# STUDY OF TOTAL PRODUCTIVE MAINTENANCE: A CASE STUDY OF OEE IMPROVEMENT IN AUTOMOBILE INDUSTRY, BENEFITS AND BARRIERS IN TPM IMPLEMENTATION

Mr.C.K Jha[1], Ashish Singh[2]
Department of Mechanical and Automation, Amity School of Engineering and Technology, Lucknow

***ABSTRACT: Purpose- The purpose of this paper is to investigate the contributions of successful total productive Maintenance (TPM) required for competitive manufacturing. It also seeks to examine the effects of strategic implementation of TPM in an automobile manufacturing organization.***
***Design/methodology/approach- The study is carried out at an automobile industry that has successfully implemented TPM and gained significant benefits as a result of TPM implementation, the approach is directed towards the justification of the TPM implementation in automobile industries.***
***Findings- The study reveals that the strategic implementation of TPM can significantly contribute towards the improvement of manufacturing performance in the organization, the increase in efficiency and productivity of machines in terms of overall equipment effectiveness(OEE), benefits and barriers are discussed, that can be used for future study towards improvement in manufacturing.***
***Research limitations/consequences-***
***The study is conducted to investigate and understand the effects of an aggressive implementation of TPM for strategically meeting global challenges and competition.***
***Keywords: productive maintenance, OEE, manufacturing systems, benefits and barriers.***

## I. INTRODUCTION

TPM is a maintenance program that involves a newly defined concept for maintaining plants and equipment. TPM had its origin in the Japanese car industry in the 1970s. This concept was first introduced by Nippon denso, a major supplier of the Toyota Car Company, as a necessary element of the newly formed Toyota Production System. The origin of TPM can be traced back to year 1951, when preventive maintenance was introduced in Japan. TPM brings maintenance into focus as a necessary and important part of the business. [17] Total productive maintenance is an innovative approach of maintenance that optimizes equipment effectiveness, eliminates the breakdowns and promotes regular maintenance by the operators through day-to-day activities. Manufacturing organizations in particular often operate at less than full capacity, having lower productivity, and the costs of producing products are high. Recent study shows that 25-30% of total production cost is attributed to maintenance activities in the factory. Like many other process improvement methods, TPM has grown into a common process management method which can be applied in many situations, even for logistic or human factors as accounted. TPM emphasizes the importance of creating a feeling of 'ownership' on the factory shop floor. Therefore, this approach is commonly associated with strong involvement of the employees. TPM establishes a system for productive maintenance during the entire lifespan of the equipment. Because machine tends to breakdown more towards its later days. Therefore, TPM aims to keep machines in good shape and even facilitates maintenance continuously. [1][3]

## II. CONTRIBUTION OF TPM TOWARDS IMPROVING MANUFACTURING PERFORMANCE

TPM is an approach, which uses a number of tools and techniques to form highly effective plants and machinery. In competition with manufacturing industries rising rapidly, TPM has proved to be the maintenance improvement theory preventing the failure of an organization. The aim of TPM is to bring management, supervisors and trade union members together to take proper actions as and when required. TPM aims to use equipment at its maximum productiveness by eliminating the waste and loss caused by failure of the equipment, setting up and adjustment, speed losses, process defects and reduced yield.[7][4]
Total Productive Maintenance (TPM) is a productive maintenance program, which contributes on the following:
• Establishing a planned system for Preventive Maintenance (PM) of the equipment.
• Empowering the employees to initiate proper activities.
• Maximization of overall equipment effectiveness.
• Involving all employees from the top management to shop floor workers.
• Increases the efficiency of a single machine or an integrated manufacturing system.
• Tends to use the available resources as more as possible.
• Total participation of all employees includes Autonomous Maintenance(AM) by the operators into small group activities.
• Various success factors like top management Leadership & involvement, traditional maintenance practices are the significant contributions of TPM.
•By introducing and by working out interrelations between various pillars of TPM to analyze the fundamental structures and identifies the most suitable strategy for the overall equipment effectiveness.

## III. PILLARS OF TPM

The basic practices of TPM are called the pillars or elements of TPM. The entire structure of total productive maintenance

(TPM) is classified into eight pillars, all of them are supported by the foundation of 5S which includes Autonomous Maintenance, Focused Improvement, Planned Maintenance, Quality Maintenance, Early management, Education & Training, Office TPM, Safety, Health & Environment.[7][11][12]

*3.1. 5S*

5S is the foundation stone of TPM. It is a systematic process to achieve an undisturbed environment in the work place involving the employees with a commitment to sincerely implement and work.

