

# Impact of Total Productive Maintenance (TPM) Practices on Manufacturing Performance: A Case Study of a Manufacturing Company

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## **ABSTRACT**

**Aim:** Total Productive Management (TPM) is a strategic change management approach that has considerable impact on the internal efficiency of manufacturing organization, both in the developed countries and developing countries. It is an innovative maintenance program with a concept for maintaining plant and equipment by the involvement of all personnel based in an organization for continuous improvement of performance. The purpose of the research was to evaluate the impact TPM pillars have on equipment availability focusing on the planned maintenance pillar. The research objectives were to; determine how the planned maintenance pillar was used at the company under study and the extent to which it was applied; to determine the impact that TPM had on the company's performance and finally to determine if the TPM pillars had helped in obtaining the overall expected results that rise from an effectively implemented TPM.

**Methodology:** A literature survey was undertaken into the elements and benefits of TPM, the pillars of TPM and finally the importance of equipment availability and overall equipment effectiveness (OEE). A quantitative and qualitative research approach was used in conducting the research. Structured interviews, questionnaires and company records were used in collecting data for the research. A total of 40 questionnaires were administered; 10 to the maintenance personnel and 30 to respondents from other departments of the company. Research data was analyzed using statistical package for social sciences (SPSS) and Microsoft excel.

**Findings:** The results from the research revealed the following, 42% of the respondents agreed a maintenance plan is prepared before any maintenance activity is carried out, 29% indicated a maintenance plan was not prepared before maintenance activities is carried out and the 29% indicated it was not prepared all the time. To determine whether planned maintenance was carried out according to schedule, 43% of the respondents indicated it was carried out according to schedule while 43% indicated planned maintenance are only carried out only when there is an equipment malfunction and 14% indicated planned maintenance actions are only carried out when need to perform maintenance arises. The researchers also the assessed how TPM had impacted on the company performance; 50% of the respondents believed TPM reduced equipment losses while 71% believed the system reduced equipment failures, 67% believed it improved productivity and 50% believed it reduced breakdown costs. As a result of implementing TPM strategy the company's overall equipment effectiveness ranges from 51% to 55%.

**Originality:** The originality of the research stems from the fact that, the research has never been conducted before at the company under study and also the reearch focuses on the relevance of the TPM planned maintenace pillar on the company manufacturing performance.

**Value:** Firstly the value of this research was to inform management on the need to employ each TPM pillar with a degree of equal importance as the entire pillars play role in enabling a company achieve world class standards in terms of manufacturing performance and overall equipment effectiveness. Secondly it points out that practicing TPM strategies is one of the best practices to achieve world class manufacturing standards.

**Key words:** Equipment Availability, Manufacturing, Performance, Total Productive Maintenance

## **1. Introduction**

Overall equipment effectiveness (OEE) is one of the key performance indicators a manufacturing company can use to determine its performance and total productive maintenance (TPM) has been used to improve OEE in most manufacturing companies. TPM is an aggressive strategy which focuses on actually improving the function and design of the production equipment. It aims to increase the availability/effectiveness of existing equipment in a given situation, through the effort of minimizing input (improving and maintaining equipment at optimal level to reduce its life cycle cost) and the investment in human resources which results in better hardware utilization (Schippers, 2001). According to Cooke (2000), the objective of TPM is to continuously improve the availability and prevent the degradation of equipment to achieve maximum effectiveness and these objectives require strong management support as well as continuous use of work teams and small group activities to achieve incremental improvements. In essence TPM seeks to integrate the organization to recognize, liberate and utilize its own potential and skills (Lee, 2002). Figure 1 depicts the TPM pillars.

