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Implementation of Total Productive Maintenance (TPM) In Nigerian Manufacturing Industries (Brewery)

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Abstract: *The problem of waste and losses has been identified as contributing to poor performance of local industries in Nigeria. It is asserted that industries have sought to improve their performance by using some modern manufacturing concepts and methods. Total Productive Maintenance (TPM) is one such concept being used by both small and medium-scale enterprises to identify and reduce waste both on the shop floor and at the enterprise level. The measure of effectiveness of TPM implementation is the Overall Equipment Effectiveness (OEE). OEE is a function of Performance Efficiency (PE), Plant Availability (A) and Quality Rate (Qr). By measuring and monitoring these parameters over time OEE can be improved and hence high efficiency and lower cost of operations ensured. This study uses Champion Breweries where TPM is being implemented as a case study. It is known that the success of TPM implementation is determined by the implementation strategies adopted by individual firms, which takes into account variables such as the firm's size measured in terms of the number and the quality of its employees. Champion Breweries is a medium sized enterprise which represents a template for measuring TPM implementation in small and medium scale enterprises in Nigeria. The purpose of the study is to have first-hand knowledge of TPM and how it is implemented at Champion Breweries, to understand the benefits derivable from TPM implementation, how improvements are being achieved, and how they can be enhanced. The study relied on information obtained through literature search and data collected from the brewery plant. Results show that in order to overcome the problem of limited resources, TPM can be implemented using the Hybrid Pillar model being adopted by Champion Breweries. The analysis of OEE of the beer packaging line for a 3-month performance period showed improvement in OEE; it increased from 56.4% to 71.7%. This is as a result of the existing focused monitoring and improvement measures being adopted. Other areas of improvement have been highlighted in this study and recommendations made in line with the objectives of the study.*

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I. INTRODUCTION

1.1 Background of Study

With the huge population of Nigeria estimated at 170 million people, there is the potential for the country to become an industrial hub in view of ready market for goods and services as well as ample availability of labour. Ironically these favourable factors are hardly exploited to the nation's advantage as over 80% of consumer goods as well as construction materials are imported either from European countries or fellow African countries, as reported by the immediate past Director General of Standards Organization of Nigeria, SON, Dr. Joseph Odumudu [6].

The potential profits of going into manufacturing by indigenous companies have been appreciated and several have ventured into it but the result most often is a backlog of debts to workers and suppliers and finally going into bankruptcy. The latest of such cases is the Honeywell Group; their bankers, Eco Bank Plc, declared the company bankrupt on 16th December, 2013 on account of a debt base of ₦4.1 billion owed as at August 6, 2015 [3].

This poor industrial performance is attributable to the huge losses/wastes which occur in the manufacturing shop floor and others. These losses occur in the areas of operations, maintenance, personnel, and process. Examples include tooling problems and non-availability of components in time. Other forms of waste include idle machines, idle manpower, breakdown of machines, and rejected parts, [7].

The primary goal of industries in the 21st century is to gain a competitive edge in their areas of business. This can only be achieved as a direct consequence of reduced cost of operations, high operational efficiency, and customer-oriented services. In view of rapidly changing industrial environments some innovative approaches are being introduced in form of methods and systems to improve performance. One such approach is “Total Productive Maintenance” (TPM).

TPM is a business process improvement concept which was developed in Japan over the past several decades and which started to gain popularity around the world. The concept was developed initially with production as its central focus and has since been adopted to improve all aspects of companies operations. TPM creates a corporate culture which constantly strives to eliminate losses through overlapping small group activities within the site. When properly implemented it creates the environment to achieve the three Zs of TPM namely Zero Defects, Zero Breakdown, and Zero Accident.

Enormous benefits have been reported in the literature following the implementation of TPM programs.

The process industries in Nigeria such as brewing industry contribute significantly to the Gross Domestic Product of the country. Therefore, any performance improvement in this sector will impact positively on the economy of the country. The author is not aware of any study on TPM implementation in the brewery industry and this study is therefore intended to fill this gap.

1.2 Statement of the Research Problem

The purpose of this research is to study the implementation of TPM at the brewery plant with the aim to understand how its benefits are being achieved, how it could possibly be enhanced and how the gains made by the brewing company could be replicated in similar companies in the industry in order to reduce losses and improve productivity.

1.3 Objectives of the Study

The main objective of this research is to study and assess the method of implementing Total Productive Maintenance (TPM) at a local brewery. The specific objectives include to:

i. Study how TPM is organised at the local brewery.
ii. Study the implementation strategies of the Autonomous Maintenance (AM) and Planned Maintenance (PM) pillars of TPM at the local brewery.
iii. Assess the effectiveness of TPM implementation at the local brewery. with respect to some performance matrices and to make recommendations for improvement.

1.4 Significance of Study

The study seeks to discover the strategies adopted by the local brewery. in implementing TPM and the results obtained therefrom, with the view to assess current performance and suggest opportunities for improvement.

This research will aid the industry by providing a means whereby individual companies can study and adopt appropriate TPM implementation strategies in view of available level of human and material resources.

The research seeks to contribute to performance improvement in the brewery plant, considering current achievement and the existing opportunities for improvement.

II. LITERATURE REVIEW

2.1 Total Productive Maintenance

The concept of TPM originated in Japan’s manufacturing industries, initially with the aim of eliminating production losses due to limitations in the Just in time (J1T) process for production operations. Seichi Nakajima is credited with defining the fundamental concepts of TPM and seeing the procedure implemented in hundreds of plants in Japan; the key concept being autonomous plant maintenance, [9].