There are five primary 5S phases: seiri, seiton, seiso, seiketsu, and shitsuke.

Table1 describes the key activates for effective 5S implementation at workplace.

Table1: key activities for effective 5S implementation at workplace.

| Japanese terms (English 5S/5C):Features |
|---|
| Seiri (Sort/Clear): Sort out unnecessary items from the Workplace and eliminate them. |
| Seiton (Set in order/Configure): Arrange necessary equipments/items in good order so that they can be easily picked up for use. |
| Seisio (Shine/Clean and check): Clean the workplace Completely to make it free from dust and other undesirable elements. |
| Seiketsu (Standardize/Conformity): To Maintain high standard of housekeeping and workplace. |
| Shitsuke (Sustain/Custom and practice): Train and Motivate people to follow good housekeeping disciplines regularly. |

Pillar1:Autonomous maintenance or Jishu Hozen:

This is the basic structure of TPM. Autonomous maintenance is the process by which equipment operators agree and share responsibility for the performance and health of their equipment.

Autonomous maintenance is further classified into three phases.

1. The first phase maintains the basic equipment conditions through restoration and eliminating causes of failure and sources of contamination. In order to ensure the conditions are sustained methods are introduced for cleaning, inspection, tightening and lubrication.
2. The second phase increases the capabilities of the employees by training them in detailed operating methods of the equipment and then improving the basic conditions.
3. Into the third phase the operators take full ownership of the equipment and tend to contentiously improving the condition and performance of the equipment.

Pillar 2: Focused improvement or kobetsu kaizen:

Focused improvement includes all the activities that maximize the overall effectiveness of equipment (OEE), processes, and plants through unwilling elimination of losses and improvement of performance. The basic concept behind Focused Improvement is Zero Losses. Maximizing equipment effectiveness requires the complete elimination of defects, and other failures.

When a focused improvement team for maintenance has been trained, they choose at least one equipment as a leader for the activities. Problems relating to the equipment are identified and improvement goals have been set in a three to five days.

The organization is able to build large base structure of employees that are expert with the correct tools for solving problems and eliminating to the root cause.

Pillar3: Planned maintenance (PM):

Planned maintenance is the scheduling of maintenance processes based on the behavior of machines observed such as failure rates and breakdowns. By scheduling these processes, the cycle of breakdowns and failure is broken thus contributing to a longer working life of machines.

Planned Maintenance aims to achieve zero breakdowns. PM follows a structured approach to establish a management system that increases the equipment reliability at idle cost.

Seven steps in planned maintenance are

1. Equipment evaluation and observing present Status.
2. Restore failure data and improve weakness.
3. Building up information management system.
4. Preparation of time based information system.
5. Select equipment, parts and members and layout Plan.
6. Prepare foretelling maintenance system by Introducing equipment diagnostic techniques.
7. Evaluation of the planned maintenance.

Pillar4: Quality maintenance (QM):

Quality maintenance pillar observes the issue of quality by ensuring that whether equipment is able to detect and prevent flaws during production. By detecting flaws, processes become reliable enough to produce the right product.

Using lean tools such autonomation (jidoka) and andon, machines detect any abnormal conditions, thereby relaxing the operators from the tiresome monitoring that is common in non-lean operations.

The quality maintenance pillar of TPM also deep rooted in the workforce the habit of finding the root cause of trouble instead of rushing to solutions. This is done by the tools such as 5 Whys root cause analysis and Ishakawa diagrams which are appropriate ways of getting to the real reasons why problems occur.

Pillar5: Early management:

Early equipment Management is the fifth pillar of TPM and aims to implement new products and processes and minimize the development lead time. It is usually deployed after the first four pillars,

By Using the input from the employees who uses the machines on a daily basis, suppliers of the equipment can improve the maintenance ability and operation ability in the next iteration of their products.
The factors that should be considered when designing new equipment include: [15]
1. Easy cleaning and inspection.
2. Easy lubrication.
3. Accessibility of equipment parts.
4. Improving operation ability of machines through ergonomically placing controls in such a way that Operator feels comfortable to use them.
5. Making it easier for operators to simplify the Procedures or eliminating the unnecessary ones.
6. Feedback mechanisms that prevent conditions as well as clears the indications of the correct description for quality products.
7. Increased safety features.

