

## PLANT MAINTENANCE STRATEGY FOR IMPROVED PRODUCTION IN THE FOOD AND BEVERAGE INDUSTRIES

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**Abstract:** The evaluation of plant maintenance methods for improved performance in the food and beverage industries was carried out using Nigerian Bottling Company Benin and Owerri Plants and BONS Industries Limited Enugu, Nigeria. The study investigated to determine the maintenance approaches used in the food and beverage manufacturing industries and to evaluate the availability rate, performance rate, and quality rate of the manufacturing industry due to maintenance. Records on maintenance activities on Filler machines, Packers, Blow mold, Monobloc (Filler/Capper/Rinser) machines, and Palletizers were collected using record forms from the logbook for a period of five years (2017 – 2021) and this serves as the primary data for the research. The world-class Overall Equipment Effectiveness (OEE) mathematical model was used to evaluate the maintenance performance of each plant. In Nigerian Bottling Company (NBC), the Availability rate of the Filler machine ranged from 93.0% - 96.9%, the Performance rate ranged from 66.2% - 129.3% and the Quality rate was 99.9% for all the years. For BONES Industries Ltd, water production line, the Availability rate of the Monobloc machine ranged from 86.8% - 95.8%, the Performance rate ranged from 47.2% - 96.1% while the Quality rate ranged from 91.8% - 93.7%. The maintenance methods/approaches used in NBC Plants were preventive and usage while the maintenance methods/approaches used in BONS Industries equipment were Preventive and Condition-based maintenance. The Availability rate, Performance rate, and Quality rate which are the parameters to evaluate equipment maintenance performance were better in NBC than in BONS Industries. The Overall maintenance cost and cost per case are also better in NBC than that of BONS about volume produced. This recommended that companies should carry out routine preventive maintenance and usage-based maintenance such as periodic machine overhauls since the better result was obtained when compared to preventive and condition-based.

**Keywords:** Food and Beverage Industries, Plant Maintenance, Production, Strategy, Food and Beverage Industries.

### 1.1 Introduction

Maintenance is defined according to the European standard (Alyouf, 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, a safe and secure work environment, increased production speed, and the overall improvement of the performance of the

plant. 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 center and not an avoidable expense (Al-Najjar et al., 2001; Al-Najjar and Alsyof, 2004). Effective maintenance results in long-term profit and it has an impact on production and its operational aspects such as capacity, quality, costs, environment, and safety. In recent times, the machines used in manufacturing companies are automated compared to simple machines used before World War II (Alsyof, 2007). Reliability, availability, maintainability (RAM), safety, quality, environment, and multi-skilling are considered very important in current machines in use.

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 the folding up of some companies. Some that are still functional do not have maximum performance because of myriad factors. However, the demand for products by the teeming population of Nigeria and competition among companies demands that the remaining companies perform maximally (Mifdal *et al.*, 2013). Industrialization in Nigeria seems to be at a crossroads given that these pursuits of the strategy would lead to more inefficient resource usage, intensified foreign exchange constraints, high cost, and balance of payment difficulties. This is paradoxical given that the industrial sector is theoretically at least expected to have the capacity to innovate and thus exude the dynamism that affects the other sectors of the economy. Businesses in the Nigerian manufacturing sector have tottered over the years due to a lack of adequate management commitment to timely funding of materials procurement coupled with unethical practices of some executives (Oba, 2008). According to a survey carried out in 2010 by the Manufacturers Association of Nigeria (MAN), 834 manufacturing companies shut down their operations in 2009 across the country due to high manufacturing costs created by exorbitant prices of raw materials and spare parts for machine maintenance among other reasons (Adeloye, 2010). The few surviving manufacturing firms are faced with stiff competition in the current markets. This has led to the need for coming up with a better method of managing and measuring how material resources are utilized by various jobs or products and therefore be able to eliminate any wastage in the value chain. With the process of liberalization, there has been a drastic change in the market which has forced manufacturing companies to devise strategies to minimize production and equipment maintenance costs to remain competitive.

Today, there are dramatic evolutions in the market environment and every organization must strive to keep itself in business. Major competition has shifted from the market to the production floor where manufacturing costs (including equipment maintenance costs) can be reduced and profitability boosted for firms to compete favorably. Backed by advanced technology, firms are closely monitoring their manufacturing costs and embarking on efficient management of materials (Ondiek, 2009). Unfortunately, few studies exist yet on the productivity analysis of manufacturing firms for a developing economy such as Nigeria. This study intends to fill this gap on mainly the equipment maintenance performance side which is huge, with the right maintenance strategy in place all these can be properly achieved.

