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Development of Standard Operations and Procedures for Maintenance for Selected Brewery Industries

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Abstract**—***Maintenance procedures have been in use but not been given high priority in the brewery industry. Inadequate maintenance procedures or routine checks of brewery equipment may result in equipment breakdown which indirectly could hinder smooth brewery production process; hence the study was conducted to improve the efficiency and performance of the brewery production system through the development of standard operations and procedures for maintenance. Two breweries (A and B) in Nigeria were selected as representative samples for the study using descriptive survey design. Questionnaire was used alongside a work-study at the brewery locations for 3 months to observe and gather the required information on brewery production activities. It was validated and reliability conducted. Copies of questionnaire were administered to the participants and collected back for analysis. With the data collected, standard operations and procedures for maintenance were developed and validated using equipment failure rate [in number of failures per hour] (μ), Mean Time Between Failure in hour/ failure (MTBF), equipment reliability (R_e) and failure probability (P_f). Both qualitative and quantitative data analyses were done using Microsoft Excel. Technical analyses showed that instrument content validity (0.989), reliability (1.00), response and return rate (100%) were highly recommendable. However, μ ranged from 0.0004 – 0.025 for 5 out of 14 equipment in Brewery A and 0.0004 – 0.0446 for 3 out of 14 equipment in Brewery B; max MTBF recorded for A and B from bright tank were 2816 and 2792 hours/ failure; R_e values were 0.3679 each for Brewery A and B; and P_f had commendable values of 0.6321*

Keywords— *Operations, Procedures, Maintenance, Brewery Industries.*

I. Introduction

Maintenance is one of the major tools used in most production industries, for instance, brewery industry for asset management. Optimizing operating conditions and maintenance cost are major techniques towards improving profitability. The form of maintenance used by a manufacturing firm determines the reliability of the production process (Lundgren *et al*., 2021). Many manufacturing sectors in Nigeria such as: cement, glass manufacturing industries, etc. have adopted reliability centered maintenance (RCM) in their production process (Iselin, 2015). Preliminary studies showed that out of the four major brewery industries in Nigeria (Champion Brewery, Guinness PLC, Nigerian Brewery, and International Brewery), only two have adopted this maintenance practice and are making smart results in terms of effective maintenance practice. The definitive aim of any maintenance practice is to provide optimal reliability of the equipment during production (Smith and Mobley, 2017; Sunday *et al.*, 2021). However, there are various kinds of maintenance strategies. These include: (i) Preventive Maintenance: This type tries to find out and repair additional minor fault in nachines and reduces its occurrence of major repairs (Ince *et al.*, 2017); (ii) Corrective Maintenance: In this type, maintenance teams get into action soon as a fault is noticed. The major aim is to bring back a faulty machine to its regular operation as quickly as possible. Here, there is no program for systematic maintenance. A problem must be noticed before maintenance action is taken (ToolSense, 2024); (iii) Predetermined Maintenance: This kind of maintenance practice follows a plan of action generated by the manufacture of machine/ equipment**,** rather than scheduled maintenance provided by an industry maintenance team;(iv) Condition-Based Maintenance: As the name suggests, condition-based maintenance concentrates on the outcomes through measurement or observation. Normal every equipment has a range of standard operating conditions (Afefy 2013; ToolSense, 2024). Within this range, the operation is acceptable. Near the edges of that range, maintenance may be necessary. Nonetheless, condition-based maintenance has a minimal overall cost. Because maintenance is scheduled when anomalies begin; (v) Predictive Maintenance: In this kind**,** data supplied by the equipment shows when maintenance is required**.** Data could also map out when the failure of a machine may occur; (vi) Reactive (Run-to-Failure) Maintenance: This maintenance system responds to when **a** failure of machinery or equipment occurs. Repairs may be done by the factory maintenance's team or by the manufacture's technicians or both. Unlike preventive maintenance, reaction maintenance occurs when a breakdown occurs (Wang and Majid, 2017; ToolSense, 2024). Furthermore, several works have been done relating the evaluation, efficiency and the impact of different kinds of maintenance carried out in different manufacturing industries (Deshpande and Modak, 2014; Rastegari and Salonen, 2016; Zhang *et al.*, 2016; Afolalu *et al.*, 2018; Abdul-Nour *et al.*, 2019). The best combination of reactive, time-or interval-based, condition-based, and proactive maintenance techniques is reactive centered maintenance (RCM), according to Ramli and Arffin's (2012) investigation of the type of maintenance to use in the brewing business. Therefore, the adoption of RCM is to predict the mean time to failure (MTTF) of the manufacturing system's component and reduce the cost of

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production. Okwuobi *et al*. (2018) investigated the breakdown trend in an automated section-forming machine and found that using failure modes and effects analysis (FMEA) aided in achieving optimal and efficient maintenance program. Emovon *et al.* (2018) analyzed the reliability, maintainability and availability of a 210 MW coal fired thermal power plant in India and discovered that considering decisive preventive maintenance with adequate planning interval and organization improved the maintenance program. Sembiring *et al.* (2017) analyzed the reliability of a single machine subsystem of a cable plant for a period of seven years and discovered that when preventive maintenance was carried out on scheduled basis, there was a gradual decrease in failure rate. Thus, there is need to develop standard operations and procedures for maintenance, especially for brewery industries in Nigeria. The findings of this study would help the brewery industries in Nigeria to: (i) maximize returns and minimize loss related to equipment breaks down or malfunctioning during production processes; and (ii) be aware of appropriate production maintenance strategies and modalities applicable to their firms.