TPM is a major departure from the “you operate, I maintain” philosophy. It is the implementation of productive maintenance by all associated personnel (whether machine operators or members of the management team), based on the involvement of all in the continual improvement of performance. TPM endeavours to eliminate the root causes of problems, through team-based decisions and their implementation. Achieving low-cost improvements and zero-deficit product quality are striven for, while designing for minimum Life Cycle Cost (LCC) maintenance and using the JIT procedure, [1]. LCC is a tool used to determine the most cost-effective option among different competing alternatives to purchase, operate and maintain an equipment or process, when each is equally appropriate to be implemented on technical grounds. The three components of the concept are:

(i) Optimized equipment-effectiveness.
(ii) Autonomous-operator maintenance.
(iii) Company-led small-group activities, throughout the entire organization.

This is a “high-employee involvement” approach. It leads to improved creative group-efforts, greater individual effort, personal responsibility, and lively innovative problem- solving meetings. TPM concepts involve commitments to long-range planning, especially on the part of senior management. Typically, TPM is initiated as a "top- down" exercise, but only implemented successfully via "bottom-up" participation, [10]. However, consensus building may take about three years, from the planning phase, for sustainability to be achieved in a large organization.

TPM is a manufacturing-led initiative that emphasizes the importance of the following:

(i) People with a 'can do' and continual improvement attitude.

(ii) Production and maintenance personnel working together in unison.

In essence, TPM seeks to integrate the organization to recognize, liberate and utilize its own potential and skills. TPM combines the best features of PM procedures with innovative management strategies and encourages total employee involvement. TPM focuses attention upon the reasons for energy losses from, and failures of equipment due to design weaknesses that the associated personnel previously thought they had to tolerate, [1].

2.2. Implementation Stages of TPM

The application of TPM is in phases so that it can be monitored and assessed perfectly.

There are 3 phases of TPM implementation, [5]. These are discussed below.

2.2.1 Stage A- Preparatory stage

This is the stage where the programme is introduced, planned and rolled out in the establishment. Steps in carrying out this stage are given below.

Step 1: Announcement by management to all staff about TPM introduction in the organization: Proper understanding, commitment and active involvement of the top management in needed for this step. Senior management should have awareness programmes, after which announcement is made. Decision to implement 1PM is published in the in house magazine, displayed on the notice boards and a letter informing the same is sent to suppliers and customers.

Step 2: Training is to be done based on the need. Some need intensive training and some just awareness training based on the knowledge of employees in maintenance.

Step 3: TPM includes improvement, autonomous plant maintenance, quality maintenance etc., as part of it. When committees are set up they should take care of all those needs.

Step 4: Each area/work station is benchmarked and target is fixed for achievement.

Step 5: Next step is implementation leading to institutionalizing wherein TPM becomes an organizational culture. Achieving PM award is the proof of reaching a satisfactory level.

2.2.2 Stage B-Introduction Phase

A small get-together, which includes suppliers and customer's participation, is conducted. Suppliers should know that we want quality supply is demanded from them. People from related companies and affiliated companies who can be customers, sister concerns etc. are also invited. Some may learn from us and some can help us and customers will get the message from us that we care for quality output, cost and keeping to delivery schedules.

2.2.3 Stage C- TPM Implementation Phase

In this stage eight activities are carried out which are called eight pillars in the development of TPM activity. These four activities are for establishing the system for production efficiency, one for initial control system of new products and equipment, one for improving the efficiency of administration and one for control of safety, sanitation and working environment.

2.2.4 Stage D- Pilot Phase

This Phase follows the introduction phase. Here data capture, which is monitoring equipment with the aim of determining their performance occurs. This process is used to identify equipment with high breakdown frequencies. These are termed bottleneck equipment and are responsible for losses in the facility.

The following practices are done in this phase.

(i) Launching of Improvement Teams

These teams are made of maintenance staff who are very experienced. They tackle pressing maintenance issues in the entire facility. Breakdown teams are examples of such teams. They are specifically tasked with carrying out repairs of faulty equipment throughout the facility.

(ii) Introduction of Audit System

Audits are carried out on the implementation processes to ascertain if it was done properly. This is because there has to be a very strong commitment from management and employees for the success of TPM.

(iii) Identification of Pilot areas

Pilot areas are equipment which are responsible for high frequencies in breakdowns. They are called pilot areas as they are identified in the data capture process of the preparatory phase and dealt with in the pilot stage. These are the equipment causing losses in terms of time and finance. Improvement teams are sent to tackle the issues while more data capture is going on.

(iv) Restoring Equipment to Its Prime Operating Condition

This step involves cleaning up the equipment, performing maintenance checks and training the operators on autonomous maintenance activities.

(v) Start Measuring OEE

To start measuring OEE first, a system is put in place to record the losses and using this information the OEE is measured for the target equipment or area.

(vi) Address the Major Losses

Here the major sources of loss are addressed by designing and implementing improvement measures. The review of OEE data continues shift-wise in order to monitor the status of the losses being addressed, and also monitor the overall improvement in performance.

(vi) Establish Proactive Maintenance Activities

In this step the Planned Maintenance pillar concepts are introduced and candidate equipment for proactive maintenance are identified and addressed.

2.3 Performance Measurement in TPM

Performance measures in TPM are used in determining the effectiveness of the implementation of the programme. Below is a breakdown of these measures.

III. METHODOLOGY

The procedures for this study have been chosen to meet each of the project objectives. Although there are 8 pillars of TPM, the pillar which is more related directly to production, quality and maintenance are the AM and PM pillar, [5]. This is because these pillars deals with equipment maintenance which is solely responsible for equipment uptime, production volume and quality. Hence, this research has focused on the AM and PM pillars of TPM at the brewery.