Pillar6: Education and training:
Education and training pillar is aimed to have multi-skilled energized employees whose morale is high and who has interest to come to work and perform all required functions effectively and independently.
This pillar is concerned with filling the knowledge gap that exists in employees when it comes to total productive maintenance. Lack of knowledge of the tools that can stand in the way of proper implementation leading to average results at best and failure at worst.
The different phase of education and training are:-
1. Do not know
2. Know the theory but cannot do
3. Can do but cannot teach
4. Can do and also teach

Pillar7: Office TPM:
Office TPM pillar should be started after activating four other pillars of TPM (Autonomous Maintenance, Focused Improvement, Planned Maintenance and Quality Maintenance). Office TPM concentrates on all areas that provide administrative and support functions in the organization. This includes analyzing processes and procedures.[18]
1. Major losses of office TPM are
   -Office equipment breakdown;
   -Cost loss in areas like accounts, sales,
   -procurement;
   -Office equipment breakdown;
   -Increased expenses on urgent dispatches/Purchases
   -Processing loss;
   -Communication loss;
   -Set-up loss;
   -Non availability of stock;
2. Benefits of office TPM are
   -Better utilized work area;
   -Reduction in number of files;
   -Reduced manpower;
   -clean and peaceful work environment;
   -Reduction in administration cost;
   -Office equipment breakdown reduced;
   -Reduction in customer complaints;
   -Reduced expenses on urgent dispatches/ purchases
   -Reduction of repetitive work.

Pillar8: Safety, health and environment:
The safety & health and environment pillar of total productive maintenance (TPM) ensures that all the workers are provided with an environment that is safe and all the conditions that are harmful to their well-being are eliminated. Safety, Health and Environment applies a methodology to achieve zero accidents. It is important to note that this is not just safety related issue but covers zero accidents, zero burdens (physical and mental stress on employees) and zero pollution.When workers are in a safe and healthy environment, their attitude towards work changes positively which as a result increase the important metrics such as productivity. This is because injuries or danger reduces when there is a effective effort to make the workplace an accident-free and healthy environment.

## IV. TPM IMPLEMENTATION METHODOLOGY

The implementation of TPM was very necessary to develop the sense of ownership of equipment among the operators and increasing their interest in work. The goal of better and increasing production can be achieved by active participation of the operators.
Depending on the size of the organization in terms of quantity of equipment, complexity of equipment handling, and availability of skilled and unskilled manpower, it takes 1-2 years to create a „total" TPM organization. However, a strategic plan is must for its proper implementation. [10][15][18] Following are the 10 steps for the implementation of TPM:-
*Step1.Announcement of TPM and commitment:* Making all the employees aware of the change of shifting the organization towards the new culture of TPM. Upper management commitment is the key to start with, by commitment of the sacrifice of short term goals into the long term goals.
*Step2.Pilot team building and meeting plan:*
The pilot team basically consists of eight persons for the line; there is one team leader for their shift, the production manager and the maintenance manager. The production manager and maintenance manager should be present at meetings.
The team comes out as: 8 operators; 1 team leader; 1maintenance person; Production Manager Maintenance Manager.
This group has to promote and sustain TPM activities. In the beginning, weekly meeting of the group should be organized up to 1 month, after a successful start, the meeting can be held fortnightly, for assessment of the progress.
*Step3. Launch of formal training program:*
This program will train and educate the pilot team as well as everyone in the organization about TPM activities, benefits, and the importance of contribution from each employee.
*Step4. Establishment of basic TPM policies and setting goals:*

During the meetings the group should analyze the existing conditions of the organization and set goals which are specific, measurable, attainable, realistic and time based.

*Step5. Making a detailed master deployment plan:*

This deployment plan will identify that what resources will be needed and when for training, equipment restoration, improvements, maintenance management systems and new technologies.

*Step6. TPM training and Kick-off:*

The practical practice and Implementation of TPM will begin at this stage.

*Step7. Improve efficiency of the equipments:*

On the basis of collected data and the recommendations for necessary improvements the restoration of the equipments should be done.

*Step8. Development of an autonomous maintenance program for operators:*

Routine cleaning and inspection will be done by the operators which will help in stabilizing the conditions and stop accelerated deterioration.

*Step9. Develop a preventive maintenance plan:* After 3 months of kick-off, make the review of preventive maintenance plan for every equipment and change it accordingly if needed.

*Step10. Follow the Continuous improvement:*

Improve measurement process; carry out scoping study, gap analysis and accountabilities. Set short, medium and long-term goals under a single master plan.

## V. OVERALL EQUIPMENT EFFECTIVENESS (OEE)

Measurement is an important requirement for continuous improvement process. TPM can be defined in terms of overall equipment effectiveness (OEE), which in turn considered a combination of the operation maintenance, equipment management, and the available resources. OEE scores provide a very valuable perception– an accurate picture of how effectively the manufacturing process is running. And, it makes it easier to track improvements in that process over time.[6][8]

The preferred OEE calculation is based on the three factors: Availability, Performance, and Quality

$$A \times P \times Q = OEE$$

Availability: Availability is calculated as the ratio of operating time of machine to running time.