II. MATERIALS AND METHODS

2.1 Design, Target Population, Sample and Sampling Technique

In this study, descriptive survey design was used. The target population was brewery industries, located in Nigeria. Samples involved two brewery industries (names withheld based on industry policy and information confidentiality) and were selected using purposive sampling method.

2.2 Instrument for the Study

The instrument was a researcher-made questionnaire that contained open-ended questions.

2.3 Validation, Reliability, Administration and Collection of the Instrument

The instrument was evaluated for both face and content validities using content validity index (CVI) given in Equation 1.

$$CVI = \frac{\text{Total number of valid items (TNVI)}}{\text{Total number of items on the instrument (TNI)}} \quad (1)$$

The recommended CVI ranges from 0.7 – 1.0. If CVI < 0.7, then changes should be made on the items to have the highest degree of content validity. Copies of the questionnaire were administered to the breweries A and B at two different occasions to guarantee instrument reliability. The results were correlated using Pearson’s Product Moment Correlation Coefficient and consistency assessed. However, if the correlation coefficient is greater than 0.7, the instrument is reliable (Beebwa, 2007). Thereafter, the copies of questionnaire were administered to the respondents and collated for analysis.

2.4 Development and Validation of Standard Operations and Procedures for Maintenance in Brewery Industry

(i) Development of Standard Operations and Procedures for Maintenance in Brewery Industry

In order to develop standard operations and procedures for maintenance in breweries, information / data relating maintenance practice as a whole, response to its cost, its aspects, frequency of equipment failure, availability of maintenance team / technicians /experts, their degree of response, availability of spare parts in inventory and general maintenance procedures observed in each brewery were stipulated in the questionnaire (Appendix I).

(ii) Validation of Standard Operations and Procedures for Maintenance in Brewery Industry

Data such as number or frequency of equipment failure while on *n*th production operations (n_f), total time used in *n*th production operations in hours (t) of each important brewing equipment/ facility were employed to compute equipment failure rate [in number of failures per hour] (μ), Mean Time Between Failure in hour/ failure (MTBF), equipment reliability (R_e) and failure probability (P_f). The parameters and their responses were used to assess the effectiveness of maintenance procedures observed in each brewery. The relationships among the aforementioned parameters are given in Equations 2 to 5 (Hans and William, 2020; Upkeep, 2021).

$$\mu = \frac{n_f}{t} \quad (2)$$

$$MTBF = \frac{1}{\mu} \quad (3)$$

$$R_e = e^{-ut} \quad (4)$$

$$P_f = 1 - R_e \quad (5)$$

2.5 Data Analysis

Data were collected and analyzed using Microsoft Excel 2019.

III. RESULTS AND DISCUSSION

3.1 Instrument Validity, Reliability, and Response and Return Rate

The results of content validity and reliability of the instrument are presented in Table 1. Besides, the response and the return rate of copies of questionnaire are shown in Figure 1.

TABLE 1: Content validity and reliability.

Parameter	Value
Content validity	0.989
Reliability	1.000

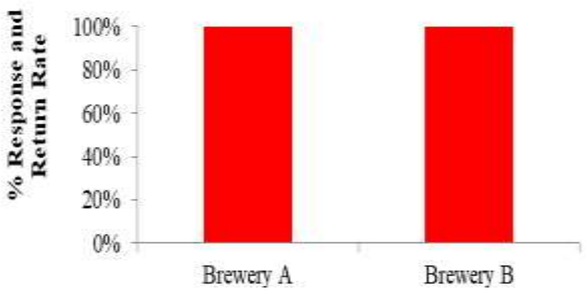

Figure 1: response and return rate (%).

Instrument content validity (0.989) was highly commendable since the observed values was greater than 0.7. Furthermore, the coefficient of correlation (r) was 1.00. The

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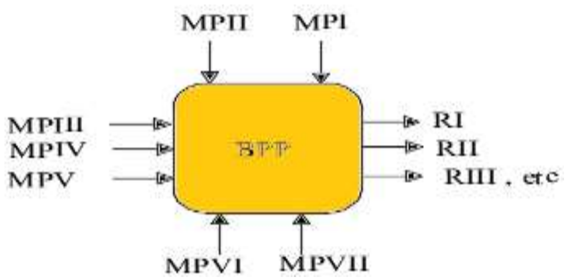
computed value shows that the instrument was reliable according to Beebwa (2007). Both Breweries (A and B) responded to the all items on the questionnaire. This yielded 100% response and return rate. According to Kumar (2010), a questionnaire response and return rate of 50% is sufficient to conduct the study effectively. In this study, the response and return rate were excellent because it exceeded the required minimum return rate by 100%. This implies a healthy response and return rate, and that the participants were willing to response but under anonymity.

