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Development of Total Productive Maintenance System: A Case Study in Beverage Industry

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Abstract: ***The purpose of this paper is to evaluate the factory maintenance system and propose total productive maintenance system towards improving performance of industry. Industries are required to practice a well - organized maintenance management system such as total productive maintenance (TPM) to increase machine productivity and produce quality products. TPM is aimed to reduce unplanned stoppage, breakdowns accidents and losses obstructing equipment effectiveness. Harar Beer Share Company (HBSC) is one of the beverage companies in Ethiopia. HBSC is affected by inefficient maintenance systems. As a result, the company is losing a considerable amount of production time each day. Hence, the objective of this study is to identify the causes of the inefficient maintenance system particular to the filler plant of HBSC. The problems are recognized through direct observation, interviews, reports, questionnaires and by analyzing machine downtime with maintenance budget. Additionally, root - cause analysis and overall equipment effectiveness (OEE) tools have been used to identify the existing problems. The study findings indicate that TPM not only results to increase in efficiency and effectiveness of manufacturing equipment's measured in terms of OEE index by reducing the failure, time loss, and defects but also it helps to improve morale of employees and working environment significantly.***

Key words: Total productive maintenance (TPM), root - cause analysis and overall equipment effectiveness (OEE)

1. Introduction

Total productive maintenance (TPM) is new maintenance strategy developed to meet the new maintenance needs. It is closely tied to Just in Time and TQM (Total Quality Management) and it is extension of PM (preventive maintenance), where the machines work at high productivity and efficiency, and where the maintenance is all employee responsibility, and focus to prevent the problem before it may occur (Heinz, 1998).

Bamber (1998) defined of TPM in two ways. The first one depends on the Japanese approach and the other depends on western approach. The Japanese approach to TPM is considered to be that a full definition which contains five main points:

1) To use the equipment more efficiently;
2) It establishes a total preventive maintenance system;
3) It requires a full participation from all department operators (equipment operator, designer, and departments workers);
4) It involves everyone in the company shop floor to the top management and
5) It promotes and implements preventive maintenance based on autonomous, small group activities.

Nakajima (1988) summarized these five points and defined TPM as "Productive maintenance involving total participation in addition to maximizing equipment effectiveness and establishing a through system of PM" where PM is a comprehensive planned maintenance system.

Currently, the concept of TPM in Ethiopian Manufacturing Industries is the critical missing concept in successfully achieving not only world class equipment performance, but also it is a powerful new means in improving overall company performance.

The study mainly deals with the principles and concepts of Total Productive Maintenance based on literature review and assess the existing maintenance system in HBSC and proposed as the selected Four TPM pillars to alleviate the identified problems. The work is organized in such a way that the results of the conducted study will be in comprehensible way.

2. Background of the Study

Maintenance is one of the areas to be given due consideration in modern management to increase machine productivity and to produce quality products as well. The modern business world is exploiting better mechanisms to be competitive. One of the ways to achieve this is to develop sustainable maintenance system which enables to optimize asset and use equipment's effectively. Through well - organized maintenance management system such as TPM, there is a way for the industries to enhance their capacity and to provide better product and service.

TPM is a maintenance program, which involves a newly defined concept for maintaining plants and equipment. Its goal is to markedly increase production while, at the same time, increasing employee morale and job satisfaction. That is; it holds emergency and unscheduled maintenance to a minimum (zero breakdowns and zero defects). This obviously improves equipment efficiency rates and reduces costs. Ethiopian brewery industries are facing maintenance management related problems affecting their productivity. Harar brewery one of the breweries in Ethiopia, this study focused on assessing the existing maintenance system of the

HBSC to investigate potential area of improvement so as to propose the Four TPM pillars to the achieve this objective.

3. Goals of Total Productive Maintenance

The Japan Institutes of Plant Maintenance (JIPM) has put forward the five goals of TPM which are the minimum requirements for the TPM development.

1) Improving equipment effectiveness;
2) Improving maintenance efficiency and effectiveness;
3) Early equipment management and maintenance prevention;
4) Training to improve the skills of all people involved and
5) Involving operators in routine maintenance.