Availability = (operating time of machine/ Running Time)*100

Operating time of machine = running time – total running time loss

Performance: Performance is the ratio of obtained output to the expected output It is calculated as:

Performance = (obtained output*100) / expected output

Expected output = idle cycle time * operating time of machine

Ideal Cycle Time – minimum time to produce one part.

Quality: It accounts for manufactured parts that do not meet quality standards.

Quality = (obtained output - rejected parts)*100/ obtained output

*World class OEE:*

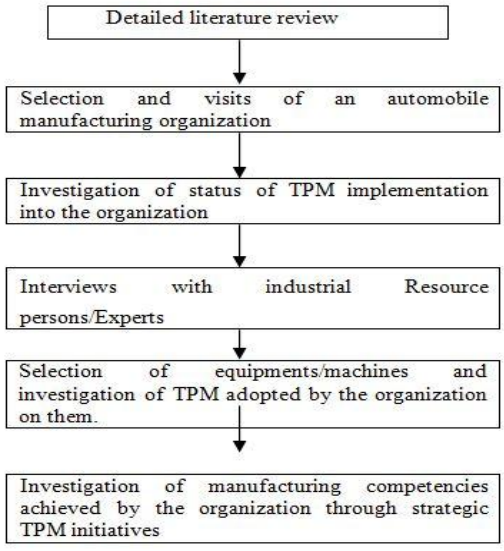
| OEE Factor | World Class |
|---|---|
| Availability | 90% |
| Performance | 95% |
| Quality | 99.9% |
| OEE | 85% |

Worldwide studies show that the average OEE rate in manufacturing units is 60%. World class OEE is considered to be 85% or better. Clearly, there is a room for improvement of OEE in manufacturing units.[4]

## VI. RESEARCH METHODOLOGY

The study highlights the contributions of TPM initiatives in manufacturing Plants, to realizing enhanced manufacturing performance. The study reveals that strategic TPM initiatives contribute significantly towards improvement in manufacturing performance in the organization and focuses on the benefits and the barriers comes into the implementation of TPM. This leads to the realization of core competencies for meeting global challenges. The performance measurement of the production process is very important for sustaining plants. Managers make decisions from the correct measurements. Therefore, appropriate measurement is necessary. The accuracy of global performance evolution is very essential to improve and succeed in business goal. One of the important and widely used tool of performance in manufacturing is OEE especially for organizations applying Total productive maintenance in order to achieve higher availability, performance and quality. [5][9][17]

The methodology employed in the present study is depicted in following Figure [17]



## VII. CASE STUDY IN AUTOMOBILE MANUFACTURING ORGANIZATION

The case study reported into this paper has been conducted at an automobile manufacturing organization in Lucknow. It has been observed that maintenance costs increased for 20-30 % of the production costs and emergency repairs were two times expensive then the same job done in pre-planned manner. Thus, the need for promoting an efficient TPM implementation program was felt fundamentally necessary.

### *7.1 SELECTION OF MACHINES*

The first step is selection of machines on which the study of OEE is carried out. Which is known as TPM model machine. Four machines have been selected for TPM implementation i.e.

2 Hydraulic bending machines, 1welding machine and 1painting machine.

These machines are used into the process of manufacturing exhaust pipes for TATA. [4]

## VIII. IMPROVEMENTS IN OEE

8.1. OEE for bending machine 1 before TPM

- shift time = 480 min
- planned downtime = 60min
- running time = 420 min
- total running time loss = 72min
- operating time of machine (C-D) = 348min
- obtained output = 316
- obtained no. of components /minute or idle cycle time= 1.08
- expected output(G*E) = 376
- rejection = 17

Availability(E/C)*100 = 82.85%
Performance(F*100)/H = 84.04%
Quality(F-I)*100/F = 94.6%
Therefore
OEE = A*P*Q
= 82.85% * 84.04% * 94.6%
= 65.8%

*8.2. OEE for bending machine 1 after TPM*

- shift time = 480 min
- planned downtime = 60min
- running time = 420 min
- total running time loss = 50min
- operating time of machine (C-D) = 370min
- obtained output = 345
- obtained no. of components /minute= 1.08
- expected output(G*E) = 399
- rejection = 8

Availability(E/C)*100 = 88.09%
Performance(F*100)/H = 86.46%
Quality(F-I)*100/F = 97.68%
Therefore
OEE = A*P*Q
= 88.09% * 86.46% * 97.68%
= 74.3%

Similarly OEE for rest of the machines is calculated

| Name of machine | OEE% Before | OEE% After |
|---|---|---|
| Bending machine 1 | 65 | 74 |
| Bending machine 2 | 63 | 76 |
| Welding machine | 56 | 65 |
| Painting machine | 59 | 67 |

## IX. RESULTS AND CONCLUSIONS

The Overall Equipment Effectiveness (OEE) is increased, Today TPM may be the only thing that stands between success and failure for some organizations; TPM has been proven to be a program that gives desirable results. The results shown above can be much more improved if the organization keeps continuing with TPM.

