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PERFORMANCE EVALUATION OF MAINTENANCE IN A MANUFACTURING INDUSTRY

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Abstract

The performance evaluation of maintenance practices in a manufacturing industry (Nigerian bottling company Benin Plant) was carried out. This was a retrospective study on the performance evaluation of maintenance in a manufacturing industry. Records on maintenance of filler machine was collected for a period of five years from 2017-2021 using a questionnaire. This questionnaire was designed to capture the cumulative end of the year production and maintenance parameters/data for the industry which includes; year of manufacture of equipment, year of installation, types of maintenance done on the machine, total hours of failure for the year, year product target, year actual volume of product produced and the quantity of defective product etc. The machine was obtained and installed in 2008, the world class OEE (Overall Equipment Effectiveness) mathematical model was used to evaluate the maintenance performance. The availability rate ranged from 93.0% - 96.9%, Performance rate ranged from 66.2% - 129.3% while the quality rate was 99.9% for all the years. The approaches used for the maintenance of the filler machine in this manufacturing company were preventive and usage-based approaches. The availability rate, performance rate and quality rate where high however performance rate was lower in the year 2020.

1.1 Introduction

Maintenance is defined according to the European standard (Alsyouf, 2004) as "the combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to a state in which it can perform the required function". It leads to high quality and low defect products, safe and secured work environment, increased production speed and the overall improvement of the performance of the plant. Nigeria is a populous developing country with a lot of economic challenges. It has undergone more than two economic recessions since 2016. This has led to folding up of some companies. Some that are still functional do not have maximum performance because of myriads of factors. However, the demand of products by the teeming population of Nigeria and competition among companies demands that the remaining companies perform maximally (Mifdal *et al*., 2013). To perform maximally, the machines have to be maintained. However, some view maintenance as a waste of resources whereas maintenance should be viewed as a profit centre and not as avoidable expenses (Al-Najjar et al., 2001; Al-Najjar and Alsyouf, 2004). Effective maintenance results in long term profit and it has an impact on the production and its operational aspects such as capacity, quality, costs,

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environment and safety (Al-Najjar, 2002). In recent times, the machines used in manufacturing companies are automated compared to simple machines used before the World War II (Alsyouf, 2007). Reliability, availability and maintainability (RAM), safety, quality, environment, multi-skilling are considered very important in current machines in use. With globalization, foreign and local linkages can be created for machine maintenance. There are different maintenance approaches which include reactive, preventive, predictive, holistic approach. (Fig 1). This seminar paper evaluated the maintenance culture and performance of a food & beverage manufacturing company: Nigeria Bottling Company Ltd and Bons Industries Ltd Enugu (PET lines). In recent times, many industries have been folding up while others are downsizing their staff These may be traced to poor maintenance, low productivity, poor line efficiency and eventual failure. To verify this assumption, this research was conducted. Improving maintenance culture is one of the ways of stimulating industrial development. Also using the right maintenance strategy and method will go a long way in sustaining the efficiency of the manufacturing equipment.

1.2 Statement of the Problem

Poor maintenance of machines and equipment is known to result in low productivity, low profit and reduced efficiency/reliability of the machines. With application of right maintenance approaches, there will be increased production, high profit and sustainability of the industry. There is a need to evaluate the maintenance culture/strategy of the industries in developing countries like Nigeria where resources are scarce.

1.3 Aims and Objectives

The purpose of the study is to analyze performance evaluation of maintenance in a manufacturing industry. Specific objectives include:

i. To assess the relationship between reactive maintenance and evaluation in the manufacturing industry.

ii. To examine the effect of Preventive maintenance on the manufacturing industry.

1.4 Hypothesis of the Study

i. There is no significant relationship between reactive maintenance and evaluation in the manufacturing industry.

ii. Preventive maintenance has no significant effect on the manufacturing industry

Review of Related Literature

2.1 Conceptual Review

Maintenance and Evaluation

Maintenance is defined according to the European standard (Alsyouf, 2004) as “the combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to a state in which it can perform the required function”. It leads to high quality and low defect products, safe and secured work environment, increased production speed and the overall improvement of the performance of the plant.

Evaluation: This is an act of ascertaining of fixing the value of worth of an equipment in this concept. It is an appraisal of the value/effectiveness of the machines.