## 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. While these organizations are busy working out means of increasing productivity and enhancing their equipment performance, the problems continue to increase. It can be pointed out here that the results or implications of these are damaging. Low productivity and poor equipment maintenance lead to unnecessary loss of huge amounts of money. These losses of money by these organizations cripple the economy of the nation. Given the above-mentioned problems, it becomes obvious that there is a need to evaluate the plant maintenance strategy for improved production in the manufacturing firm in Nigeria and also determine the equipment maintenance performances. Hence, 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 Objective

To evaluate the equipment maintenance strategy for improved performance in the food and beverage industries.

#### Research Objectives

1. To determine the maintenance approaches used in the food and beverage manufacturing industries.
2. To evaluate the availability rate, performance rate, and quality rate of the manufacturing industry due to maintenance.

### 1.4 Hypothesis of the Study

The following Alternative hypotheses guided the study.

- ❖ There are no maintenance approaches used in the food and beverage industries.
- ❖ Evaluation of the availability rate, performance rate, and quality rate of the manufacturing industry will not be improved due to equipment maintenance.

## 2.0 Review of Related Literature

### 2.1 Conceptual Review

#### Maintenance

Maintenance is defined according to the European standard 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, a safe and secure work environment, increased production speed, and the overall improvement of the performance of the plant. Equipment maintenance is any process used to keep a business's equipment in reliable working order. It may include routine upkeep as well as corrective repair work or procedures used by Technicians to keep the machine in top shape. Equipment may include mechanical assets, tools, heavy off-road vehicles, and computer systems. The need for maintenance is predicated on actual or impending failure – ideally, maintenance is performed to keep equipment and systems running efficiently for at least the design life of the component(s).

Maintenance strategy gives room for strategic maintenance decision making which involves selecting the right care and repair methodologies that maximize equipment life and performance for the least cost to the user. But to be able to make successful maintenance management strategy choices you must understand how equipment fails. When you know the equipment’s weaknesses and strengths you can care for it properly and get maximum

service from it at the least cost. We have different types of maintenance approaches/strategies which include Preventive, Corrective, Predictive, Condition-based, Usage-based maintenance, etc. Maintenance has had a tremendous impact on the company's proficiency to optimize its production system to meet its long-term objectives. Generally, a production system in which maintenance is not given attention may easily lead to the system producing defective products as a result of machine defects, (Alyouf, 2004).

### **Types of maintenance approaches**

The need for maintenance is predicated on actual or impending failure – ideally, maintenance is performed to keep equipment and systems running efficiently for at least the design life of the component (s). As such, the practical operation of a component is a time-based function. Anytime we fail to perform maintenance activities intended by the equipment's designer, we shorten the operating life of the equipment. But what options do we have? Over the last 30 years, different approaches to how maintenance can be performed to ensure equipment reaches or exceeds its design life have been developed in the United States. In addition to waiting for a piece of equipment to fail (reactive maintenance), we can utilize preventive maintenance, predictive maintenance, or reliability-centered maintenance, (Piotrowski, 2001).

### **The Strategies/approaches:**

- Reactive Maintenance: The moment the machine breaks down, it will be immediately fixed.
- Preventive Maintenance: There will be a parts replacement schedule ahead of time before parts breakdown, usually at a regular interval.
- Usage-Based Maintenance: The parts are replaced when the machine has been used for a certain period before they break down.
- Condition-Based Maintenance: The parts are replaced when they seem to getting too worn out to continue functioning appropriately.
- Predictive Maintenance: The historical data are utilized to make predictions about when a part will break and replace the parts based on these predictions before they break. This usually, but not always, utilizes artificial intelligence and machine learning.
- Prescriptive Maintenance: This involves using advanced data analysis methods to do more than predict failure points, but instead provides hypothetical outcomes to choose the best action that can be taken before failure, safety hazards, and quality issues arise as well as the timing of implementation.

Using the right maintenance approach for manufacturing equipment gives room for better machine performance. However, we will go further to elaborate on the strategies/types of maintenance that are mostly used in manufacturing industries, (Al-Najjar, 1997; Kelly, 1997; Pintelon and Gelders, 1992).