1) The Benefits of TPM

Johansson (1999) depicted the following benefits derived from the implementation of TPM

- Productivity is improved through fewer losses in the company;
- Quality is also improved as a result, that the failures and malfunctions are reduced and the order and method are focused;
- The cost are lower, because the losses, and other not value generating work are reduced;
- Environment and security are better, because leakages are tightened and
- Motivation is higher, because the responsibility and rights are delegated and the investment in the personnel is done, in the form of education.

2) Pillars of Total Productive Maintenance

The Japan Institute of Plant Maintenance propose the introduction of TPM program is based on the implementation of a series 8 pillars of TPM in a systematic way to optimize plant and equipment efficiency by crating perfect relationship between man and equipment.

a) Five S

The 5S practice is a preparatory phase of TPM which is a technique used to establish and maintain quality environment in an organization. A well - organized workplace motivates people, both on the shop floor as well as others.5'S improves safety, work efficiency, improves productivity and establishes a sense of ownership.

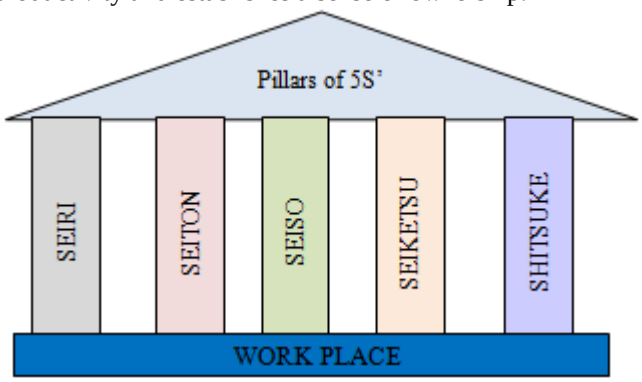

Figure 1: Pillars of 5s'

b) Autonomous maintenance (JishuHozen)

JishuHozen, which means autonomous or self - maintenance, promotes development of production operators to be able to take care of small maintenance tasks, such as cleaning, inspecting, and lubricating their equipment, thus freeing the maintenance associates to spend time on more value - added activities and technical repairs.

The effects of Autonomous Maintenance include:

- Equipment condition is known at all times;
- Unexpected breakdowns are minimized;
- Corrosion is prevented, wear is delayed, and machine life is extended;
- Parts costs are reduced and
- Machine operation ratio is improved.

c) Focused Improvement (Kobetsu Kaizen)

Kaizen is a Japanese word which means 'improvement' that aimed at incorporating a number of small continuous improvements to achieve and sustain zero losses with respect to minor stops, measurement and adjustments, defects and unavoidable downtimes. The objective of TPM is maximization of equipment effectiveness. TPM maximizes machine utilization, not merely machine availability. As one of the pillars of TPM activities, Kaizen activities promote efficient equipment and proper utilization of manpower, materials, and energy by eliminating 16 major losses.

d) Planned Maintenance

The goal of planned maintenance is to have trouble - free machines and equipment that produce defect - free products for total customer satisfaction. Planned Maintenance achieves and sustains availability of machines at an optimum maintenance cost, reduces spares inventory, and improves reliability and maintainability of machines.

e) Education and training

The goal of training is to have multi - skilled revitalized employees whose morale is high and who are eager to come to work and perform all required functions effectively and independently. Operators must upgrade their skills through education and training. It is not sufficient for operators to learn how to do something; they should also learn why they are doing it and when it should be done. This will enable the operators to maintain their own machines, understand why failures occur, and suggest ways of avoiding the failures occurring again (Denso, 2006).

The employees should be trained to achieve the four phases of skill. The goal is to create a factory full of experts. The different phase of skills is

Phase 1: Do not know;
Phase 2: Know the theory but cannot do;
Phase 3: Can do but cannot teach and
Phase4: Can do and also teach.

f) Problem Solving Tools

The following are some of the problem - solving tools in industries (Smith, 1993).