Types of maintenance approaches

i. Reactive Maintenance: The moment machine breaks down; it will be immediately fixed. Before the World War II, this approach was used. No action is taken to prevent failures or to detect the onset of failure. Machines were simple and are usually replaced when they break down. The maintenance related costs are usually high, but this approach could be considered cost-effective in certain cases (Al-Najjar, 1997; Kelly, 1997; Pintelon and Gelders, 1992). Reactive maintenance is the starting point for most manufacturers. It’s the traditional method of maintenance that has been with manufacturing as long as manufacturing has existed.

ii. **Preventive Maintenance**: After the World War II, Preventive maintenance was practiced. It is formally defined as ‘‘the maintenance carried out at predetermined intervals or corresponding to prescribed criteria and intended to reduce the probability of failure or performance degradation of an item’’ (British Standard, 1984). These pre- determined intervals can be either time-based (calendar time) or usage-based, total operating time, number of operations, mileage (Waeyenbergh and Pintelon, 2002; Kumar, 1996). These intervals are determined using statistical-based models and optimization, which is the case when implementing preventive maintenance (PM) policies such as age and block replacements (Sherwin, 2000). Once manufacturers see that reactive maintenance isn't working, the next logical step is calendar-based maintenance, also known as time-based maintenance (TBM) or preventive maintenance. This is a form of planned maintenance that is scheduled ahead of time in order to replace parts before they break down. This is done at a set interval such as every 30, 60, or 90 days. In this way, manufacturers can expect a certain amount of downtime or schedule maintenance during off hours. This helps ensure that equipment will be up and running during all planned production periods barring emergencies or unforeseeable circumstances. Calendar-based maintenance uses the concept of "Mean Time between Failures" (MTBF) to determine the best interval at which to replace parts based on when they have failed in the past. It works best for parts that encounter regular use and predictable wear-and-tear. Preventive maintenance can work well for machinery that is used on a regular schedule that has affordable parts that can be easily replaced, has a predictable wear-and-tear rate. It's simple, predictable, and effective in these cases. Preventive maintenance can be beneficial when paired with other maintenance strategies such as predictive or prescriptive maintenance.

iii. Predictive maintenance:

This approach was used in the 1970s and it is concerned mainly with detecting hidden and potential failures and predicting the condition of the equipment. Predictive maintenance outperforms our prior-discussed options by blending many of the benefits of each category. This system helps manufacturers predict when maintenance is most likely to be needed, and it does so with increasing accuracy. Predictive maintenance utilizes technology such as artificial intelligence, machine learning, and IoT devices in order to predict when failures will occur so manufacturers can plan for them in advance and replace parts before consequences arise. The goal of predictive maintenance is to hit the Goldilocks zone of maintenance frequency not too often and not too rarely. This avoids pitfalls in over-maintenance such as excessive parts and labor costs, waste, and increased risk of human error. It also prevents issues associated with under-maintenance such as critical failure, unplanned downtime, and damage to machinery or employees. In order to do this, data is collected from factory machines equipped with IoT sensors which is then analyzed based on both current and historical data, often utilizing machine learning, to find trends and predict failure.

iv. Condition-Based Maintenance

Condition-Based Maintenance takes some of the guesswork out of predicting maintenance schedules using the calendar- and condition-based maintenance methods mentioned previously. This form of maintenance is similar to usage-based maintenance, but with much more frequent monitoring and a greater volume and depth of data. Is the tool showing signs of wear? Is performance decreasing or is it showing other signs of impending failure? Maintenance only occurs when the quality of an item dips below a certain predetermined threshold. Measurements may occur continuously using sensors connected to the tool or machine, or it may come from less frequent analog methods of data collection such as visual inspection. Condition-based maintenance is a step up from usage-based, calendar-based, and reactive maintenance when it comes to the cost of parts. Because condition-based maintenance only replaces parts when they are expected to fail soon manufacturers get more usage for their money without the damage and downtime that comes from pushing parts to the point of failure as occurs with a reactive maintenance strategy. There are additional costs associated with frequent monitoring, whether that is done through a sensor or a human inspector. However, these costs are generally offset with savings from reduced downtime as well as part and machine longevity. If sensors are used, costs associated with the installation can add up, especially in hostile operating environments where sensors may get destroyed regularly. Some sensors may require that manufacturers modify their machinery in order to implement them, oftentimes voiding their warranty. Additionally, training employees to inspect, install, and calibrate sensors can become costly. The time between maintenance actions can be unpredictable using this method, because parts are only replaced as needed. This makes it more difficult to plan for scheduled downtime well in advance. Condition-based maintenance improves the usage of parts while largely protecting machines from critical failures and unscheduled downtime, but training workers and using aftermarket sensors can become expensive and time-consuming, especially if sensors must be replaced frequently.