3.1 Methods

The methods used in the research were:

i. Studying and/ application of relevant theories and models.
ii. Data collection from maintenance and production log books at the local brewery.
iii. Interview with Managers, Engineers and machine operators at the local brewery.
iv. Data analysis and results.

3.2 Studying and Application of Relevant Theories and Models

The literature search was made in order to understand the philosophy behind TPM, including the underlying theories and models used in TPM. The results obtained here assisted in gaining some basic understanding in order to carry out further enquiries.

3.3 Interview with Managers, Engineers and machine operators at the local brewery.

Two (2) TPM managers as well as a host of Engineers and machine operators who are conversant with maintenance and production activities at the local brewery. were interviewed.

The TPM managers acted as consultants by sharing precious experience and data on the implementation and assessment of TPM.

The Engineers in charge of planned maintenance and production departments gave detailed activities of their departments in line with the Autonomous Maintenance (AM) and Planned Maintenance (PM) pillars of TPM.

3.4 Collection of Data from Maintenance and Production Log Books at the Brewery

Data regarding equipment maintenance, production at the local brewery were consulted. These included charts and templates as follows:

- Loss deployment Charts.
- Equipment evaluation and ranking template.
- Quality output.
- Maintenance calendar.
- Planned Maintenance Calendars.
- PM Day audit sheets.
- Maintenance Check lists and Task lists.

3.5 Data analysis and results.

The data collected from charts, tables and interviews were summarized and analysed in line with the study objectives.

3.5.1 Performance Measurement in TPM

Performance measures in TPM are used in determining the effectiveness of the implementation of the programme. Below is a breakdown of these measures.

3.5.2 Overall Equipment Efficiency (OEE)

3.5.3 Overall Equipment Effectiveness (OEE*)* is one of the key measures of TPM which indicates how effectively the machinery and equipment is being run, [1]. It combines measures of machine Availability, Performance and Quality. The simplest way to calculate OEE is as the ratio of Fully Productive Time to Planned Production Time, [5]. Fully Productive Time is just another way of saying manufacturing only Good Parts as fast as possible (Ideal Cycle Time) with no Stop Time. Hence the calculation is:

OEE = (Good Count × Ideal Cycle Time) / Planned Production Time (2.1)

Although this is an entirely valid calculation of OEE, it does not provide information about the three loss-related factors: Availability, Performance, and Quality. For that we use the preferred calculation.

The preferred OEE calculation is based on the three OEE Factors: Availability, Performance, and Quality, defined as follows:

3.5.3 Availability

Availability takes into account all events that stop planned production long enough where it makes sense to track a reason for being down (typically several minutes), [8].

Availability is calculated as the ratio of Run Time to Planned Production Time:

$$\text{Availability (A)} = \frac{(\text{Total Time} - \text{Total downtime}) \times 100}{\text{Total time}} \qquad (2.2)$$

Where Total Time refers to planned production time and total down time refers to summation of all losses incurred during production. They include breakdown time, planned stoppages, break time and planned maintenance time.

3.5.4 Performance Efficiency (PE)

Performance takes into account anything that causes the manufacturing process to run at less than the maximum possible speed when it is running, [4].

It is calculated as:

$$\text{Performance Efficiency (PE)} = \frac{(\text{Target Production} - \text{Actual Production}) * 100}{\text{Target Production}} \qquad (2.3)$$

Target production refers to the projected production output for a period of time and actual production is the production volume produced for a particular period of time. Performance should never be greater than 100%. If it is, that usually indicates that Ideal Cycle Time is set incorrectly (it is too high).

3.5.5 Quality Rate (Qr)

Quality takes into account manufactured parts that do not meet quality standards, including parts that need rework. Remember, OEE Quality is similar to First Pass Yield, in that it defines Good Parts as parts that successfully pass through the manufacturing process the first time without needing any rework, [8].

Quality is calculated as:

$$\text{Quality Rate (Qr)} = \frac{(\text{Processed Quality} - \text{Defective Quality}) * 100}{\text{Processed Quality}} \qquad (2.4)$$

Where, the quality defects mean the amount of products which are below the quality standards that is, the rejected items after the production process. This formula is very helpful to calculate the quality problem in the production process [2].

3.5.6 Preferred Calculation of (OEE)

OEE takes into account all losses, resulting in a measure of truly productive manufacturing time, [2]. It is calculated as:

OEE = Availability × Performance × Quality (2.5)

IV. DISCUSSION OF DATA AND RESULTS

4.2 Overview of TPM Implementation at the local brewery.

Champion Breweries implements the TPM Alternative Roadmap Master plan from Heineken who own about 70% equity in the establishment.

The method of TPM implementation at the brewery is unique as it uses hybrid pillar teams which are tasked to implement more than one pillar. This is as a result of the following constraints:

(i) It is a brewery producing a volume lower than 420,000hl per annum
(ii) It has a relatively low amount of full time staff (FTS)
(iii) It has a highly complex production system
(iv) The relatively low level of educated man power in the establishment

The implementation process is carried out by the TPM Coordinator (TPMC) and overseen by the Brewery Manager (B.Mgr.). The Alternative TPM roadmap is given below.

