work is frequent breakdown of equipment namely Xerox machine due to poor unpleasant work environment. Thus the above problems lead to disrupt exams and other productive work in the university. In this work TPM is used as modern approach by equipping the concept namely Overall Equipment effectiveness. Thus at the end authors have stated the outcomes of using TPM concepts in practical applications.

**T. Ahamed et al. [20]** - TPM helps to maximize the equipment usage and its performance. The goal of TPM is to improve the effectiveness through proper handling of tools by following the guidelines as framed by the top management team within the organization. The entire work was divided into two phases namely phase 1 and 2

respectively. In phase 1 the possible losses and the contributing losses which affect the process are addressed here. In the second phase TPM implementation and suggested training program is initiated by the management of company for smooth operation of processes.

#### **Summary of literature:**

Based on the above survey it is observed that several researchers have contributed their ideas on TPM which includes the integration of OEE concepts in enhancing the efficiency of machines and supporting equipments. In some research articles focus is made on 5S Concepts in TPM then followed by various pillars of TPM like autonomous maintenance, planned maintenance and quality maintenance are implemented for successive functioning of TPM.

### **3 Methodology**

In this section the diversified survey (Table 1) is collected from around 27 respondents from various departments within the same organization. The methodology carried out for survey mechanism is through Google survey forms with 6 different questions as described below:

*Table 1 The diversified survey*

## **TPM (TOTAL PRODUCTIVE MAINTENANCE) - SURVEY FOR WORKPLACE MAINTENANCE**

**MANAKULA VINAYAGAR INSTITUTE OF TECHNOLOGY**

**Email \***

**QUESTION 1 How often your organization supports Total Productive Maintenance methodology**

- very rare  
 always  
 few times  
 none

**QUESTION 2 Does your Institutes have enough resources to implement TPM strategy**

- yes  
 NO

**QUESTION 3 Does your Institutes follow 5 S concepts in TPM Methodology as regular practice.**

- yes  
 NO

**QUESTION 4 Does your Employees are trained enough to use TPM Guidelines in real time situations.**

- yes  
 NO

**QUESTION 5 In a day how many times you keep your work system neat and clean by TPM approach.**

- 2 times in a day

- 1 time in a day
- 4 times in a day
- none

**QUESTION 6 What type of Maintenance strategy you prefer to use in your work place for guiding the employees?**

- Autonomous Maintenance
- Corrective Maintenance
- Predictive maintenance
- none

The outcome of the survey is described as follows:

1. 55.6% of the respondents gave positive feedback about TPM support within the organization.
2. 18.5% of the responded that only few times they used TPM support within the organization.
3. 25.9% of the respondents said very rare cases TPM resources are supported within the organization.
4. Only 11.1% of the respondents said that the institute does not have effective TPM strategy.
5. 88.9% of the respondents said that their institutes have enough resources to have effective TPM strategy.
6. 74.1% of the respondents replied that their institutes have regular resources for 5S practices.
7. 25.9% of the respondents replied that their institutes will adapt to 5S practices.
8. 66.7% of the respondents said that their organization has well trained employees to use TPM Guidelines.
9. 33.3% of the respondents said that their organization has well trained employees to use TPM Guidelines.
10. 29.6% of the respondents said that only 2times in a day the work system was maintained neat and clean by TPM Approach.
11. 25.9% of the respondents said that only 1 time in a day the work system was maintained neat and clean by TPM Approach.
12. 37% of the respondents said that only 4 times in a day the work system was maintained neat and clean by TPM Approach.
13. 7.4% of the respondents said that none are not maintaining the work system neat and clean by TPM Approach.
14. 40.7% of the respondents preferred autonomous maintenance in workplace for guiding employees.
15. 25.9% of the respondents preferred predictive maintenance in workplace for guiding employees.
16. 33.3% of the respondents preferred corrective maintenance in workplace for guiding employees.