V. Usage-Based Maintenance

What about all of those instances that aren't readily covered by preventive maintenance or for which that method would be far too excessive and expensive? Manufacturers then move toward usage-based maintenance to account for variable machine usage, create more sensible timelines, and reduce costs in the long run. Just as calendar-based maintenance uses a set time interval to replace parts, usage-based maintenance utilizes a usage interval, eg:

- Replace the Blow mould cavity every 30 days (calendar-based maintenance)
- Change the Mould ring seal every 500 hours ran. (usage-based maintenance)

In the latter scenario, it doesn't matter if it takes you one month or one year to hit five hundred hours, the seal only needs to be replaced once it has been used to its potential and further use could cause degradation of other parts of the rotating main wheel. Usage-based maintenance is a step in the right direction in that it accounts for actual usage over time intervals which could be arbitrary in some cases. It reduces the likelihood of over-maintenance and reduces waste. However, it can be taken further to greater effect with predictive and prescriptive maintenance.

Evaluation of maintenance

Overall equipment effectiveness (OEE)

OEE is used to evaluate maintenance performance. When the machines are maintained, the overall equipment effectiveness will be high. Availability rate, quality rate and performance rate are taken into account (Ahuja and Khamba, 2007; Ahuja and Kumar, 2009). Hence OEE = availability rate x quality rate x performance rate. There is a world class goal for OEE (Table 1). When machine maintenance is done, the OEE will be close to world class standard. In a study carried out by Igbokwe and Godwin (2021) in a food and beverage manufacturing company in Anambra State, Nigeria; the OEE was 55.3% which is below the world class standard. Another study in four companies in Akure, Ondo State showed that machine maintenance was poor resulting in low productivity

Table 1: World class overall equipment effectiveness

OEE factor	World class rate (%)
Availability	>90
Performance rate	>95
Quality rate	>99
OEE	85

Source: Jain *et al*., 2013

Availability rate

Here, equipment failure, set up and adjustment results in losses and it is calculated as the ratio of operating time to loading time.

$$\text{Availability} = \frac{\text{Planned runtime-planned down time}}{\text{planned run time}} \times 100$$

Performance rate

Performance rate accounts for losses due to idle time and minor stoppages and is calculated as ratio of net operating time to operating time and it is calculated as follows:

$$\text{Performance rate:} \frac{\text{Total actual amount of product}}{\text{Target amount of product}} \times 100$$

Quality rate: It factors is the defects in process and reduced yield and is defined as ratio of valuable operating time to net operating time calculated as follows:

$$\text{Quality rate} = \frac{\text{Processed quantity–defective quantity}}{\text{processed quantity}} \times 100$$

Existing preventive model

PM models are categorized into three groups: age reduction models, hazard rate reduction models, and a hybrid of both.

• ***Age reduction models*** These models are developed by considering age reduction in the hazard function. Using the concept of age reduction, we might say that a certain PM has reduced the virtual age of a maintained system to a younger age, for example, from an age of 12 years old to a condition as good as 5 years old. That is, the hazard function changes from before a PM to after a PM.

• ***Hazard rate models*** These models are developed considering the reduction of the hazard rate of a system. This group of models assumes that the hazard rate of a system changes, for example, from before a PM to after a PM.

• ***Hybrid models*** These models are combinations of the above two groups; the hazard rate changes from to, for example. the Malik model (1979), the improvement of the PM is that the year old system is no longer that old, and its post-maintenance age is reduced in terms of its reliability, where varies between zero and one. The effect of the maintenance can also be expressed by hazard functions as follows. Nakagawa (1988) proposes two PM models: one is an age reduction model, and the other is a hazard rate reduction model. In what follows, these two models are referred to as NAK1, and NAK2, respectively.

Major maintenance variables

The variables in this study includes

1. Down time: this is when a piece of machinery or equipment is offline, whether due to equipment failure or servicing requirements such as replacement/replacement of parts or maintenance.
2. Breakdown: This is a cessation of normal operation. The act of disrupting an established order so it fails to continue.
3. Type of maintenance done: This is can be preventive, corrective etc.
4. Total production volume: the quantity of materials produced.
5. Target production volume: the anticipated quantity of product
6. Number of maintenances per year
7. Year of purchase of the various machines.

Empirical Reviews

Bolaji and Adejuigbe (2012) conducted a study on the appraisal and the evaluation of maintenance culture, enhancing productivity through optimal machine availability and utilization in manufacturing industries in Akure, Nigeria. Mathematical models were used for this study. The results revealed that production machines are already getting old, thereby resulting to frequent breakdown.

Chikezie *et al.* (2017) conducted a study on how preventive maintenance influences the product quality of the selected manufacturing industries in Benue State. Questionnaires was used to obtain data for this study. The result revealed that maintenance culture significantly influences product quality of the selected firms at 5% level of significance.