**Availability rate:** Equipment availability is a metric used to measure the percentage of time a machine can be used. It is the amount of time in which a machine runs and is available for production. Availability can also be called 'uptime', and it is one of the key metrics that give us insight into our production efficiency. Machine availability, or uptime, is the total amount of time a machine runs versus the time it was scheduled to run. Availability is the percentage of time a machine is in operation. The scheduled time is based on understanding

available capacity, having the raw materials on hand in appropriate quantities, and having the staff and sales orders required to run. Downtime can slow or stop the machine during this scheduled time. Total downtime includes preventive maintenance, changeovers, and other controlled, known variables. Unplanned downtime means breakage, quality fallout, jams, or other unpredicted stoppages. For example, a machine could be scheduled to run for eight hours and only be active for six hours. In this case, the availability score for the machine is 75%. All manufacturing operations should measure availability and downtime, taking into account the duration and reason for downtime. However, if this is tracked by hand, it is likely to be highly inaccurate, severely delayed, and far less actionable. Machine availability also referred to as uptime, is the total amount of time a machine runs versus the time it was scheduled to run. Availability is a key figure to monitor when it comes to production planning. Production capacity, delivery dates, expected breakdowns, and costing are determined from availability data, (Waeyenbergh and Pintelon, 2002; Kumar, 1996).

Machine availability is calculated in the following way:

$$\text{Availability} = \frac{\text{Production Run Time}}{\text{Planned Production Time}}$$

**2.1.4 Performance rate:** Performance, also known as process rate, measures the speed at which the workstation or machine processes units. It is also represented as a percentage of the ideal, with performance losses being caused by logistical problems, searching for tools, small stops, operator inefficiency, decreased speed of the machine, etc.

$$\text{Performance} = \frac{(\text{Total Units} \times \text{Ideal Cycle Time})}{\text{Real Run Time}}$$

**Quality rate:** The quality rate is defined as the ratio between the yield produced and the total production quantity. For the calculation of the quality rate, the scrap quantity incurred must be recorded. This can be done, e.g., by manual input which is made directly at the machine terminal, or by comparing the total production volume recorded with the possibly existing weighing of the actual yield. Quality is calculated by dividing the number of usable units produced by the total units stated. If an asset produces 12,000 units in a 12-hour production time frame, but 300 of them have defects that make them unusable, then the number of usable units is 11,700. Therefore, the quality score would be 0.975 or 97.5%. 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.

Quality is calculated as:

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

$$\text{Hence Quality Rate} = \frac{\text{Good Count}}{\text{Total Count}} \times 100$$

### Improved Performance

Performance is the result of work and work behavior that has been achieved in completing the tasks and responsibilities given in a certain period. Didier (2002) considers that performance is to "achieve the goals that you have given in convergence with the company guidelines" and that performance is not simply finding a product but rather is the result of a comparison result and objective. Performance improvement is measuring the output of a particular business process or procedure, then modifying the process or procedure to increase the output, increase efficiency, or increase the effectiveness of the process or procedure. The primary goals of organizational improvement are to increase organizational effectiveness and efficiency to improve the ability of the organization to deliver goods and or services. A third area sometimes targeted for improvement is organizational efficacy, which involves the process of setting organizational goals and objectives. Improving performance can pertain to various domains such as personal productivity, physical fitness, or even organizational efficiency. There are two main ways to improve performance: improving the measured attribute by using the performance platform more effectively, or by improving the measured attribute by modifying the performance platform, which in turn allows a given level of use to be more effective in producing the desired output. All companies strive for better performance since high performance means high competitiveness, which in turn generates more money. However, there are different ways to increase performance, depending on which viewpoint you choose to take, efforts to improve performance in manufacturing operations have been important since the start of the industrialization era, (Kirkpatrick, 2006).

### **Food and Beverage Industries**

The Food and Beverage Industry includes all the companies involved in transforming raw agricultural goods into consumer food products as well as processing, packaging, distribution, and retail, which are all included in the large, diverse food and beverage industry. Due to their provision of necessary goods and services that support life and promote social and economic advancement, these industries are vital to both the global economy and human welfare. It does not cover raw food production, which falls into the closely related agriculture industry. This industry includes fresh food, packaged food, and beverages (both alcoholic and non-alcoholic). From food sold at the grocery store to cooked meals served at restaurants, institutions, and events, this industry serves a huge variety of retail outlets.