The above information is represented in the form of pie chart as described below (Figure 2 - Figure 7):

QUESTION 1 How often your organization supports Total Productive Maintenance methodology  
27 responses

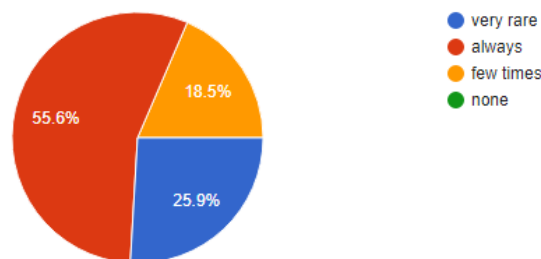


Figure 2 Respondent feedback

QUESTION 2 Does your Institutes have enough resources to implement TPM strategy

27 responses

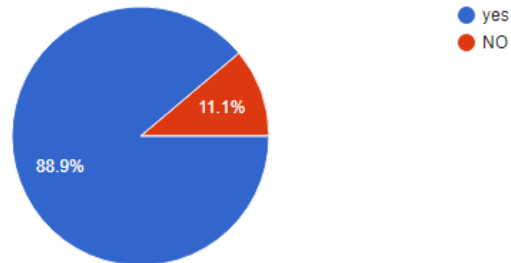


Figure 3 Respondent feedback

QUESTION 3 Does your Institutes follow 5 S concepts in TPM Methodology as regular practice .

27 responses

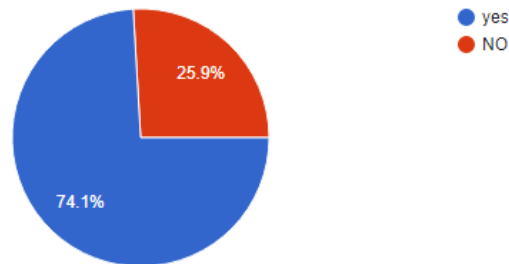


Figure 4 Respondent feedback

QUESTION 4 Does your Employees are trained enough to use TPM Guidelines in real time situations .

27 responses

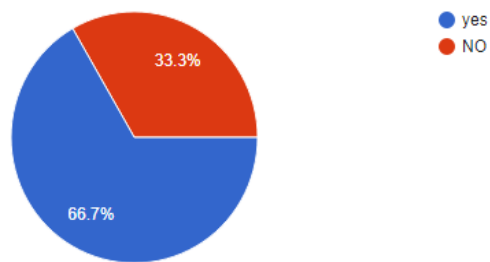


Figure 5 Respondent feedback

QUESTION 5 In a day how many times you keep your work system neat and clean by TPM approach .

27 responses

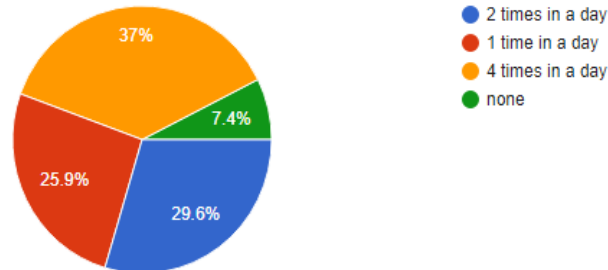


Figure 6 Respondent feedback

QUESTION 5 What type of Maintenance strategy you prefer to use in your work place for guiding the employees ?

27 responses

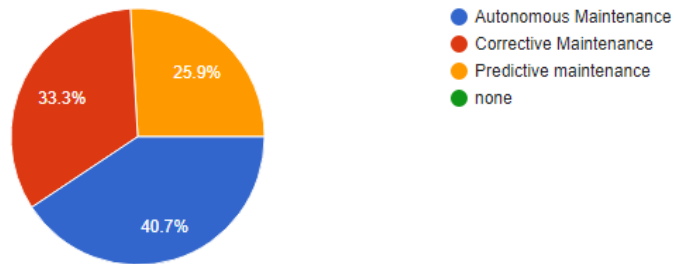


Figure 7 Respondent feedback

#### 4 Case study

In this section attempt has been made to conduct detailed investigation on lab equipment maintenance using TPM strategy. Maintenance study was carried out in Higher Learning Technical institutions situated in south Tamil Nadu. The study conducted in the Department of Mechanical Engineering laboratories namely production technology lab, Metrology and Instrumentation lab, Material Testing and Metallurgy lab, Thermal lab and Design Engineering lab. The details of lab are shown in below figures (Figure 8 - Fugure 10):



Figure 9 Machine Shop

Production Technology lab:



Figure 8 CNC Laboratory

Metrology and Instrumentation lab:



Figure 10 Metrology Laboratory



**Conclusion**

Panneerselvam Sivasankaran

The specific focus of work is carried out in Production Technology lab especially Machine shop. In this study both 5S and scheduled maintenance is followed here in this study as described below:

**5S in lab Equipment Maintenance:**

Following are the steps followed in 5S implementation in lab setup as listed below:

1. First thing in machine shop sort out the unwanted materials away from the place that will not add any value.
2. Next thing set in order as per the sequence all basic facilities such as machineries, tools and equipment.
3. Next important job clean the machines daily in order to maintain it in better workable condition.
4. Then standardize the process to improve the setup time as well as through put time.
5. At last sustain in improving the effectiveness of work by maximizing the performance efficiency.