- 5 whys
- Cause and effect analysis
- PDCA
- Industrial Engineering techniques
- Value analysis
- FMEA (Failure Mode and Effect Analysis)

3) Calculating Overall Equipment Effectiveness

It has been attempted to gather some relevant data to estimate the OEE of the typical machinery.

a) Availability

The availability is the ratio of time needed for operating the equipment to the time actually consumed for operation and it is expressed as:

$$\text{Availability} = \frac{\text{OperatingTime}}{\text{PlannedProductionTime}}$$

The required availability can be defined as the time of production to operate the equipment minus the other planned downtime like breaks, meetings etc.

From the observations and few recorded data to calculate the availability of the machine, therefore accordingly the available machines on the days arecollected and recorded in the following table.

Operating time: planned production Time– (planned down time + unplanned down time)

Planed down time can include Planned shutdown, No scheduled Prod and Planned Maintenance.

To find the availability of the machines, equipment failure loss of 15 production days' March and April is collected and shown in table: 2 and table 3.

Table 1: Availability of filler machine in the first fifteen production days for March

Day (march)	1	2	3	5	6	7	8	9	10	12	13	14	15	16	17
Planned production time	1440	960	960	960	960	960	960	960	960	960	960	960	960	960	960
Down time	631	355	345	275	285	215	200	320	300	315	240	495	300	190	305
Availability%	56	63	64	71	70	77	79	66	68	67	75	48	68	80	68

Table 2: Availability of filler machine in the first fifteen production days for April

Day (April)	2	3	4	5	6	7	9	10	11	12	14	16	17	18	19
Planned production time	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960
Down time	280	265	235	375	630	350	265	400	290	540	310	320	400	345	245
Availability	70	72	76	60	34	63	72	58	68	42	68	67	58	64	74

b) Performance Rate

Performance Efficiency: The degree to which the equipment operates at design speeds, rates, and/or cycle times. Performance efficiency can vary widely depending on the material and/or products being run. Performance takes into account Speed Loss, which includes any factors that cause the process to operate at less than the maximum possible speed, when running.

$$\text{Performance Rate} = \frac{(\text{TotalPieces}/\text{OperatingTime})}{\text{IdeaiRunTime}}$$

To find the Performance Rate for the machines, the collected data indicates that the scheduled production speed of the machineries is 28000 bottles per hrs. The following table shows the performance of filler machine.

Table 3: Performance of filler machine in the first fifteen production day for March

Day (march)	1	2	3	5	6	7	8	9	10	12	13	14	15	16	17
Total production rate (bottl/hr)	358460	298000	267432	298918	225025	255050	243201	246027	227668	227061	218650	167679	240776	169946	253296
Design production rate	28000	28000	28000	28000	28000	28000	28000	28000	28000	28000	28000	28000	28000	28000	28000
Performance rate in %	85.8	76	68.2	76.2	57.4	65	62	62.7	58	57.9	55.7	42.7	61.4	43.3	64.6

Table 4: Performance of filler machine in the first fifteen production day for April

Day (April)	2	3	4	5	6	7	9	10	11	12	14	16	17	18	19
Total production (bottle/hr)	229356	214735	242057	243136	145704	235536	297288	240384	311088	165648	239400	268224	244920	207970	298440
Design production rate	28000	28000	28000	28000	28000	28000	28000	28000	28000	28000	28000	28000	28000	28000	28000
Performance rate in %	58.5	54.7	61.7	67.1	37.1	60	75.8	61.4	79	42.2	61	68.4	62.4	53	76

c) Quality Rate

Quality is fitness to use or exceeding customer satisfaction and so on. Quality Loss, which takes into accounts for produced pieces that do not meet quality standards, including pieces that require rework. The quality problems in the bottling factories arise from different reasons. But recorded data showsthat the main reason for poor quality product is low quality bottle and sensor electrical and mechanical related problems. Hence, it is expressed as:

$$\text{Quality} = \frac{\text{Good Pieces}}{\text{Total Pieces}}$$

Table 5: Quality of filler machine in the first fifteen production day for March

Day (march)	1	2	3	5	6	7	8	9	10	12	13	14	15	16	17
Total out put	358460	297702	267432	298918	225025	225050	243201	246027	227668	227061	218650	167679	240776	170546	253296
Defect	13333	7878	8196	12609	11904	6768	8632	8182	7272	10286	10711	4844	6812	7914	9831
Quality in %	96	97	96	95	94	97	96	96	97	95	95	97	97	95	96