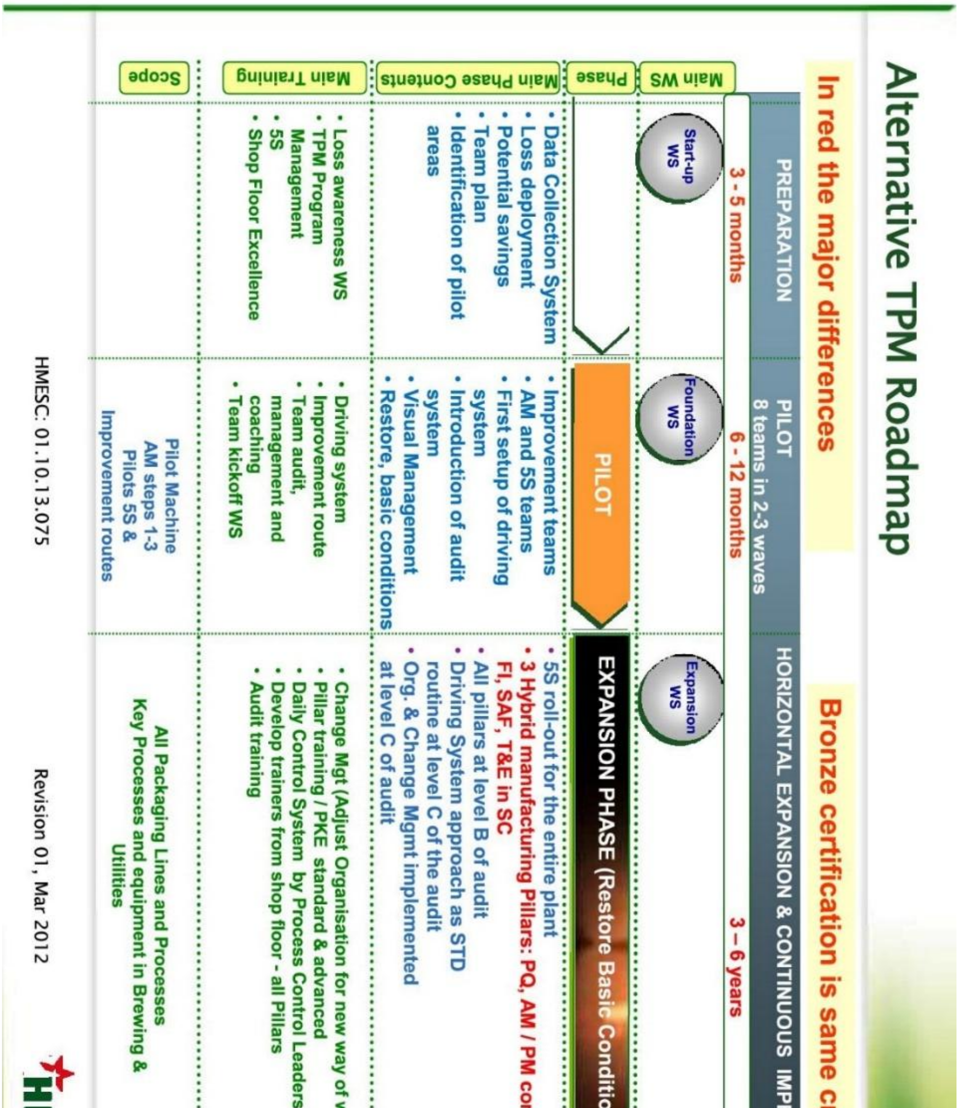


Figure 4.1: Alternative TPM Implementation Road Map Overview.

TPM is implemented in 3 phases which are the preparatory phase, pilot phase and the expansion phase. This is because phase implementation aids in properly monitoring the implementation method and its effectiveness. At the end of every phase, an audit called Gate review is carried out where the implementation is graded to ascertain if the process was done correctly in concordance with world standards.

Champion Breweries implements the 8 pillars of TPM in just 3 pillars overseen by 3 hybrid teams against the 8 teams used to implement each distinctive pillar. The 3 hybrid teams carry out the implementation of the 8 pillars.

Before TPM is implemented, there has to be the establishment of a governing body responsible for overseeing its implementation and assessment. This governing body is called the Steering Committee.

As the name implies, this committee gives direction on how the phases of TPM are to be implemented. The committee is responsible for specifying the duration of each exercise, the number of teams that will be involved and the heads of these teams as well as the methodology of achieving the key performance indicators (KPI's) of each pillar. The Steering Committee is comprised of the following full time staff (FTS):

- Brewery Manager (B Mgr.)
- Total Productive Maintenance Champion (TPMC)
- Planned Maintenance Engineer (PME)
- Engineer in Charge of Plant Maintenance (EPE)
- Head Brewer (HB)
- Automation Engineer (AM)
- Packaging Manager (PKM)

4.3 TPM Pillar Structure at the local brewery.

Due to the fact that champion breweries is a low volume capacity production company, for TPM to be implemented completely in a structured manner, the brewery dose not launch the core 8 pillars driven by classical individual pillar teams.

Instead, the 8 pillars are implemented using 3 hybrid teams. These 3 teams implement the 8 pillars of TPM at the establishment. Below is a figure showing the distribution of the 8 pillars.