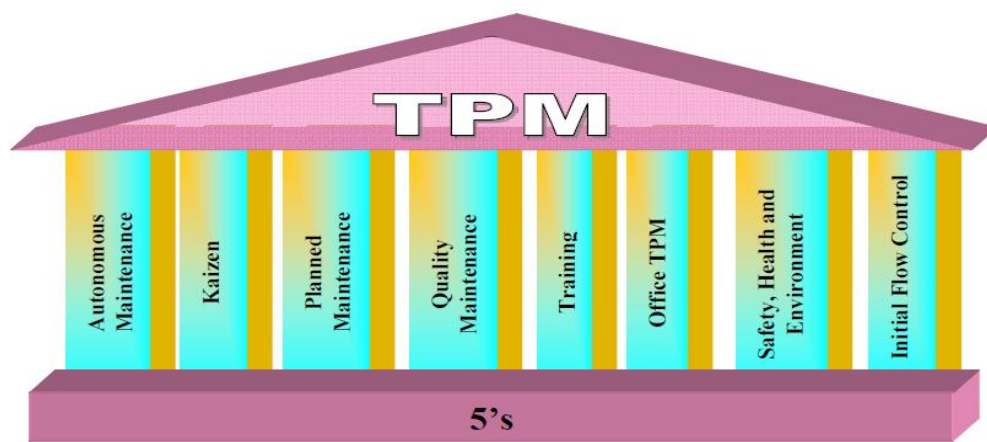


Fig 1: TPM Pillars ( Venkatesk, 2005)

According to the Japan Institute of Plant Maintenance (JIPM), they developed an eight pillar approach to TPM. This approach focuses on achieving zero defects, zero accidents and zero break-downs. TPM pillars are the change streams which were developed to create systems, processes and standards with people. These pillars were developed to bridge the gaps in hierarchies and in order to form unified and cohesive structures that spans all levels and functions to achieve common aims. The TPM pillars are Kobetsu-Kaizen (Continuous Improvement), Autonomous Maintenance, Planned Maintenance, Early Maintenance, Quality Maintenance, Training and Education, Office TPM, Safety, Health and Environment. These pillars are considered important in their own respective way and for successful implementation of TPM, all the pillars are indeed important. Continuous improvement pillar provides a structured, team-based approach to drive elimination of specifically identified losses in any process. It includes all activities that maximize the overall effectiveness of equipment, process and plants through uncompromising elimination of losses (Owen, 2012). According to Robinson and Ginder (1995), the autonomous maintenance pillar is the process by which equipment operators' accept and share responsibility for the performance and health of their equipments. It is a concept of autonomous maintenance for improving equipment reliability. Planned maintenance pillar is a cross functional team activity. Its function is to resolve more complex issues such as eliminating recurring problems and improving equipment efficiency (Borris, 2005). Its purpose is to establish and maintain optimal equipment and process conditions (Suzuki, 1994). Early Management pillar focuses on using the lessons from previous experiences to eliminate the potential for losses through the planning, development and design stages (Campbell 2009). Its main goal is to introduce a loss and defect free process so that equipment downtime is minimal and maintenance costs are all considered and optimized, from commissioning onwards. The sole purpose of the quality maintenance pillar is to reduce the cost of quality by preventing waste from poor quality products, reworks, consumer complaints and the need for inspection (Lysons, 2012). The JIPM (2009) considers the quality maintenance as activities that are to set on equipment conditions that preclude quality of products. The training and education pillar focuses on operator and maintenance personnel training to achieve zero breakdowns as many breakdowns are a lack

of skill (Lysons, 2012). Increased skills and performance of all personnel throughout the organization is essential for the successful implementation of TPM. Without the training and education pillar, the impact on kobetsu-kaizen, autonomous maintenance and planned maintenance will not be sustainable (Ogaji et al, 2004). TPM Office ensures that all processes support optimization of manufacturing processes and that they are completed at optimal cost (Vankatesh, 2008). Ensuring equipment reliability, preventing human error, and eliminating accidents and pollution are the key tenets of TPM.” (Suzuki 1994) and the SHE pillar activities aim to reactively eliminate the root causes of incidents that have occurred, to prevent reoccurrence, and proactively reduce the risk of future potential incidents by targeting near misses and potential hazards (Tsang , 2011). From the analysis of the TPM pillars, it is clear that each pillar is unique in its own way and should be implemented with the same level of importance in order to achieve zero defects, zero accidents and zero breakdowns.