The food and beverage industry is divided into two major segments, which are the production and the distribution of edible goods. As the world's population grows, so does the demand for food and drink. But that's not all. It's one of the oldest industries on the planet, but still full of innovation. From new products to higher-volume, lower-cost production techniques, this industry is always looking for new ways to produce the food consumers want at the best possible price. And vital equipment is there every step of the way. Consumers want more than *just* food and drink for sustenance; their demands are now more health, ethically, and environmentally driven, (FAO, 2018).

### **2.2 Theoretical Framework**

#### **The Systems Theory**

This theory viewed the inputs/output models. The inputs are taken through processes to transform them into outputs. The outputs are compared with the objectives and feedback is sent to the inputs to enhance improvement

of efficiency and productivity of the system (Ludarig, 1968). He noted that maintenance management was the system, the inputs were labor, materials, spares, tools, information, and external services. The maintenance system processes these inputs into availability, maintainability, safety, and profits as the outputs. Systems theory is a concept that originated from biology, economics, and engineering, which explores principles and laws that can be generalized across various systems (Alter, 2007; Dubrovsky, 2004). A system is a set of two or more elements where: the behavior of each element affects the behavior of the whole; the behavior of the elements and their effects on the whole are interdependent; and while subgroups of the elements all affect the behavior of the whole, none has an independent effect on it (Skyttner, 1996). In other words, a system comprises subsystems whose inter-relationships and interdependence move toward equilibrium within the larger system (Martinelli, 2001; Steele, 2003).

### 2.3 Empirical Review

Foon and Terziowski M (2014) conducted a study to evaluate the impact of operations and maintenance practices on power plant performance in Australia and Malaysia. The study aimed to examine the impact of Operations and Maintenance (O&M) practices, individually and collectively, on power plant performance. A survey research design was used for this study. The results revealed that the relationship between O&M practices and plant performance is significant and positive in a cross-sectional sense.

Maletic et al (2014) examined the role of preventive maintenance in improving a company's competitiveness and efficiency in a Slovenian textile company. This study aimed to discuss the potential improvement areas from the company's perspective and to examine maintenance impact on the company's business. An empirical case study was utilized for this study. The results revealed that preventive maintenance practices and condition-based maintenance (CBM) approach represent the highest opportunity for improvement of organizational performance.

Oseghale (2014) conducted a study on the impact of maintenance strategies on the performance of industrial facilities in selected industrial estates in Lagos state, Nigeria. The study aimed to appraise the facilities and the maintenance management strategies employed in selected industrial estates in Lagos State by identifying and examining facilities maintenance strategies, and determining their impact on the physical condition of the facilities. Both quantitative and qualitative were employed for this research. The results revealed that there was no significant relationship between the types of maintenance strategies and the respondents' level of satisfaction with the physical condition of their facilities.

Uforo et al, (2022) conducted a study to examine the relationship between Maintenance Management and organizational performance among selected manufacturing firms in Akwa Ibom State. The study aims to study the relationship between corrective maintenance, preventive maintenance, conditions-based maintenance, organizational culture, maintenance management, and organizational performance in manufacturing firms. A survey research design was adopted for this study. The results revealed that management has to provide the maintenance teams with maintenance management software to ensure proper intervention monitoring as well as smooth communication between technicians and other professionals to enhance business success.

### 3.0 Methodology

A retrospective study of performance evaluation of maintenance of Nigerian Bottling Company Ltd (Coca-Cola) Benin, Owerri Plant, and BONS Industries Limited, Enugu from 2017 – 2021 (5 years) was adopted. Logbooks, work orders, operating statistics, and production reports including target volume and actual volumes were assessed to obtain primary data. The study was carried out at Nigeria Bottling Company Ltd (NBC), Benin Plant, Edo State, and Nigerian Bottling Company Ltd (NBC) Owerri Plant, Imo State, Nigeria. A record form containing questions on year of study, type of machine, type of maintenance, machine breakdown records, downtime incurred in each equipment, hours of operation, target amount of product, actual amount of product, quantity of defective product, cost of maintenance and major maintenance done on the lines were used. Record analysis of relevant data was obtained from the company's annual maintenance report and journals.