Onyeizugbe e*t al. (*2018) conducted a study on maintenance culture among rice industries in Ebonyi State. Survey research design was used. The study revealed that maintenance culture has a vital role to play in the performance of manufacturing outfits.

Igbokwe and Godwin (2021) conducted a study on maintenance performance evaluation and downtime analysis of manufacturing equipment in a food and beverage manufacturing company based in Anambra state, Nigeria. Probability sampling was used for this study. The results revealed there is a required urgent improvement of maintenance policies and strategies otherwise it will be difficult for the manufacturing organization to sustain it.

Methodology

This was a retrospective study of performance evaluation of maintenance of Nigerian Bottling Company Ltd (coca cola) Benin Plant and BONS INDUSTRIES Ltd, Enugu from 2017 – 2021. After due permission from the management of the companies, the maintenance procedures and management information system for Filler machine (1650CPH) by Krones Germany and Caser/Packer machine in NBC were assessed in the logbooks, work orders, operating statistics and production reports including target volume and actual volumes. They were thoroughly examined to obtain primary data. Information on production and maintenance activities on the filler machine and Caser/Packer were collected from year 2017 - 2021. These also were carried out on Blow mould, Monobloc (filler, Capper and Rinser machine) and Packer of BONS Industries Ltd PET Line.

3.4 Data analysis

Data was analyzed using Microsoft excel. The type of maintenance conducted was recorded. The availability rate, performance rate and quality rate were calculated.

Data Presentation and results

This study was for a period of five years (year one: 2017; year two: 2018; year three: 2019; year four: 2020; years five: 2021)

Table 2: Data obtained from the company (Nigerian Bottling Company (NBC) Filler Machine)

Variables	2017	2018	2019	2020	2021
Name of machine	Filler	Filler	Filler	Filler	Filler
Year of purchase, installed and commissioned?	2008	2008	2008	2008	2008
Type of maintenance	Preventive Usage based	Preventive Usage based	Preventive Usage based	Preventive Usage based	Preventive Usage based
Total number hours of breakdown per year(hours)	123.66	107.33	146.33	153.4	108.5
Number of hours of operation per year(hours)	2386.67	2462.56	3626.02	2028.80	3481.41
Number of hour of overtime per year	242	201	166	143	129
Target amount of product per year	3102244	3505644	4799560	5234767	4878455
Actual amount of product per year	3230017	3794995	6207177	3467081	5543752
Quantity of defective product per year	1213	983	1310	643	4891
Machine capacity (CPH)	1650	1650	1650	1650	1650

Table 3 shows that the machine was purchased in 2008 and the type of maintenance approaches carried out were preventive or usage based maintenance. The machine has a capacity of 1650CPH

Table 3: General information of the filler machine

Variables	Information
Name of machine	Filler
Year of purchase	2008
Type of maintenance	Preventive and usage based
Capacity of machine	1650CPH

Figure 3 shows that the availability rate of the filler machine. The availability rate was highest in the year five 96.9% while it was lowest in year four (93.0%)

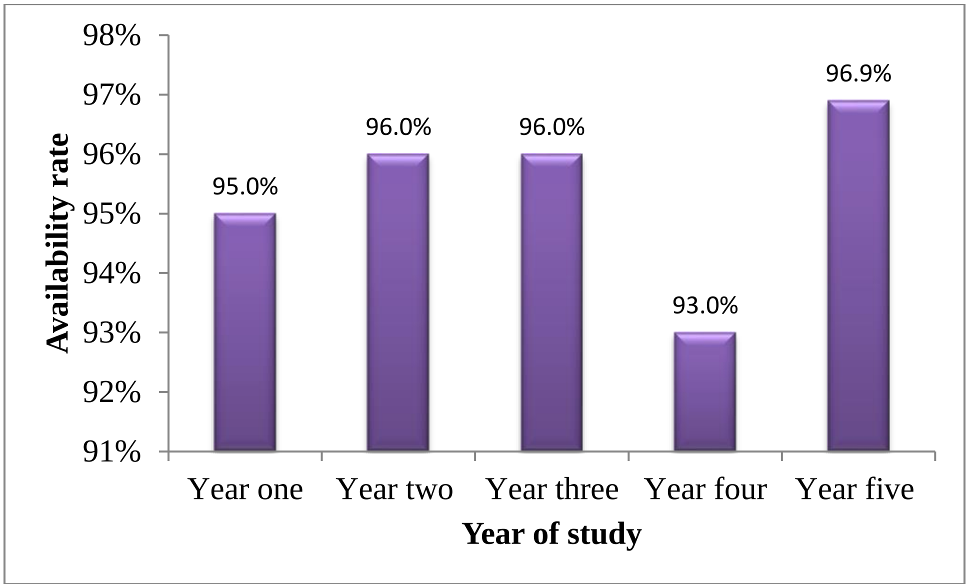

Figure 3: Availability rate of the filler machine

Figure 4 shows that performance rate was least in year four (2020 (66.2%) while it was highest in year three (129%)