## X. BENEFITS OF TPM IMPLEMENTATION

Following are the potential benefits of successful TPM implementation in any organization. [16][21]

1. Improved Quality: Quality will be improved by reducing all types of failures and defects.
2. Improved Productivity: Productivity will be improved by reducing all major losses in the organization.
3. Reduction in cost: The TPM focuses on the Optimum utilization of the resources, which leads to the reduction in cost which is a supreme benefit for any company.
4. Employee Ownership: Due to implementation of TPM, operators perform the autonomous maintenance on their own machine and this brings the employee ownership in the organization this leads to the continuous improvement culture.
5. Improved working environment: Since the 5S is the foundation of TPM the neat and clean Shop floor improves the working environment in the industry and this also leads to increased reliability.
6. Customer Delightness: TPM creates a world class Manufacturing infrastructure in any organization And this leads to good quality, better delivery Which ultimately increase the customer Delightness.
7. Enhancing market image: Due to the TPM the high quality of productivity helps in enhancing the Company's image into the market.
8. High employee morale: The morale of employee increases due to the healthy Environment and employee's ownership.
9: Organizational development: As better as the TPM Followed as good as the organizational Developments become.

## XI. BARRIERS IN TPM IMPLEMENTATION

After understanding the basics and improvement of TPM, we will now discuss the barriers in TPM implementation. TPM implementation though easy on paper, but is difficult to achieve and this is mainly due to unwillingness by the organization to understand and implement the concepts of TPM and fail to realize the benefits obtained by implementation of TPM.[13][20]

Following are the barriers in TPM implementation:

- Lack of top management commitment.
- Non-Involvement of non-management staff.
- Unwillingness to invest on resources.
- Lack of communication between management and non-management staff.
- Lackadaisical approach of employees.
- Lack of knowledge of TPM.
- Lack of training of employees.
- Lack of Long term commitment of management and employees.
- Lack of manpower.
- Non involvement of employees into the decision making process.
- Non-implementation of pilot study.
- Non-availability of Standard Operating processes.
- Lack of Tools and instruments.
- Inconsistent and unclear expectations.
- Resistance to daily discipline.
- To much focus on output measures rather than the quality process.
- Lack of analysis capability.
- Non availability of skilled employees.
- Neglecting the basics of variation reduction, service, cost and safety.
- Objectives that creates organizational conflicts.
- Strategic plans of organizations are not customer driven.
- Lack of access to data and results.
- Failure of organizational structure and culture.
- Lack of reward and recognition.
- Higher level of absenteeism.

## XII. SCOPE OF STUDY

Today, the competition in industry at an all time high. TPM can be adapted to work not only in manufacturing plants, but also in construction, building maintenance, transportation, and in variety of other works. However, as a future research work, the contributions of TPM in conjunction with other related lean manufacturing tools like Just-in-Time manufacturing(JIT), Quality Function Deployment (QFD), Six Sigma, Business Process Reengineering(BPR) etc. can also be undertaken for assessing the contributions of world class manufacturing.

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[4] Amit Kumar Gupta1, Dr. R. K. Garg2 1Associate Professor-Deptt. of Mechanical Engineering, CEC, Landran, Mohali (India) 2Professor- Deptt. of Industrial and Production Engineering, NIT Jalandhar (India)
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[15] Jagtar Singh Ȧ, Vikas Rastogi Ḃ and Richa Sharma Ċ* Ȧ Mechanical Engineering Department, SLIET Longowal-148106, Distt. Sangrur, Punjab, India Ḃ Department of Mechanical &Production Engineering, Delhi Technological University Delhi-110042 Ċ Department of Mechanical & Automation Engineering, Amity University, Noida-201301.
[16] Yash Dave, Lecturer Manufacturing Engineering, Dhâr Polytechnic College, Dhar (M.P)
[17] I.P.S. Ahuja,University College of Engineering, Punjabi University, Patiala, India, and Pankaj Kumar Total Quality Management Initiatives, Tata Steel, Jamshedpur, India

  

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