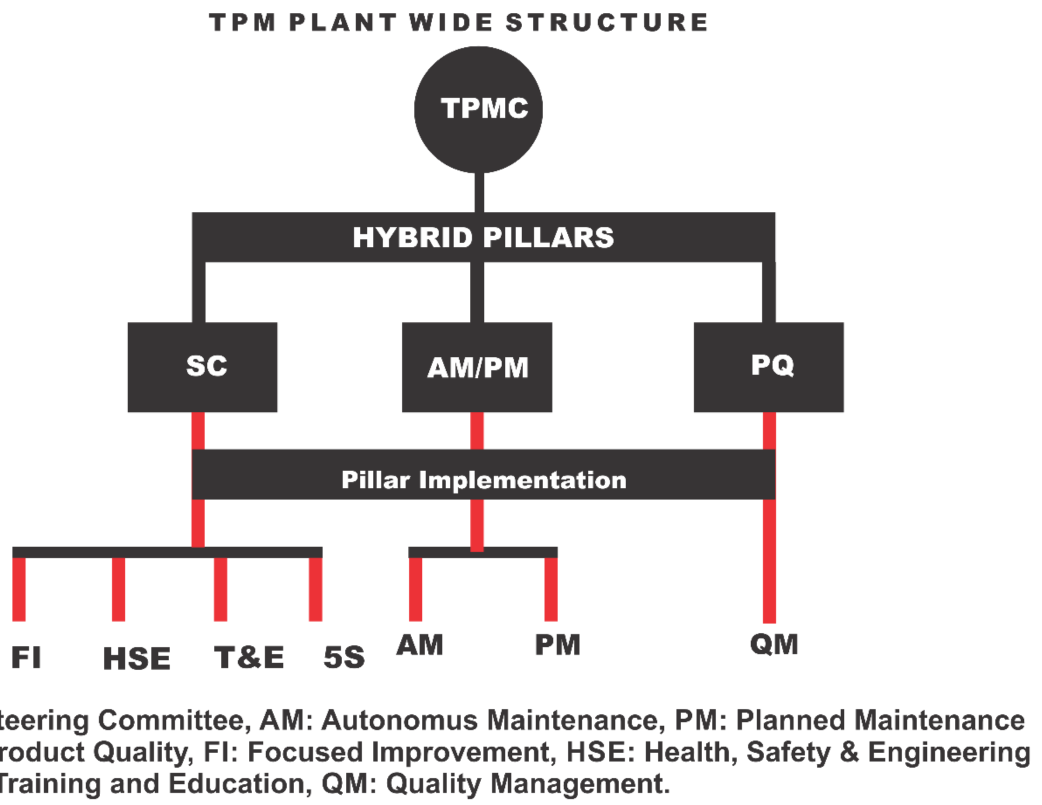


Figure 4.2 TPM Implementation structure at the brewery

4.4 Combination of the 3 Hybrid Pillars of TPM at the local brewery.

The hybrid pillars constitute the following:

(i) The steering committee: this hybrid team acts as a pillar which implements the following pillars:

- Health, Safety and Education (HSE) Pillar
- Training and Education (T & E) Pillar

It is also in charge of constituting focus improvement (FI) teams. These are special teams tasked with the objective of solving specific problems in the facility.

(ii) The AM / PM Pillar team: This team take care of implementing the following pillars:

- Autonomous Maintenance pillar
- Planned Maintenance pillar

(iii) The Production Quality (PQ) Pillar team: This pillar team will implement the Quality Management (QM) pillar.

Table 4.1: break down of pillar functions by the 3 Hybrid Pillars

S/N	STEERING COMMITTEE	AM/PM PILLAR	PQ PILLAR
1	Focused Improvement team constitution	Autonomous Plant Maintenance (AM) Pillar	Product Quality (PQ) Pillar
2	Safety, Health and Environment Pillar	Planned Maintenance (PM) Pillar	
3	Training and Education Pillar		

4.5 Description of Hybrid Pillar Team Functions

(i) The Steering Committee (SC):

This committee developed and implemented the following:

- The implementation driving System.
  This involves the interpretation of the alternative TPM implementation road map.
- Organisation of pillar teams.

This involves selecting members to constitute the pillars and also forming specialised teams to tackle reoccurring issues which affect productivity and the implementation process.

Beside these two (2) crucial tasks, it has the role of a pillar team for standard FI, HSE and T&E pillar routes.

- **Steering Committee Meeting Participation**

As the range of activities for the SC is very wide, only relevant members participate during meetings according to the agenda for discussion in order to avoid inactive participation.

(ii) AM / PM Pillar

Instead of having two (2) distinctive pillars implementing their own route separately, one combined AM/PM pillar was launched.

The pillar implemented both autonomous and planned maintenance at the brewery.

- **AM / PM Pillar Members**

The following FTS made up this pillar. They are: the Engineering Manager (EM), Engineer in Charge of Planned Maintenance (EPE), Planned Maintenance Support (PMS), Planned Maintenance Engineer (PME), Planned Maintenance Machine Leaders (PMML), Breakdown Teams (BDTs), Packaging Manager (PKM).

The leadership is taken alternatively by the Engineering and Packaging Managers respectively according to the implementation phase.

(iii) PQ Pillar

This pillar applied the PQ pillar route in a standard way. No specific master plan will be defined. Only the implementation speed will be adopted to the available resources.

- **PQ Pillar Members**

The Engineering Manager (EM), Engineer in Charge of Planned Maintenance (EPM), Planned Maintenance Engineer (EPE), Head Brewer (HB), Packaging Manager (PKM).Planned Maintenance Support (PMS), Store Keeper, Machine Leaders and Breakdown Team membeJrs. These teams make up the pillar.

4.11 Analysis of OEE at th packaging line of the brewery via maintenance and production Data

For every maintenance task, data is captured which is used in positioning the plant in terms of productivity and efficiency. Analysis was done specifically at the packaging line of the brewery were calculations were made to know the true state of the line in terms of plant availability (A), performance efficiency (PE), quality rate (Qr) and overall equipment effectiveness (OEE).

In assessing the packaging line of the brewery the following maintenance as well as production data were consulted.

(i) The Production Line Layout of the Packaging Line.
(ii) Loss deployment data.
(iii) Production data.
(iv) Quality output data.