Table 6: Quality of filler machine in the first fifteen production day for April

Day (April)	2	3	4	5	6	7	9	10	11	12	14	16	17	18	19
Total out put	284544	292752	302424	262248	145704	235536	297288	240384	311088	165648	239400	268224	244920	444816	244104
Defect	5821	7625	4242	6363	7272	6354	5757	6060	7575	11205	9393	8000	6363	12759	11212
Quality in %	97	97	98	97	95	97	98	97	97	93	96	97	97	97	95

From November to April total OEE summarized shown in table 8. This data collected from machine board, physical observation, and maintenance and production department.

Table 7: Monthly production, total downtime and rejection

Month	Total production	Total down time (min)	Reject
November	5610606	10860	189394
December	5849394	10500	190606
January	7605454	9600	216061
February	8696363	10000	250000

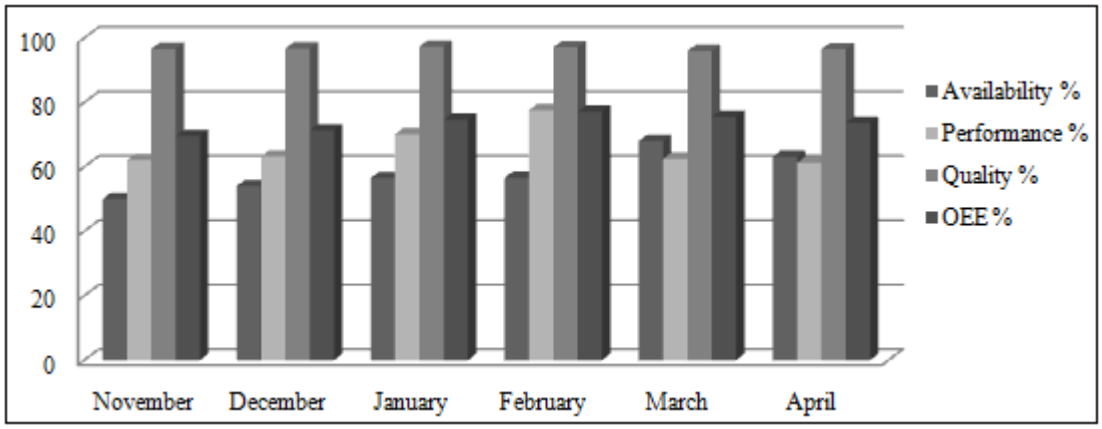

Figure 2: OEE value of HBSC of filler machine

From the observations, interview and available data for the calculation of OEE; The researcher calculated the performance of the filler machines. According to the records the average performance rate of the filer machine is 73.6%. This indicates that the OEE value of the filler machine is less that the value of word best practice.

d) Root cause analysis

A root cause analysis shall be used to investigate and to develop the solution for the reasons of production time losses and their duration.

During physical observation in production floor there are many cause that affect the filler machine in order to produce at full capacity, some of the major cause are show in figure5.2 that affect the production