Industrial manufacturing of products is facing accelerating changes of pace in technology and market demands (Jackson, 2000) and in recent years, many manufacturing industries have also experienced unprecedented degree of change in management, process technology, customer expectations, supplier attitudes and competitive behavior ( Beach et al, 2000). As a result of these changes, many manufacturing companies have implemented world-class manufacturing techniques such as TPM. The company under-study is not an exception of the changes that have occurred and therefore it implemented TPM. After the implementation of TPM by the company under-study, equipment availability improved and increased by 60% however equipment malfunctions and breakdowns were still experienced. Further analysis of the cause of equipment breakdowns, the causes indicated that, the activities of planned maintenance were not carried out as scheduled. In order to determine the impact of planned maintenance on a company that had fully implemented TPM, it was significant that, the researchers conduct the research.

Many studies have been conducted in developed and developing countries on the impact of TPM on Equipment availability. Afefy (2013) conducted a research on the implementation of TPM and OEE evaluation at a Salt Company in Egypt. The researcher concluded that, performance measurement for production process is very important for sustaining firms and one of the important and widely used metrics of performance in manufacturing is OEE especially for firms applying TPM. Mwanza and Mbohwa (2015) conducted a research on the design of TPM model for effective implementation at a chemical manufacturing company in Zambia. The researchers proposed the designed model as the company OEE was calculated at 36.5% which was below the world class standard. They concluded that TPM can be used to enhance OEE of a company. Tamizharasi and Kathiresan (2012) conducted a research on Optimizing Overall Equipment Effectiveness of high precision special precision tools (SPM) using TPM tools in Chennai. The researchers concluded that, TPM is an appropriate tool for enhancing and improving OEE. Afefy (2013), Mwanza and Mbohwa (2015) and Tamizharasi and Kathiresan (2012) have affirmed and concluded that TPM is an appropriate tool to improve OEE but in their researches, they did not determine the impact each TPM pillar has on enhancing and improving OEE. The studies provide relevant information on the application of TPM. The researchers therefore conducted this research to examine the impact of TPM pillars on performance with a focus on the planned maintenance pillar at a beverage manufacturing company in Zambia. The following research questions were addressed; how is planned maintenance pillar used at the company and the extent to which it is applied? How has TPM impacted on the company’s performance? And have the TPM pillars contributed in obtaining the overall expected results expected after effectively implementing TPM?

In section 2, the empirical case-study presented. A description of the results and discussion is presented in section 3 while conclusions are presented in section 4.

## **2. Empirical Case Study**

### **2.1 Research methodology, data and analysis**

Explanatory research design was employed as the researchers needed to understand and interpret the company responses on TPM and the TPM pillars. Research data was collected from maintenance personnel and other members from different departments of the company such as quality, production and

procurement departments. Questionnaires, structured interviews and company records were used to obtain data.

Two types of questionnaires were designed; one for the maintenance personnel and the other for personnel in other departments..

The RAOSOFT sample size calculator was used to determine the sample for the research. A population of 200 employees was considered. Using a margin of error of 5%, confidence level of 95% and response distribution of 50% for the research, the sample size was calculated at 132.

40 questionnaires were administered, and the remaining number of the sample size was randomly selected for structured interviews. A total of 10 questionnaires were randomly distributed in the maintenance department while 30 were distributed in other departments

The questionnaire for the maintenance department focused on;

- Whether a maintenance plan was prepared before conducting the actual work
- The type of planned maintenance actions conducted on the machinery and equipment
- The frequency of conducting the planned maintenance
- Whether TPM was well implemented in the company
- How have the TPM pillars contributed to performance of the company.

The questionnaire distributed in other departments focused on;

- Understanding the respondents views on TPM in the company
- How familiar the respondents are to TPM pillars
- The level of importance they would give to TPM
- How have TPM impacted on the company

Interviews were conducted with the production foreman and the production controller. Interviews provided first hand information pertaining to maintenance and its effect on production.