In calculating the OEE, the packaging line was seen as a machine. This is because, all equipment on the line are linked together as the breakdown of one will cause a halt in the lines functionality.

Analysis was done on production data over a period of three (3) months.

The production line layout which is the distribution of equipment on the job floor is shown below.

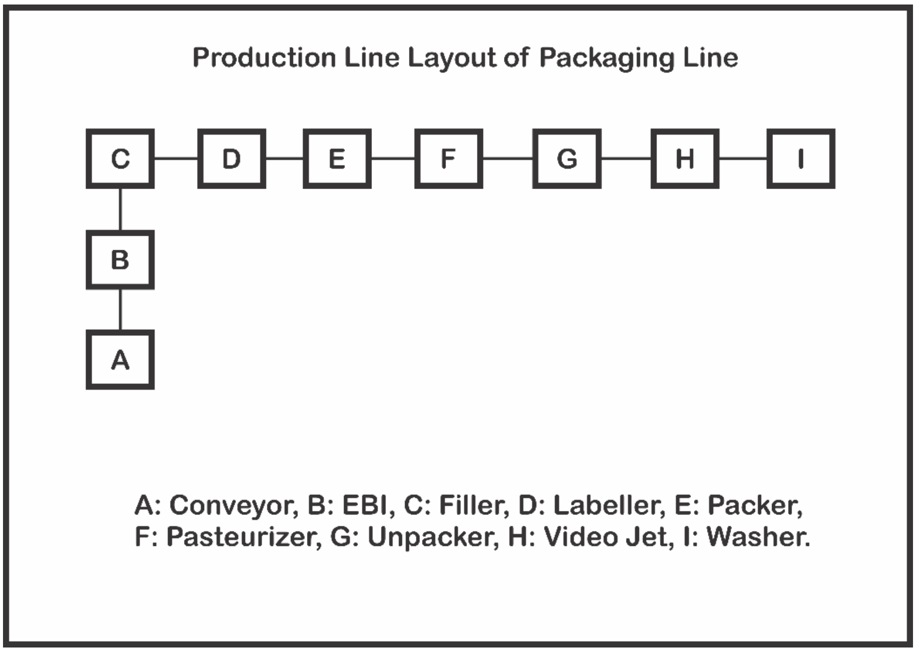


Figure 4.10 : Production line layout

(i) Production data

This shows the amount of brew produced in terms of hectolitres for a given time frame. It also gives the target output for the given time frame. This is used in evaluating the performance efficiency (PE) of a production run.

(ii) Quality Output data

This shows the amount of output which conformed to specification and the amount that was within the boundary of conformance. This is used in evaluating the quality rate (Qr) of a production run.

(iii) Loss Deployment data

This shows the number in hour's equipment spends in down time before they are put back into service. Loss deployment is done daily and is used in calculating the Availability (A) of equipment in the plant.

Considering the loss deployment data for August, September and October 2016, we see the following:

Table 4.5: Analysis of time losses for August, September and October, 2016

EQUIPMENT	ANALYSIS OF TIME LOSSES FOR 3 MONTH														
	AUGUST					SEPTEMBER					OCTOBER				
	BDT (hrs)	MS (hrs)	ES (hrs)	COT (hrs)	PDT (hrs)	BDT (hrs)	MS (hrs)	ES (hrs)	COT (hrs)	PDT (hrs)	BDT (hrs)	MS (hrs)	ES (hrs)	COT (hrs)	PDT (hrs)
CONVEYOR	0.5	-	-	-	-	0.4	-	-	-	-	0.6	-	-	-	-
EBI	0.5	3.0	-	-	-	4.7	12.8	-	-	-	-	4.0	-	-	-
FILLER	14.4	-	9.9	2.3	5.7	2.1	0.1	19.2	15.6	-	0.7	-	12.2	-	2.0
LABELLER	28.1	-	-	-	-	4.3	-	-	-	-	2.7	-	-	-	-
PACKER	14.8	-	-	-	-	2.1	-	-	-	-	-	-	-	-	-
PASTEURIZER	30.4	-	0.7	-	-	5.1	-	-	-	-	1.2	-	-	-	-
UNPACKER	2.8	-	-	-	-	4.1	-	-	-	-	0.9	-	-	-	-
VIDEO JET	3.3	-	-	-	-	1.3	-	0.2	-	-	5.8	-	-	-	-
WASHER	-	-	1.5	-	-	1.1	-	1.2	-	0.5	0.6	-	0.5	-	-
SUM OF LOSSES PER MONTH (hrs)	117.9 hrs					107.8 hrs					31.2 hrs				

KEY	
ABBREVIATION	**FULL MEANING**
BDT	Breakdown Time
MS	Minor Stops
ES	External Stops
COT	Change Over Time
PDT	Planned Downtime