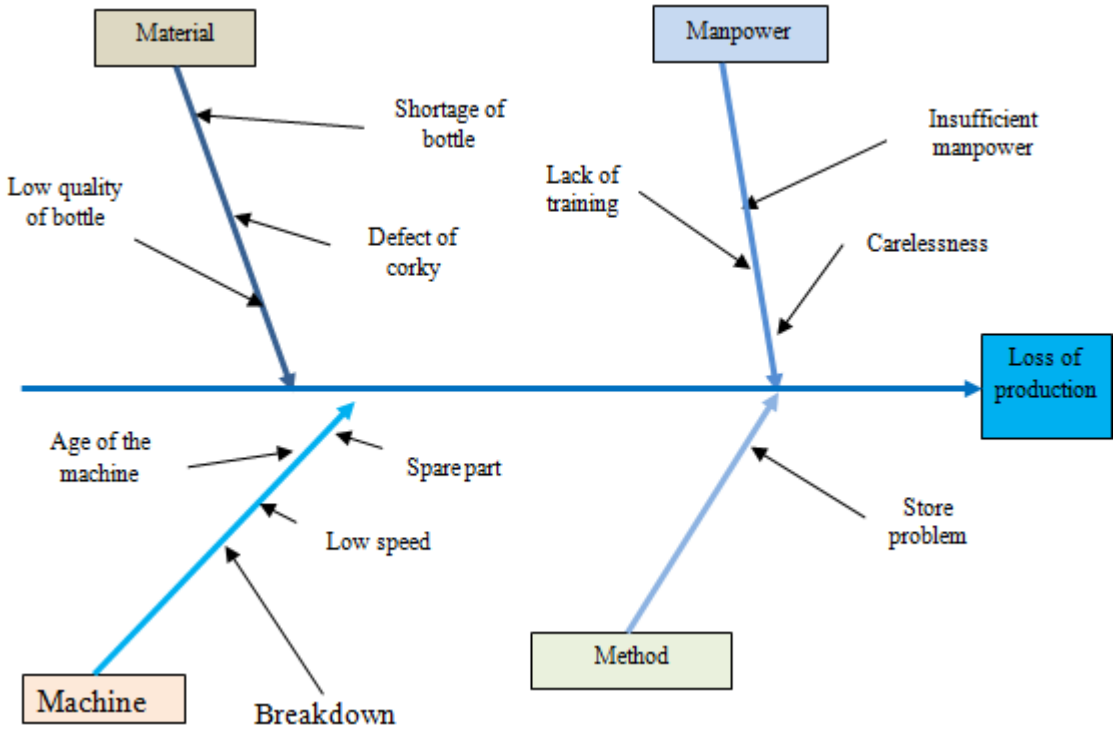

Figure 3: Cause –effect diagram

Based on the cause –effect diagram, the cause of loss of production was mentioned. The major cause is related to machine, the machine run under its speed because of lack proper maintenance this cause machine deterioration, insufficient spare part and age of machine.

The other problems related to materials, some bottles have low quality to resist to high temperature as well as the CO_2 pressure, the bottles are blast at this time the operator stop and clean the machine so many productions time was waste in each day. Corky size different also affect the loss of production, when the different size corky come to the sensor stop the machine, in order to adjust the corky its take time.

The input of bottles reduces due to insufficient workers assigned on washer machine. Sometime store is crowded, all machine stop production.

4) Proposed of Improving the Current Maintenance System

Implementing TPM pillars, the maintenance personnel can begin to make use of the skills of the operators to perform the expected maintenance activities which allows the maintenance personnel to ponder and expand moreon proactive maintenance and elimination of recurrence failure. In order improve the above problems proposed four TPM Pillars based on the problem identified:

Autonomous Maintenance (JISHU HOZEN)

Level 1. Preparation Stage

Explain the motive of autonomous maintenance and the operators' duties in maintenance activity, in addition to this explain about skill, knowledge and safety required for this stage.

Level 2 Initial Cleaning

In this level the operator able to clean and finding out abnormalities and rectifying themmakes the equipment healthy to achieve zero failure and defect.

Level 3 Counter Measures Sources of Contamination and Hard to Access Areas.

Remove all abnormalities found in level Tow to eliminate forced deterioration to achieve zero failure & defect and eliminate the sources of contamination.

Level 4 Preparations of Tentative Cleaning, Lubrication, Inspection and Tightening Standard.

Continuously Maintaining and Management of Basic equipment conditions those are Cleaning, Lubrication, Inspection & Tightening in addition to this enhancing Equipment Reliability.

Level 5 General Inspections:

The employees are trained in disciplines like Pneumatics, electrical, hydraulics, lubricant and coolant, drives, bolts, nuts and Safety.

Level 6 Autonomous Inspections

Each employee prepares his own autonomous chart / schedule in consultation with supervisor

Level 7 Standardizations

Upto the previous step only the machinery / equipment was the concentration. However, in this step the surroundings of machinery are organized. Necessary items should be organized, such that there is no searching and searching time is reduced.