A literature survey was conducted in order to have an in-depth understanding of TPM and its pillars. It was also conducted in order to understand TPM theories in the real world scenarios. Company records were also very useful in understanding the impact TPM has had on the company since its implementation. Research data was analysed using Microsoft excel and statistical package for social sciences.

## **2.2 Key Findings**

A total of 40 questionnaires were distributed, 10 were distributed to the maintenance department and only 8 were retrieved while 30 were distributed in other departments and only 24 were retrieved.

Of the 10 questionnaires distributed in the maintenance department, the respondents who answered the questionnaire were found to be machine operators, assistant controllers, specialized workers, loss controller, maintenance manager and maintenance technicians. Interviews were randomly conducted with employees in the departments such as procurement, marketing, accounts and production. Company records used were from the production and maintenance departments.

### **2.3.1 Planned Maintenance Pillar**

According to Clifton (2009), Nakajima (1988) and Takahashi (1981), planned maintenance is one of the pillars that make up TPM. As a result of this, the researchers assessed the whether planned maintenance was practiced at the company under-study. The findings after the analysis of planned maintenance revealed that, 42% of the respondents agreed a maintenance plan is prepared before any maintenance activity is carried while 29% indicated a maintenance plan is not prepared before any maintenance activity is carried and another 29 % indicated it was not prepared. Figure 1 depicts the findings after the analysis of planned maintenance practices.

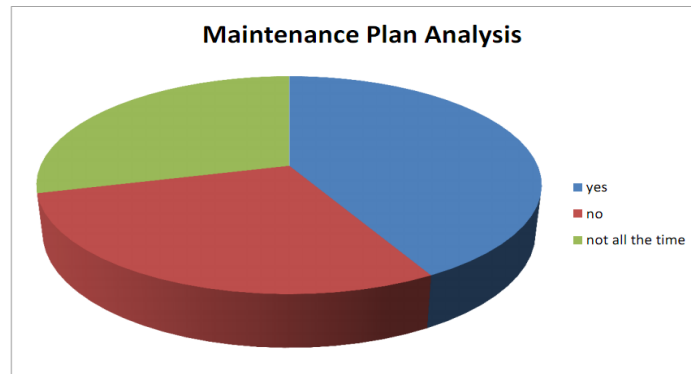


Fig 1: Planned Maintenance Analysis

Further analysis of the extent to which the planned maintenance pillar is practiced in the company, the researchers analyzed the maintenance tasks conducted on the machinery and 7 out of the 10 respondents in the maintenance department responded to this question. Table 1 shows the maintenance actions performed.

Table 1: Planned Maintenance Actions Performed

ACTIONS	RESPONSE OUT OF 7	PERCENTAGE (%)
Lubrication	5	71
Cleaning	7	100
Adjustments	4	57
Application of Protective clothing	5	71
Examination of components	3	43
Analysis of history of behavior of machine components	2	29
Replacement of worn out components	3	43
Repair of cracks and other repairable damages	3	43
Modification	2	29
Replacement of equipment	3	43

Analysis of the planned maintenance actions performed, 100% of the respondents agreed cleaning was performed, 71% indicated lubrication and application of protective coatings. 57% of the respondents indicated adjustments on the equipments were carried out while 43% indicated examination of components, replacement of worn out components and repair of cracks. 29% of the respondents indicated historical behavior of machine components and modifications are carried out.

Further analysis of planned maintenance practices in a company that has implemented TPM, the researchers assessed whether planned maintenance was practiced as scheduled on the machinery. The results revealed the following; 43% of the respondents indicated planned maintenance actions are carried out as scheduled while another 43% indicated planned maintenance actions are carried out only after malfunction of the machinery and 14 % indicated planned maintenance actions are only carried out when need arises.

### 2.3.2 TPM Impact on Company Performance

50% of the workers indicated TPM system reduced equipment loss, 71% indicated the system reduced equipment breakdowns while 67 % indicated the system improved productivity and 50% indicted it reduced breakdown costs. Further analysis of the impact TPM has had on the company performance; the researchers further analyzed the data obtained from the company records regarding equipment availability from two separate years; 2013 and 2014. Table 2 shows equipment availability.