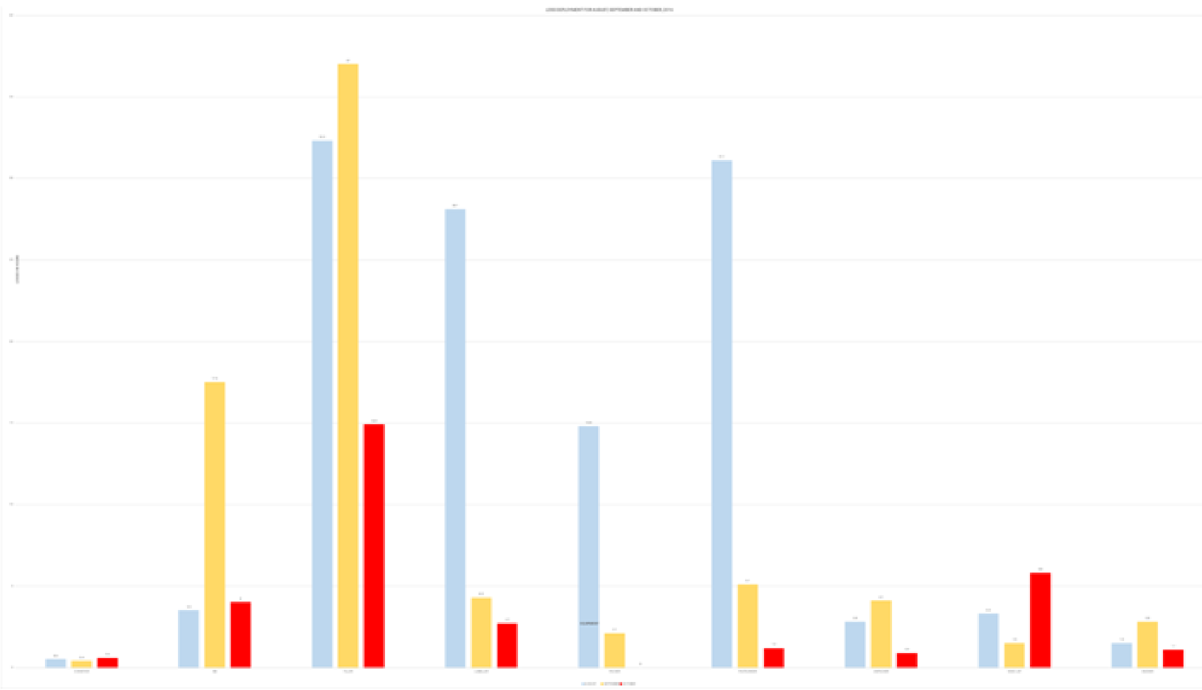


Figure 4.11: Loss deployment Chart for Equipment at Packaging Line for August, September and October, 2016

Table 4.6: Analysis of OEE factors using production and quality output data

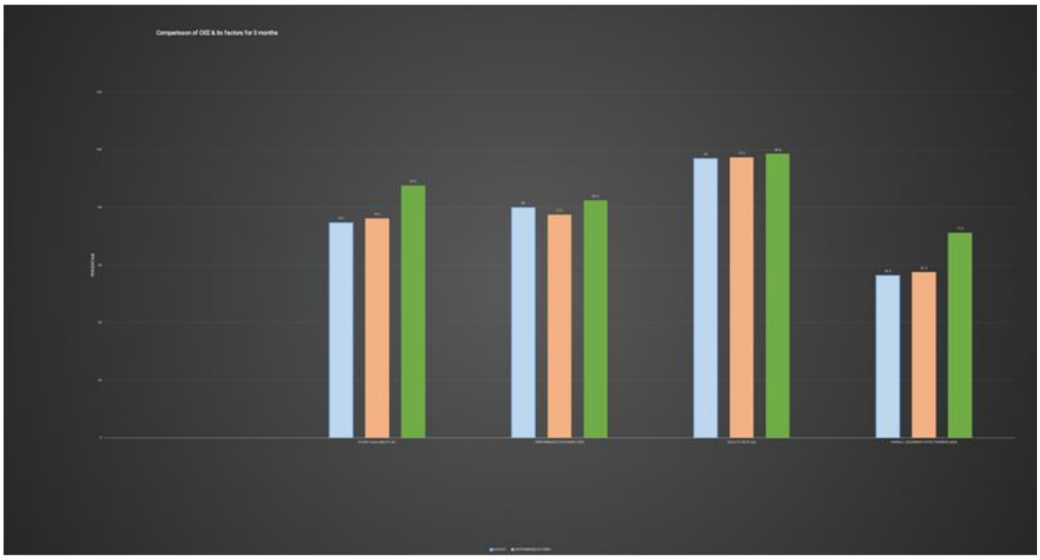
AVAILABILITY (A)	**MONTH**	**TOTAL PRODUCTION TIME (hrs)**	**BREAKDOWN TIME (hrs)**	**FORMULA** $A = \frac{\text{Total Production Time} - \text{Total Downtime}}{\text{Total Production Time}} \times 100$	**VALUE (%)**
	AUGUST	672	117.9	$A = \frac{672 - 117.9}{672} \times 100$	**74.7 %**
	SEPTEMBER	672	107.8	$A = \frac{672 - 107.8}{672} \times 100$	**77.5 %**
	OCTOBER	672	31.2	$A = \frac{672 - 31.2}{672} \times 100$	**87.6 %**
PEFORMANCE EFFICIECY (PE)	**MONTH**	**TARGET PRODUCTION VOLUME (hl)**	**ACTUAL PRODUCTION VOLUME (hl)**	**FORMULA** $PE = \frac{\text{Actual Production Volume}}{\text{Target Production Volume}} \times 100$	**VALUE (%)**
	AUGUST	40,000	32,000	$PE = \frac{40000 - 32000}{40000} \times 100$	**80.0 %**
	SEPTEMBER	40,000	31,000	$PE = \frac{40000 - 31000}{40000} \times 100$	**77.5 %**
	OCTOBER	40,000	33,000	$PE = \frac{40000 - 33000}{40000} \times 100$	**82.5%**
QUALITY RATE (Qr)	**MONTH**	**PRODUCED QUANTITY (bottles)**	**DEFECTIVE QUANTITY (bottles)**	**FORMULA** (Qr = $\frac{\text{(Produced Quantity - Defective Quantitiy)} \ast 100}{\text{Produced Quantity}}$	**VALUE (%)**
	AUGUST	35000	1200	$Qr = \frac{35000 - 1200}{35000} \times 100$	**97.0 %**
	SEPTEMBER	35000	900	$Qr = \frac{35000 - 900}{35000} \times 100$	**97.4 %**
	OCTOBER	35000	500	$Qr = \frac{35000 - 500}{35000} \times 100$	**98.6 %**

Table 4.7: Analysis of OEE for 3 months.