Following are the numerical data taken within the machine shop for 30 days as described below (Table 2).

*Table 2 the numerical data taken within the machine shop*

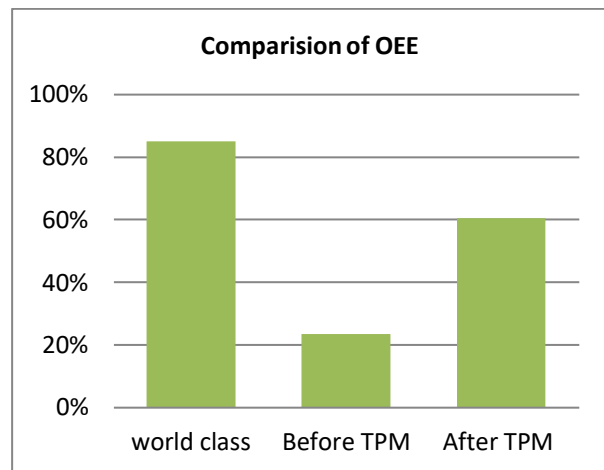
S.NO	Category	Before TPM	After TPM
1.	Total time	16 hrs	5 hrs
2.	Down time	15 days	6 days
3.	Run time	15 hrs	6 hrs
4.	Availability	60%	80%
5.	Performance Efficiency	65%	90%
6.	Quality rate	60%	84%
7.	OEE	23.4%	60.48%

According to world class standards for manufacturing OEE must be 85% but here the observed OEE value obtained after implementing TPM is said to be 60.48% (Figure 11). There is some difference significant difference between the observed value and standard value.

From the above data it is clearly observed that there is lot of misconception of TPM implementation due to the following challenges as described below:

1. Lack of technical support teams.
2. Lack of awareness about the concept of TPM from learning stage.
3. Poor implementation procedures.
4. Lack of coordination within the team members.

These are the above reasons for obtaining poor OEE score even though after implementing TPM in machine shop environment.



*Figure 11 Comparison of OEE*

From graph 1 (Figure 11), it is clearly understood that observed OEE value is far less compared to world class standards. Based on the above reasons the organization has to take some remedial measures in improving the effectiveness of TPM. Thus this case study clearly describes the challenges and various views within the machine shop environment. The main thing which is commonly noted here is lack of technical maintenance and other support facilities in addition to that top level management vision is not much clear in forming the guidelines for TPM implementation in work place. Hence strong focus is made on to improve the 5S and other maintenance systems within the work area.

**5 Conclusion**

TPM has become the key important business strategy for improving the enterprise planning and development in various ways starting from planning to implementation and execution level. The effective TPM implementation helps to optimize the machine performance in terms of productivity. It is highly important to understand the basic philosophy of TPM and its features in manufacturing systems. In highly competitive environment following TPM practices will lead the organization to go for high scale of production. Thus TPM Prove to be the best competitive strategy followed in manufacturing organization.

In this paper attempt has been made to review the various literatures of TPM and its future extensions followed by data collection through Google survey obtained from around 27 respondents within the same organization. In addition to that case study is also presented here to highlight the TPM challenges applied in lab setup of technical higher learning institutes.