Data were analyzed using Microsoft Excel. The availability rate, performance rate, and quality rate were calculated using OEE, The availability of the machine was further analyzed with a bar chart or pie chart, and the explanation was done to see how it affected equipment performance. Also, the performance rate and the quality of the product produced by the machines were further analyzed using the bar chart and pie chart and the result was explained. The mathematical expressions below are used to obtain the actual values in percentages of these parameters (availability, performance, and quality rates):

$$\text{Availability rate of the equipment} = \frac{\text{Planned runtime} - \text{planned downtime}}{\text{planned run time}} \times 100$$

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

$$\text{Quality rate of the equipment} = \frac{\text{Processed quantity} - \text{defective quantity}}{\text{processed quantity}} \times 100$$

The total cost of maintenance and cost per case of each maintenance strategy were also analyzed to obtain the best method of maintenance for effective food and beverage production. The mathematical expression/formula below was used.

$$\text{Preventive Maintenance percentage cost} = \frac{\text{Preventive maint. Cost}}{\text{Total Maintenance cost}} \times 100$$

$$\text{Cost Per Case} = \frac{\text{Preventive Maint. Cost}}{\text{Total volume of product}}$$

$$\text{Usage Based Maintenance percentage cost} = \frac{\text{Usage Based maint. Cost}}{\text{Total Maintenance cost}} \times 100$$

$$\text{Cost Per Case} = \frac{\text{Usage Based Maint. Cost}}{\text{Total volume of product}}$$

This is done for the condition-based maintenance strategy used in this study.

#### 4.0 Data Presentation and Analysis

##### 4.1 Presentation of 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)

##### The Filler Machine – NBC Benin Plant.

Table 4.1 shows that the Filler machine – Benin Plant 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 – (CPH: Cases Per Hour).

Table 4.1: 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

Table 4.2: Data obtained from the company (Nigerian Bottling Company (NBC) Benin plant South-South) - Filler Machine RGB

Variables	2017	2018	2019	2020	2021
Total number of hours of breakdown per year(hours)	123.66	107.33	146.33	153.4	108.5
Planned number of hours of operation per year(hours)	2386.67	2462.56	3626.02	2028.80	3481.41
Number of hours of machine overtime per year	242	201	166	143	129
Target amount of product per year (cases)	3,102,244	3,505,644	4,799,560	5,234,767	4,878,455
Actual amount of product per year(cases)	3,230,017	3,794,995	6,207,177	3,467,081	5,543,752
Quantity of defective products per year (Cases)	4213	4983	5310	4643	4891
Machine capacity (CPH)	1650	1650	1650	1650	1650

### Calculations Using the Oee Model for the Filler Equipment:

The calculations in Appendix 1 show the workings using the Overall Equipment Effectiveness world-class model for evaluation of the Availability rate, Performance rate, and quality rate of the Filler machine.

#### The Availability rate:

Table 4.3 shows that the availability rate of the Filler machine ranges from 92.5% - 97.0%. In 2017, it was 94.8%; 2018 (95.6%); 2019 (96.0%); 2020 (92.5%); 2021 (96.9%). However, it was highest in year five at 97.0% while least in year four at 92.4%.

Table 4.3: Availability rate of the NBC Filler machine – Benin Plant.

Year of Study	Availability Rate (%)
Year One (2017)	94.8
Year Two (2018)	95.6
Year Three(2019)	96.0
Year Four (2020)	92.5
Year Five (2021)	96.9

Figure 4.1 shows the availability rate of the filler machine. The availability rate was highest in year five 96.9% while it was lowest in year four (93.0%)