MONTH	**PARAMETER**			**OEE**	**OEE VALUE (%)**
	AVAILABILITY (A) (%)	**PEFORMANCE EFFICIENCY (PE) (%)**	**QUALITY RATE (Qr) (%)**	**OEE = A x PE x Qr**	
AUGUST	74.7	80.0	97.0	**OEE** = 74.7 x 77.5 x 97.0	**56.4 %**
SEPTEMBER	77.5	77.5	97.4	**OEE** = 77.5 x 77.5 x 97.4	**57.5 %**
OCTOBER	87.6	82.5	98.6	**OEE** = 87.6 x 82.5 x 98.6	**71.2 %**

Summary of OEE data generated for the 3 months is given in the table below.
Table 4.14: Comparison of OEE Factors for 3 months.

Table 4.8: OEE Comparison for 3 months.



4.12 Discursion of Results

From the analysis done and by inspecting the trends generated in the charts we see that for the month of August, plant availability was 74.7%, performance efficiency was 80%, quality rate was 97% and OEE was 56.4%.

For the month of September, plant availability increased to 76.2%, performance efficiency reduced to 77.5%, Quality rate increased to 97.4% and OEE increased to 57.4%.

For the month of October, plant availability increased to 87.6%, performance efficiency increased to 82.5%, quality rate increased to 98.6% and OEE increased to 71.2%.

It is seen that OEE is increasing from August to October and after proper study of the loss deployment chats, the reasons for this increment are due to the use of the following AM/PM tools.

(i) The use of loss deployment chat

This chat assists in identifying equipment responsible for the generation of losses in the production line. The deployment chats also show reasons for the failure of equipment and this makes it very easy for maintenance personnel to spot and thoroughly eliminate the cause of failure. This act prevents the fault from reoccurring.

(ii) The use of Root Cause of Failure Analysis (RCFA)

Whenever problems occur on equipment, a generalised approach is followed in solving the issue. This process is already discussed in chapter 4 of this research.

(iii) The use of Focused Improvement (FI)

FI involves setting up a dedicated maintenance team to tackle a specific issue that has reoccurred over a period of time.

From the loss deployment charts for the packaging line it is seen that the bottleneck equipment for the first month, August was the Labeller. It had a breakdown time totalling 30.4 hours. But for the next month September, its breakdown time was reduced to 4.3 hours and finally it reduced to 2.7 hours in October. Here we see the effect of FI teams in reducing the breakdown frequency.

In the second month, the filler had the highest breakdown time of 28.3 hours, this was reduced to 12.2 hours in the next month.

In general, it is almost impossible to know when equipment will malfunction but what we have learnt from the study of the loss deployment chats is that whenever an equipment resulted in high breakdown, the fault was identified and thoroughly dealt with by the maintenance team and its breakdown time greatly reduced in the month that followed its failure.

(iv) The Use of effective Cleaning Lubricating Inspection and Tightening (CLIT) standards

These activities are done mainly by machine operators on equipment before production begins. The thorough application of these processes greatly reduces equipment failure and cut down planned maintenance time.

(v) The use of Maintenance schedules and task lists

As discussed above in this write up, PM Days are pre planned maintenance days set aside for carrying out pre-planned maintenance of all equipment in a functional area. On this day, maintenance task lists which contain detailed tasks which each maintenance staff is mandated to perform on specific equipment is used. Hence every part of an equipment is addressed properly ensuring a good maintenance activity. It is also the use of these practices that have led to increment in OEE at the line.

(vi) Training and retraining of Machine operators

Maintenance staff and machine operators are trained within the company and some sent to other breweries also owned by Heineken for training. This has contributed in capacity building of staff which has affected the production process positively.

V. CONCLUSION

The research has established that Champion Breweries Plc implements the 8 pillars of TPM with just 3 hybrid teams against the 8 teams used by standard companies worldwide. This is as a result of the relatively low man power and resources at their disposal. The Steering Committee (SC), the Autonomous maintenance and planned maintenance pillar (AM/PM) team and the Production quality pillar (PQ) team constitute the hybrid teams.

This research has shown that MSMEs in manufacturing with extremely low FTS can also implement TPM by the formation of hybrid pillar teams.

The research also shows that the AM and PM pillars are the most important pillar in TPM implementation. This is because all activities affecting equipment, directly or indirectly are managed by staff under the unit.

From the research we see that overall equipment effectiveness (OEE) at the packaging line of Champion Brewery Plc increased from 56.40% in August, 2016 to 57.5 % in September, 2016 and to 71.2 % in October, 2016. We also see from data analysis that equipment availability at the packaging line of the Brewery increased from 74.7 % in August to 76.2 % in September and then to 87.6 % in October. This goes to show that the AM/PM hybrid team maintenance management technique has been effective but room for improvement still exists.

The analysis has shown that TPM is an effective means of eradicating equipment breakdown and improving productivity as focused improvement (FI), incorporation of PM Day, KPIs, machine operator training and effective data collection are very effective tools in identifying faulty equipment and solving these faults.

Thus ailing manufacturing companies should devise means of introducing TPM into their organisational structure so as to reduce the effects of the 5D's in production which are delays, defects, dissatisfied customers, decline in profits which all give rise to demoralised employees.

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