Table 2: Equipment Availability for 2013/2014

Lines Availability %	Budget Year	Budget Month	Budget YTD	2014 Jan	2014 Feb	2014 Mar	2014 Apr	2014 May	2014 Jun	2013 Jan	2013 Feb	2013 Mar	2013 Apr	2013 May	2013 Jun
Availability %	57.5 %	57.5 %	57.5 %	60.4 %		46.1 %	39.5 %	38.4 %	44.1 %	68.9 %	62.0 %	66.9 %	68.1 %	69.5 %	66.1 %
Start-up/shutdown %	3.8%	3.8%	3.8%	5.8%		4.1%	4.4%	4.0%	3.6%	0.8%	4.9%	6.1%	5.2%	3.6%	3.7%
Changeover %	2.3%	2.3%	2.3%	2.3%		1.0%	1.3%	1.7%	1.9%	2.7%	3.5%	1.9%	1.6%	2.6%	2.8%
Cleaning %	8.0%	8.0%	8.0%	13.0 %		9.5%	10.4 %	9.5%	9.8%	13.0 %	13.4 %	13.4 %	12.0 %	8.7%	9.6%
Prev. Maintenance %	4.8%	4.8%	4.8%	5.2%		1.4%	2.0%	2.6%	1.8%	4.6%	3.6%	4.5%	4.1%	6.1%	6.6%
Downtime -waiting %	5.1%	5.1%	5.1%	8.7%		0.7%	2.4%	2.7%	1.4%	5.2%	8.6%	3.2%	5.3%	5.1%	7.0%
Downtime - Mechanical %	4.9%	4.9%	4.9%	4.7%		0.9%	1.4%	2.1%	2.1%	4.9%	4.2%	3.9%	3.7%	4.4%	4.2%
Others %	13.2%	13.2%	13.2%	0.0%		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Further analysis of the impact TPM has had on company performance, figure 3 shows the company records of the Ultra High Temperature OEE trends for the first 6 months of 2012 and 2013 respectively. The company targeted OEE ranges from 51% to 57%. This is a good impact on the company performance as the OEE is closer to the world class standard.

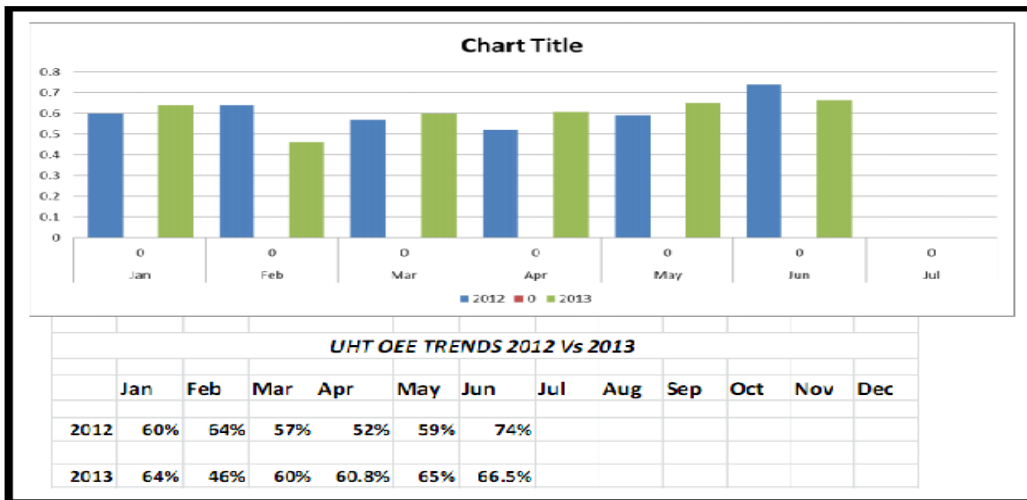


Fig 2: UHT OEE Trends

### 2.3.3 Contributions from the TPM Pillars

The goals of a good TPM system are to achieve zero defects, zero accidents and zero breakdowns. The results from the respondents regarding TPM pillars revealed the following; 100% of the respondents indicated training and education on TPM was offered. Further analysis of whether technical training and education was provided in other departments other than the maintenance revealed that 79.2% of the respondents agreed that technical training is offered while 20.8% indicated it was not provided. The respondents also indicated that training is provided through workshops and seminars. Regarding autonomous maintenance, 100% of the respondents indicated operators were involved in equipment maintenance and that, the operators ensured equipments in good condition are used to produce products. As a result of this, high quality products are manufactured at the company under- study. This has also helped the company achieve less or zero product returns.