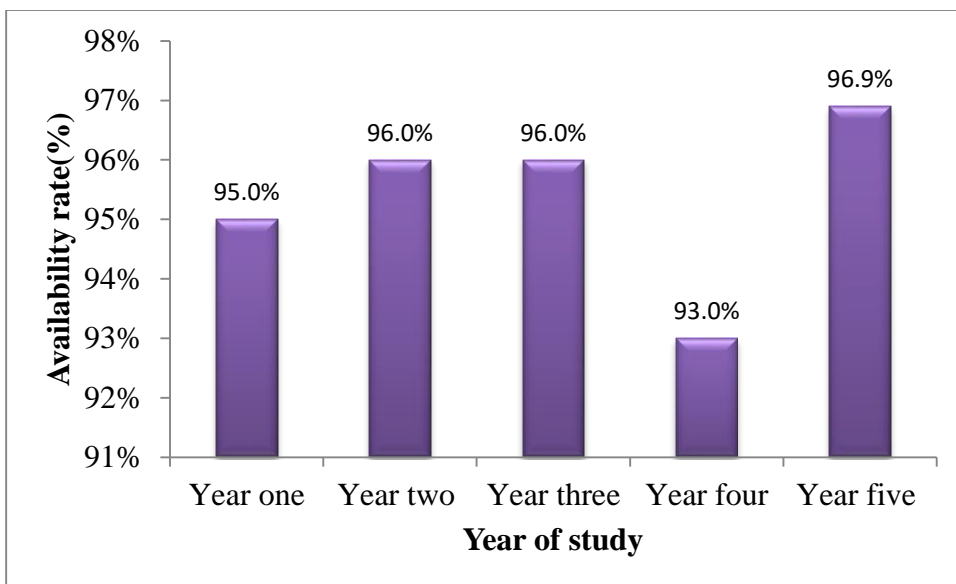


Figure 4.1: Availability rate of the filler machine

From Table 4.3 and also looking at Figure 4.1, the availability rate is higher in year five than in year three despite the higher planned hours of operation for year three. This is because the availability rate of equipment is

considered about downtime incurred during operation and even the corresponding volume of product produced. For example looking (table 4.2) at the planned number of hours of operation in years three and four, that of year three is more but that does not make that year the highest in equipment(filler) availability due to downtime it incurred. This implies that a year with smaller planned hours of operation might turn out to be the year with the best availability of the equipment if the downtime or machine breakdown is reduced due to the maintenance strategy that may be applied.

However, in this case, the actual hours of operation about the planned hour give a higher availability rate in year five. Also when the machine breakdown is reduced with the corresponding reduced downtime, there is always a positive effect on the volume of product produced and all these are influenced by the type of maintenance strategy/method involved as can be seen in Table 4.2 for year three (6,207,177) and year five (5,543,752).

**The Performance rate:**

Table 4.4 shows that the Performance rate of the Filler machine ranges from 66.2% - 129.3%. In 2017, it was 104.1%; 2018 (108.3%); 2019 (109.3%); 2020 (66.2%); 2021 (113.6%). However, it was highest in year three with 129.3% while least in year four 66.2%.

Table 4.4: Performance rate of the NBC Filler machine – Benin Plant.

Year of Study	Performance Rate (%)
Year One (2017)	104.11%
Year Two (2018)	108.25%
Year Three(2019)	129.32%
Year Four (2020)	66.23%
Year Five (2021)	113.63%

Figure 4.2 shows that the performance rate was lowest in year four 2020 (66.2%) while it was highest in year three (129%).

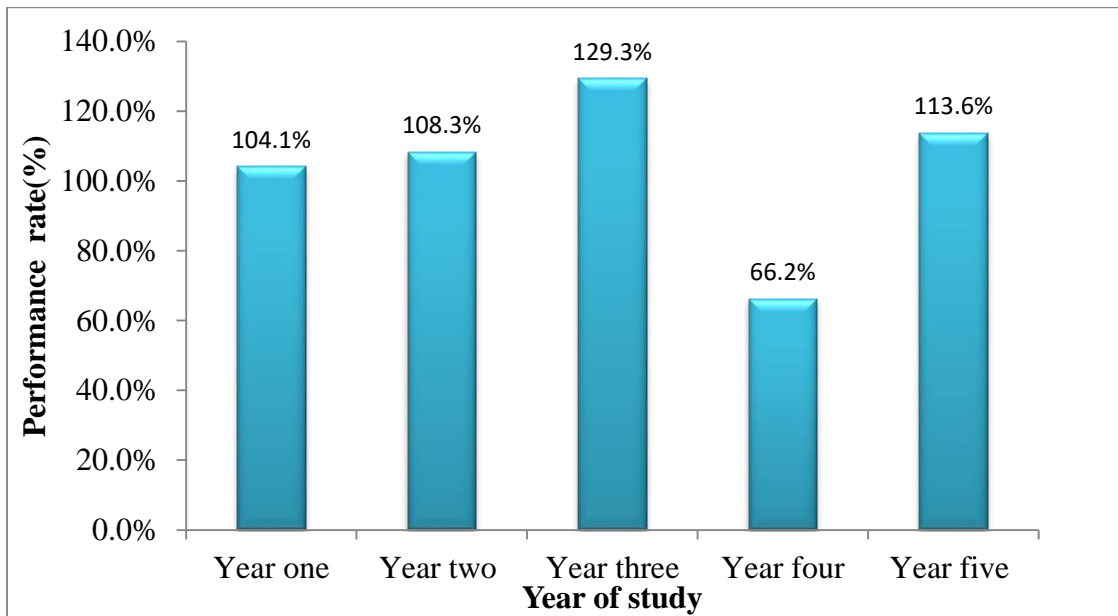


Figure 4.2: Performance rate of the filler machine.