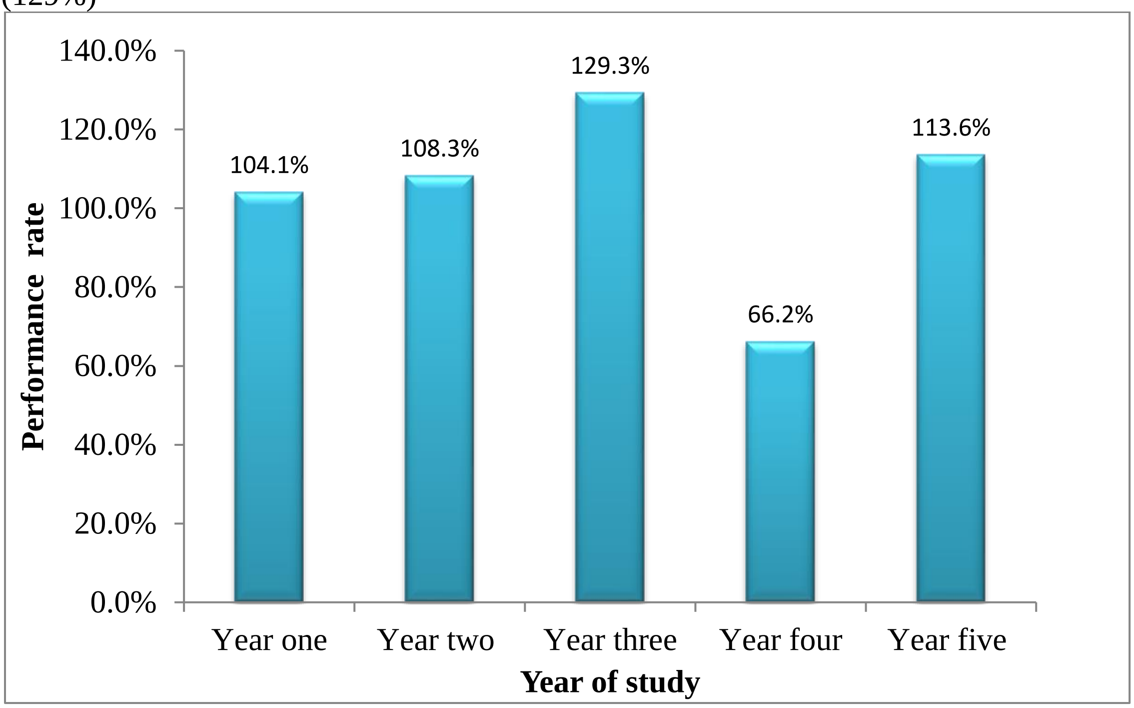

Figure 4: Performance rate of the filler machine

Table 4 shows that the quality rate was 99.9% all through the five years of study.

Table 4: Quality rate of the filler machine

Year of study	Quality rate (%)
Year one (2017)	99.9
Year two (2018)	99.9
Year three(2019)	99.9
Year four (2020)	99.9
Year five (2021)	99.9

Table 5: Data obtained from the company (Nigerian Bottling Company (NBC) Packer/Caser Machine)

Variables	2017	2018	2019	2020	2021
Name of machine	Packer/Caser	Packer/Caser	Packer/Caser	Packer/Caser	Packer/Caser
Year of purchase, installed and commissioned?	2008	2008	2008	2008	2008
Type of maintenance	Preventive Usage based	Preventive Usage based	Preventive Usage based	Preventive Usage based	Preventive Usage based
Total number hours of breakdown per year(hours)	154.5	117.66	158.3	264.5	128.6
Number of hours of operation per year(hours)	2392	2472.5	3635	2048.3	3498.3
Number of hour of overtime per year	249	221	169	183.5	148
Target amount of product per year	3,102,244	3,505,644	4,799,560	5,234,767	4,878,455
Actual amount of product per year	3,219,900	3,694,895	5,207,100	3,467,092	5,043786
Quantity of defective product per year	1243	998	1310	893	4851
Machine capacity (CPH)	1650	1650	1650	1650	1650

Table 6 shows that that the packer/caser was purchased in 2008 and the type of maintenance approaches carried out were preventive and usage based maintenance. The machine has a capacity of 1650CPH

Table 6: General information of the Packer/Caser machine

Variables	**Information**
Name of machine	Packer/Caser
Year of purchase	2008
Type of maintenance	Preventive and usage based
Capacity of machine	1650CPH

Table 7 shows that availability (96.3%) and performance rates(103%) of packer/Caser machine were highest in year five while they were least in year four: 87.0% and 66.2% respectively.