Regarding the safety, health and environment (SHE) pillar, 29% of the respondents rated the levels of SHE to be average while 71% of the respondents rated it good. These responses were mainly from the maintenance department.

Management involvement in TPM was assessed and was rated at average by most of the respondents in non- maintenance departments. Assessing management commitment to TPM was in relation to the office TPM pillar. Further analysis of office TPM, the researchers assessed whether other departments were involved in maintenance planning, 58.3% of the respondents from other departments were involved in maintenance planning.

### **3. Results & Analysis**

The purpose of the research was to evaluate the impact TPM pillars have on equipment availability focusing on the planned maintenance pillar. The research objectives were to; determine how the planned maintenance pillar was used at the company under study and the extent to which it was applied; to determine the impact that TPM had on the company's performance and finally to determine if the TPM pillars had helped in obtaining the overall expected results that rise from an effectively implemented TPM.

The results from the questionnaire, structured interviews and company records have given a clear picture as regards to the impact that TPM has on the company performance. Analysis of the data on whether a maintenance plan was prepared before any maintenance work is carried out, the results revealed only 42% of the respondents indicating it is carried out. The result gives an indication for improvement on the part of maintenance plans. 42% is certainly very low for a company aiming to achieve OEE of 100%. Further analysis of the maintenance actions performed on the machinery, actions such as modification of equipment and analysis of history of behavior of machine components was very low. If planned maintenance pillar is a cross functional activity whose function is to eliminate recurring problems and improving equipment efficiency then having a 42 % figure regarding maintenance plan been carried out will certainly have an effect on the performance of the company.

Analysis of the results in Table 2 regarding equipment availability show that, from January to September in 2014 the recorded results on equipment availability are better than the results on equipment availability for January to September 2014. In August and September 2014, equipment availability was at 27.6% and 29.5 % extremely below the budgeted equipment availability of 57.5%. For a company that has fully implemented TPM, such figures on equipment availability should not be acceptable.

Analysis of the OEE at UHT shows that, the company has not been able to achieve the world class OEE of 80%. Its OEE ranges between 51% and 74.

Analysis of operator involvement in equipment maintenance has directly impacted on the company experiencing less customer complaints as the quality of the products is high.

### **4. Conclusion**

The impact of the TPM system on the company performance is evidenced through zero breakdowns, zero accidents and zero defects. Though the research did not quantitatively analyze those variables, the evaluation and assessment of how planned maintenance is practiced has clearly indicated that there is need for improvement. Due to the gaps in practicing planned maintenance, there has been a direct effect on the impact that TPM has had on the company since planned maintenance and TPM have a relationship.

The researchers have shown that TPM is a tool that can be used to improve the OEE of company as the company OEE ranges from 51-57%. The extent to which each TPM pillar is employed has been highlighted.

TPM is a tool that can be used to improve the company performance but all the TPM pillars should be given equal attention during the implementation stage in order to achievement success.

The researchers therefore recommended the following to the company.

- The Company should consider revisiting the planned maintenance pillar and ensure that all activities involved in planned maintenance are carried out.
- A Planned maintenance activity/task analysis should be carried to determine the specific information and resources for each item that maintenance requires.
- Planned maintenance activities should always be carried according to schedule
- If the company is to have a consistent record of availability of machines some certain aspects of TPM such as management's commitment to participation in maintenance must be high and not average because they are practically a part of the maintenance team

- There should be a provision for technical training over issues concerning maintenance for each and every one in the organization.

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