From Figure 4.2, the bar chart, the performance rate was highest in year three (129.3%). This may be attributed to the complete year-round refit (quarterly overhaul) done on filler, the preventive maintenance was routinely carried out hence the equipment availability for that same year was 96.0% above the OEE world-class standard (90%) and that of the Performance rate 129.3% also above 95% OEE world-class standard (Jain et al., 2013).

Also looking at Table 4.2, comparing the actual volume of product produced and the target, the margin/difference between the actual and target for year three (2019) is 1,407,617 cases and that of year five (2021) is 665,297 cases hence the margin was higher positively in year three with over a million cases of the product and hence the year with the highest performance for filler Benin plant even though year five recorded highest availability rate. However, through the year of the study from year one (2017) to year five(2021), the production targets were met and exceeded. This may be attributed to the type of plant maintenance strategy used and in this case, a combination of preventive and usage-based was used.

**The Quality rate:**

Table 4.5 shows that the quality rate was 99.9% all through the five years of study.

Table 4.5: 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

From Table 4.5, it was seen that the quality rate was 99.9% throughout the five years of the study of the filler machine RGB Benin plant. This will be attributed to the quarterly refit/overhaul done on the equipment year-round. This quarterly maintenance program is done on this machine. The refit is carried out four times every year on each plant, the filler is refurbished and the result is this excellent quality rate/quality product.

However, this represents the usage-based maintenance recommended by the equipment manufacturer which is being followed by the NBC plants. Apart from the routine preventive maintenance strategy, refit (usage-based) being combined gives a quality rate that met and exceeded the OEE world-class standard of 99% (Jain et al., 2013). With the right plant maintenance strategies 99.9% quality rate was obtained.

### 5.1 Summary

This was a retrospective study on the evaluation of maintenance in food and beverage manufacturing industries using Nigerian Bottling Company (NBC) Ltd, Benin Plant Owerri Plant, and BONS Industries Limited, Enugu. Machines for the study were Filler (Krones), and Packer/Palletizer 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 in NBC while BONS Industries Limited used Preventive and condition-based based. Availability rate, performance rate, and quality rates were high in both industries although NBC was better for both Benin Plant – South-South and Owerri Plant – South-East. This was because of the maintenance strategy used generally by NBC Ltd, there is a quarterly refit on all production line equipment yearly. This means that there is a major maintenance/overhaul/refit schedule four times each year and a normal routine preventive maintenance is done routinely.

However, all these maintenance activities are done in NBC with the embedded equipment manufacturer's engineers/technicians team. Also, the manufacturer's (KRONES Germany) maintenance recommendations were Quarterly refit/overhaul and weekly preventive maintenance.

### 5.2 Conclusions

The approaches used for the maintenance of these machines in these manufacturing companies are preventive and usage-based in all the NBC plants used in this study 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 the reasons given above (COVID-19 Pandemic). However, it was concluded after going through this study that the combination of preventive maintenance and usage-based maintenance strategies is the best and should be adopted/used by the food and beverage industries for optimal output and improved equipment performance.

The cost of maintenance is better in NBC Ltd than in BONS Industries Ltd, The cost per case is also higher in BONS Industries than in NBC which is lower and considered favorable and friendly to the company's profit margin. For NBC the CPC value is within two digits which is the standard/target for the company's CPC. That of BONS the value is up to three digits which is higher than the standard value for a manufacturing firm. Hence, the combination of Preventive and Usage-based (overhauls) is considered better than the combination of Preventive and Condition-based used by BONS Industries Ltd.

### 5.3 Recommendations

It is recommended that companies should carry out routine preventive maintenance and usage-based maintenance such as periodic machine overhauls since better result was obtained when compared to preventive and condition-based based. For local/ Indigenous companies like BONS Industries Ltd, 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 as routinely done by the NBC plants.

Also, the equipment manufacturer's maintenance recommendation should always be followed to achieve a highly favorable machine performance like that of NBC Ltd. The equipment manufacturer's guidelines/recommendation for maintenance are Preventive and quarterly refit which is usage-based maintenance. For BONS Industries Limited the equipment (China) manufacturer's recommended routine preventive maintenance only. However, the company included condition-based maintenance to manage their equipment.

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