Table 7: Availability rate, Performance rate and Quality rate of the NBC Packer/Caser machine.

Year of Study	**Availability Rate (%)**	**Performance Rate (%)**	**Quality Rate (%)**
Year One (2017)	93.5%	103%	99%
Year Two (2018)	95.2%	105%	99%
Year Three (2019)	95.6%	108%	99%
Year Four (2020)	87.0%	66.2%	99%
Year Five (2021)	96.3%	103%	99%

Table 8: Data obtained from BONS Industries Ltd (Bottle Blow mould)

Variables	2017	2018	2019	2020	2021
Name of machine	Blow Mould	Blow Mould	Blow Mould	Blow Mould	Blow Mould
Year of purchase, installed and commissioned?	2014	2014	2014	2014	2014
Type of maintenance	Preventive, Condition based	Preventive, Condition based	Preventive, Condition based	Preventive, Condition based	Preventive, Condition based
Total number hours of breakdown per year(hours)	125	130	227	397	132
Number of hours of operation per year(hours)	3024	3024	3024	3024	3024
Number of hour of overtime per year	119	118	110	102	128
Target amount of product per year	2,140,000	2,140,000	2,140,000	2,140,000	2,506,000
Actual amount of product per year	1,722,240	1,823,200	1,910,000	1,000,800	2,056,850
Quantity of defective product per year	47,760	56,800	69,150	38,200	99,150
Machine capacity (BPH)	550	550	550	550	550

Table 9 shows that the machine was purchased in 2014 and the type of maintenance approaches carried out were preventive and condition-based maintenance. The machine has a capacity of 550CPH

Table 9 : General information of the Blow Mould machine

Variables	**Information**
Name of machine	Blow mould
Year of purchase	2014
Type of maintenance	Preventive and Condition based
Capacity of machine	550BPH

Table 10 shows that the availability rate was highest in year one (95.8%) while the performance rate was least in (46.7%) in year four. The quality rate also varied being highest in year one (97.2%).

Table 10: Availability rate, Performance rate and Quality rate of the BONS Blow mould machine.

Year of Study	**Availability Rate (%)**	**Performance Rate (%)**	**Quality Rate (%)**
Year One (2017)	95.8%	80.5%	97.2%
Year Two (2018)	95.0%	85.1%	96.8%
Year Three (2019)	92.4%	89.2%	96.3%
Year Four (2020)	86.8%	46.7%	96.1%
Year Five (2021)	95.6%	82.0%	95.1%

Table 11:Data obtained from BONS Industries Ltd Monobloc – (Filler, Capper & Rinser).

Variables	2017	2018	2019	2020	2021
Name of machine	Monobloc (Filler)	Monobloc (Filler)	Monobloc (Filler)	Monobloc (Filler)	Monobloc (Filler)
Year of purchase, installed and commissioned?	2014	2014	2014	2014	2014
Type of maintenance	Preventive, Condition based	Preventive, Condition based	Preventive, Condition based	Preventive, Condition based	Preventive, Condition based
Total number hours of breakdown per year(hours)	120	130	217.5	386	114.5
Number of hours of operation per year(hours)	3024	3024	3024	3024	3024
Number of hours of overtime per year	110.3	117.8	119.5	112	118.5
Target amount of product per year	2,136,400	2,136,400	2,136,400	2,136,400	2,500,000
Actual amount of product per year	2,006,800	2,010,600	1,898,450	1,008,500	2,403,700
Quantity of defective product per year	129,600	125,800	150,400	76,400	196,400
Machine capacity (BPH)	600	600	600	600	600

Table 12 shows that the Monobloc machine was purchased in 2014 and the type of maintenance approaches carried out were preventive and condition based maintenance. The machine has a capacity of 600CPH

Table 12: General information of the Monobloc machine

Variables	**Information**
Name of machine	Monobloc (Filler/Capper/Rinser)
Year of purchase	2014
Type of maintenance	Preventive and Condition based
Capacity of machine	600BPH

Figure 5 shows that the availability rate of the Monobloc was lowest in year 4 (2020**)**