Continuous Improvement

Improvement is everyone's activity and use for eliminate Production losses and reduce cost [Venkatesh J]. Continuous

improvement includes all activities that maximize the overall effectiveness of equipment, processes and plants through uncompromising elimination of losses.

Level 1 Select model equipment /line/process.
Select any Lines, processes and equipment in' kobetsu kaizen' plans that produce many losses

Level 2 Organize project team
Form a team that leads by departmental head.

Level 3 Grasp present losses
Grasp the losses from the selected machine and confirm losses.

Level 4 KAIZEN theme and goal setting
Set up KAIZEN themes based in results of present status survey.

Level 5 Mapping out KAIZEN plan
Plan analysis and countermeasures and prepare procedures for implementing KAIZEN and schedule computation plan.

Level 6 Mapping out and evaluation of analysis and countermeasures
Map out KAIZEN plans fully utilizing techniques and inherent technologies such as analysis, Investigation and experiments for KAIZEN and evaluate plan.

Level 7 Implementation of KAIZEN
Allocate necessary budget and implement KAIZEN

Level 8 Confirm effects.
Confirm effects for each loss type after implementation of KAIZEN

Level 9 Taking measures to prevent recurrence
Implement standardization and measures needed for preventing recurrence, such as production, work, purchasing, and maintenance standards.

Level 10 Horizontal replicate
Horizontally replicate in other lines, processes and equipment of same type. The detail Implementation step of Continuous Improvement in appendix D.

Plan Maintenance
It is aimed to have trouble free machines and equipment's producing defect free products for total customer satisfaction. Develop a planned maintenance system means raising output (no failures, no defects) and improving the quality of maintenance technicians by increasing plant availability (machine availability).

- Preparing and distributing documents to conduct maintenance
- Machine maintenance history record sheet;
- Equipment deficiency tag);
- Weekly maintenance report;
- Weekly lubrication program;
- Notification of inspection result;
- Annual plane of spare part and

Evaluation and monitoring implementation.

Training and education
It is aimed to have multi - skilled revitalized employees whose morale is high and who has eager to come to work and perform all required functions effectively and independently. Education is given to operators to upgrade their skill.

Steps in Educating and training activities:
1) Setting policies and priorities and checking present status of education and training.
2) Establish of training system for operation and maintenance skill up gradation.
3) Training the employees for upgrading the operation and maintenance skills.
4) Preparation of training calendar.
5) Kick - off of the system for training.
6) Evaluation of activities and study of future approach.

If all the maintenance personnel and machine operator are well trained, the expected result for the implementation of TPM pillars is going to be satisfactory.

4. Conclusion

This study has been conducted and written in relation to the implementation of TPM System in HBSC. The study examines the maintenance system of HBSC based on the observation and questioners then problems area is identified.

HBSC are follows corrective maintenance systems because of lack of well - trained manpower and insufficient spar part in store, as a result of this the company was loss a considerable amount of production time in each year.

This study proposed Four TPM Pillars based on the investigation problems, those are Autonomous Maintenance, Planned Maintenance, Continuous Improvement and Education and Training.

Developed Autonomous maintenance and Planned Maintenance system can be used to involves every operator in routine maintenance activity and take some minor correction. Planned maintenance also used to plan and schedule maintenance activity for each machine and well record different data like type of maintenance executed on a given machine, spare parts replaced and the actual time to complete the job. Implementing those system minimize break down of machine and down time of machine for waiting maintenance personnel, can save the time elapsed during planning and scheduling and minimize maintenance cost by a considerable amount.

Developed Continuous Improvement system help the factory to reducing losses in the workplace that affect the efficiencies, by using a detailed and thorough procedure we eliminate those losses in a systematic method using various Kaizen tools. So, factory full beneficial to achieve and sustain zero loses with respect to minor stops, measurement and adjustments, defects and unavoidable downtimes.

Developed Training and Education methodology can be used for identified those training requirements will help the company have multi - skilled revitalized employees whose

morale is high and who are eager to come to work and perform all required functions effectively and independently. This helps the factory achieving and sustaining zero losses due to lack of knowledge / skills / techniques.

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