**References**

[1] SINGH, R., GOHIL, A.M., SHAH, D.B., DESAI, S.: Total Productive Maintenance (TPM) Implementation

## Conclusion

Panneerselvam Sivasankaran

- in a Machine shop: A Case Study, *Procedia Engineering*, Vol. 51, pp. 592-599, 2013.
- [2] PATEL, D.K., TOMAR, P.S.: *Implementation of TPM Concept In Manufacturing Industry*, International Conference on Ideas, Impact and Innovation In Mechanical Engineering, Vol. 5, No. 6, pp. 102-110, 2017.
- [3] SURESH, S.D.: Implementation of TPM for Improving Overall Equipment Effectiveness in Manufacturing shop, *International Journal Of Recent Technology & Engineering*, Vol. 8, No. 3, pp. 1-6, 2019.
- [4] HASRULNIZZAM, W. et al.: *Development of Office TPM for Lecturer Room*, Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka, 2008.
- [5] ACHARYA, J.P., BHATT, M.J.: A Brief Literature Review on Total Productive Maintenance - A Positive approach to solve manufacturing problem, *International Journal of Advanced Engineering Research and Development*, Vol. 1, No. 5, pp. 1-8, 2014.
- [6] HANGAD, W.S., SANJAYKUMAR, S.: Review Paper on TPM – A Key strategy for Productivity improvement in medium sized industry, *International Journal of Scientific and Engineering Research*, Vol. 4, No. 11, pp. 12348-1252, 2013.
- [7] DANDAGE, R.V., HAJARE, P.K., DHEBE, M.V., LAD, A.U., PINJARI, S.S.: Development of Framework for Effective Implementation of TPM in Engineering Education Institute, *International Journal of Innovative Research in Science and Engineering*, Vol. 2, No. 2, pp. 109-114, 2016.
- [8] SHANMUGAM, V., MARAN, M., GURU, M.: Impact of TPM Implementation: Literature Review & Directions, *International Journal of Innovative Science, Engineering & Technology*, Vol. 2, No. 12, pp. 114-120, 2015.
- [9] GAIKWAD, H.V.: TPM in Manufacturing Industry: A Case Study of JishuHozen Implementation, *Indian Journal Of Science and Technology*, Vol. 11, No. 37, pp. 1-13, 2018.
- [10] PARIK, Y., MAHAMUNI, P.: TPM: Need & Framework, *International Journal of Innovative Research in Advanced Engineering*, Vol. 2, No. 2, pp. 126-130, 2015.
- [11] AHUJA, I.P.S., KHAMBA, J.S.: Total Productive Maintenance: Literature Review and Directions, *International Journal of Quality and Reliability Management*, Vol. 25, No. 7, pp. 709-756, 2008.
- [12] KORGAL, R.V., BADIGER, A.S.: Application of TPM in Engineering Education: Literature Review, *International Journal of Science Technology & Management*, Vol. 5, No. 1, pp. 54-75, 2016.
- [13] SIVANATHAM, A., SIVARAM, N.M.: A literature Review on TPM, *International Journal of ChemTech Research*, Vol. 10, No. 13, pp. 138-144, 2017.
- [14] ZUBAIR, M. et al.: Manufacturing productivity analysis by applying overall equipment effectiveness metric in a pharmaceutical industry, *Cogent Engineering*, Vol. 8, No. 1, 2021.
- [15] LISBETH DEL CARMEN NG CORRALES, LAMBAN, M.P.: KORNER, M.E.H., ROYO, J.: Overall Equipment Effectiveness: Systematic Literature Review and Overview of Different Approaches, *Applied Sciences*, Vol. 10, No. 18, pp. 1-20, 2020.
- [16] RAMAKRISHNAN, V., NALLUSAMY, S.: Implementation of Total Productive Maintenance Lean Tool to Reduce Lead time – A Case study, *International Journal of Mechanical Engineering and Technology*, Vol. 8, No. 12, pp. 295-306, 2017.
- [17] PINTO, G. et al.: TPM Implementation and Maintenance Strategic Plan - A Case Study, *Procedia Manufacturing*, Vol. 51, pp. 1423-1430, 2020.
- [18] WAKIJRA, M.W. et al.: Total Productive Maintenance: A case study in Manufacturing Industry, *Global Journal of Researches in Engineering Industrial Engineering*, Vol. 12, No. 1, pp. 25-32, 2012.
- [19] ALI, A.Y.: Application of Total Productive in Service Organization, *International Journal of Research in Industrial Engineering*, Vol. 8, No. 2, pp. 176-186, 2019.
- [20] AHAMED, T. et al.: A Total Productive Maintenance (TPM) Approach to Improve Production Efficiency and Development of Loss Structure in a Pharmaceutical Industry, *Global Journal of Management and Business Research*, Vol. 10, No. 2, pp. 186-190, 2010.

## Review process

Single-blind peer review process.