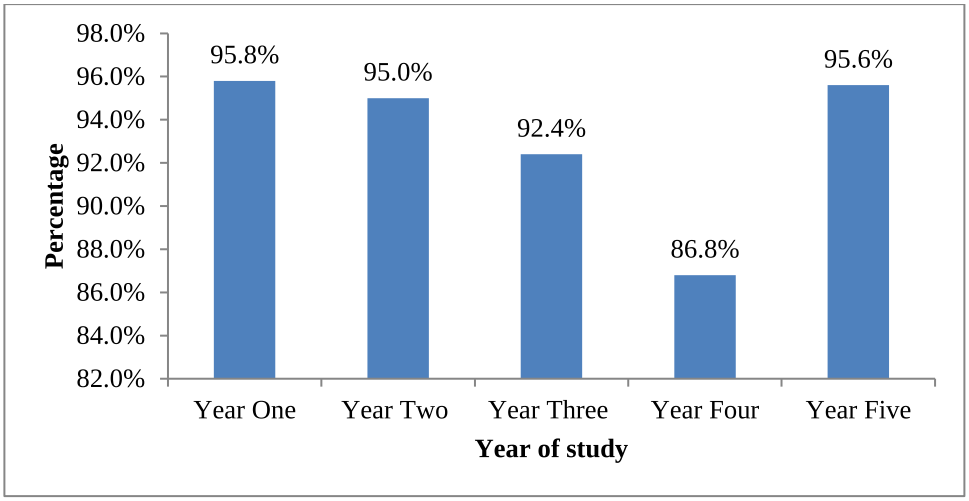

Figure 5: Availability rate of mono bloc machine (BONS Industries limited)

Figure 6: Performance rate of monobloc machine shows that there was high performance in 2021(year five)

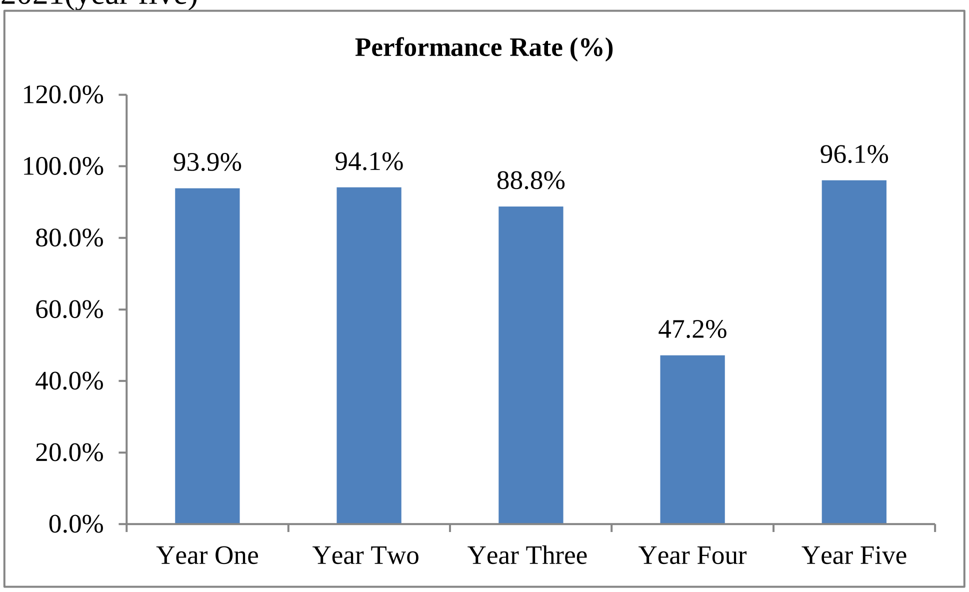

Fig 6: Performance rate of Monobloc

Table 13 shows that the quality rate of the monobloc machine varied for the different years. it was highest in year two (93.7%)and least in year five(91.8%)

Table 13 : Quality rate of the Monobloc (Filler/Capper/Rinser)

Year of Study	Quality Rate (%)
Year One (2017)	93.5%
Year Two (2018)	93.7%
Year Three (2019)	92.0%
Year Four (2020)	92.4%
Year Five (2021)	91.8%

Table 14: Data obtained from BONS Industries Ltd --- Packer/Caser machine

Variables	2017	2018	2019	2020	2021
Name of machine	Packer/Caser	Packer/Caser	Packer/Caser	Packer/Caser	Packer/Caser
Year of purchase, installed and commissioned?	2014	2014	2014	2014	2014
Type of maintenance	Preventive, Condition based	Preventive, Condition based	Preventive, Condition based	Preventive, Condition based	Preventive, Condition based
Total number hours of breakdown per year(hours)	321.5	165.8	285.5	364.3	216
Number of hours of operation per year(hours)	3024	3024	3024	3024	3024
Number of hour of overtime per year	110	117	118	113.5	116.3
Target amount of product per year	178,000	178,000	178,000	178,000	201,600
Actual amount of product per year	149,200	156,400	143,100	82,500	173,300
Quantity of defective product per year	12,300	15,600	11,800	7,500	17,300
Machine capacity (BPH)	600	600	600	600	600

Table 15: General information of the Packer/Caser machine

Table 15 shows that the packer/caser machine was purchase in 2014 and has a capacity of 600BPH. Type of maintenance done was preventive and condition based

Variables	**Information**
Name of machine	Packer/ Caser
Year of purchase	2014
Type of maintenance	Preventive and Condition based
Capacity of machine	600BPH

Table 16: Shows the Availability rate, Performance rate and Quality rate of the BONS – Packer/Caser

Year of Study	**Availability Rate (%)**	**Performance Rate (%)**	**Quality Rate (%)**
Year One (2017)	89.0%	83.8%	91.7%

Year Two (2018)	94.5%	87.8%	90.0%
Year Three (2019)	90.5%	80.4%	91.7%
Year Four (2020)	87.9%	46.3%	90.9%
Year Five (2021)	92.1%	85.8%	90.0%

Discussion of Findings

This study showed that the filler machine and Packer/Caser used in NBC were effective even though they were bought in 2008 which is 14 years ago. This is contrary to the finding in Akure by Bolaji and Adejuigbe, (2012) where there was frequent machine breakdown due to poor maintenance of the 15 years old machine in the manufacturing company. The maintenance approach used by the company may have accounted for the function ability of the machine since 14 years ago. NBC Benin plant practiced a combination of different maintenance approach for the filler machine: Preventive and usage based. . The kind of maintenance practice by BONS Industries Ltd is preventive and condition based. Here, the parts of the machine are replaced when they seem to getting too worn out to continue functioning appropriately. At the time the machine is getting worn out, it may affect effectiveness. Comparing the availability and performance rates of the filler machines of NBC and Monobloc of BONS Industries Limited, the rates were better in NBC than BONS. This may be attributed to the kind of maintenance done and the technical know-how. It is known that machine breakdown and failures affect the effectiveness of the machine. But in this study, it was shown that the filler machine was available most of the time resulting in high product manufacturing. This was also seen in the performance rate and quality rate. This finding is similar to the world class standard (Jain *et al.,* 2013) but higher than the finding by Igbokwe and Godwin (2021) in a food and beverage manufacturing company in Anambra State, Nigeria; the OEE was 55.3%. This may be attributed to the fact that the NBC fathoms coordinated maintenance in its operations. Being a multinational company, maintenance of the filler machines is done by both local and foreign maintenance personnel. In-fact, the producer of the machine (Krones Germany) is always involved in the maintenance of the Filler machine and other NBC equipment. In BONS industries limited, maintenance was done by the locally available technicians. More training may be needed by these technicians and the producers of the machine should be involved in the maintenance. It was however seen that in year four (2020), the availability rate was lower than other years in both companies. This may be attributed to COVID 19 pandemic which limited the availability of foreign man- power to assist in the machine maintenance in the case of Nigerian Bottling Company Ltd and lay off of some Technicians/reduction of manpower by BONS Industries Limited. Airports, sea ports and land travels were closed down during the lock down to prevent the spread of the infection. This indirectly affected the company's maintenance operations. Local markets were also closed except food markets which affected procurement of spare parts. BONS Industries limited which lay off some technician was also due to low market sales/share during the pandemic.

5.1 Summary of Findings

This was a retrospective study on evaluation of maintenance in food and beverage manufacturing industries using Nigerian Bottling Company (NBC) Ltd, Benin Plant and BONS Industries Limited, Enugu. Machines for the study were Filler (Krones) and Packer for NBC while Blow Mould, Monobloc, and Packer/Caser for BONS Industries Limited (these are Bottling line equipment). It was found that the maintenance approaches used were preventive and usage-based approaches in NBC while BONS Industries Limited used Preventive and condition based. Availability rate, performance rate and quality rates were high in both industries although NBC was better.

5.2 C**onclusions**

The approaches used for the maintenance of these machines in these manufacturing companies are preventive and usage based in NBC and preventive and condition based in BONS Industries Limited. The availability rate, performance rate and quality rate were high however performance rate was lower in the year 2020 in both companies due to reasons given above (COVID 19 Pandemic).

5.3 Recommendations

It is recommended that companies should carry out routine preventive maintenance and usage base maintenance since better result was obtained when compared to preventive and condition based. Local manpower should be trained on machine maintenance and in some cases of overhaul or refit, the owners/manufacturers of the machine should be involved.

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