3.3 Development of Standard Operations and Procedures for Maintenance in Brewery Industry

The responses from the items on questionnaire relating maintenance procedures indicated the affirmation of the following in both Breweries:

i. Implementation of maintenance after each batch of operation;
ii. Use of planned preventive maintenance and corrective maintenance;
iii. Regular response to equipment maintenance cost;
iv. Routine cleaning, sanitization and management of the facilities;
v. Availability of team of maintenance engineers/technicians to rectify any faulty equipment; and
vi. Availability of sufficient spare parts in brewery inventory.

However, after a careful scrutiny of the responses concerning operations and procedures maintenance in the breweries investigated, a model could be presented in Figure 2.



Note: MPI- Development of equipment maintenance schedules, MPII- Routine cleaning and sanitization of brewing facilities, MPIII- Daily inspection, MPIV- Rapid responses by equipment maintenance team, MPV- Tracing the service history, MPVI- Minimal cost of maintenance, MPVII- Proper labeling of containers with specific content, BPP- Brewing production process, RI- Smooth production process, RII-Minimal production cost, RIII- Satisfaction of customers' order in time, etc.

Figure 2: Structure of standard operations and procedures for maintenance in Breweries

As could be seen in Figure 2, MPI, MPII, MPIII, MPIV, MPV, MPVI and MPVII may be regarded as independent variables while RI, RII, RIII, etc. are the dependent variables. Based on the responses relating maintenance operations and procedures, for both breweries the following have been carried out based on the entire maintenance practices. Breweries A and B always implemented their maintenance after each batch of operation. Both were found to be using planned preventive maintenance which involves forecasting of maintenance need based on previous data or information of the equipment and corrective maintenance (unplanned maintenance which is always administered when there is sudden fault in a machine irrespective of earlier inspection made). Both breweries have been paying for maintenance cost frequently as need would arise. Both have been carrying out routine cleaning, sanitization and management of the facilities. However, equipment / facilities are bound to fail or have one fault or the order within certain period of operation. Both recorded these scenarios which are presented in Tables 2 and 3. Both affirmed the availability of team of maintenance engineers/ technicians, ready at any time to respond to any maintenance issue with immediate effect, as far there are sufficient spare parts available in brewery inventory, or else immediate order for replacement.

Considering MPI in Figure 2, developing a preventive maintenance schedule would permits fixation of some minor issues before they become compounded and cause interruption during production process. For MPII, as soon as batch of production is over, all the vessels/ processing equipment are expected to be cleaned with acid (Zep's FS concentrated foaming acid) and thereafter flush with alkaline solution (Zep's FS Process Cleaner, etc.) to lessen the vessels' cleanup time, mineral deposits, microbial harborage and biofilm formation on the surfaces. Again, cooler doors, cart and foot traffics, are often opened and closed. These permit water condensate to amass at the cooler entrance.

Consequently, biofilm and microbial growth are found on the walls, around the door, floors and ceiling. Besides, debris and soil could be transferred from workers' shoes, carts and forklifts wheels into the cooler floors. Hence, these facilities must be cleaned on regular basis. In order not to disrupt the end use water temperature, it is advisable to clean CIP systems and tanks with water at 77^0C. Other equipment expected to be cleaned include cooling system, hoses, etc. Looking at MPIII critically, all facilities are to be inspected daily to discover issues that might have gone unnoticed and caused downtime during operation. Perhaps, while on inspection, once it is found, it is recommended that such should be tagged "*out of service*" or "*unsafe to use*." Furthermore, in an event of an issue, MPIV comes into play. Once the problem is identified, it is expected that the maintenance team should swing into action following instruction of the equipment maintenance procedures.

Sometimes, it is necessary to recognize MPV. An equipment maintenance history could provide useful data / information into the condition and worth of the equipment. Such service may be automated through equipment management software which creates access to all service data and maintenance records in an instant. MPVI as one of the vital components of maintenance procedure should not be ignored, because knowing precisely how much equipment maintenance cost is, can help in decision making whether to make repairs or buy a new one so as to maximize profit. To avoid using wrong chemical for a job or even mixing accidents, MPVII must be adhered. All containers are always and properly labeled to enhance employee safety. Leakages

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from tanks bases (high humidity regions) could become sources of biofilm formation and microbial growth and may result in contamination. In such cases, leakages are sealed usually with sealant (ultra-step) as stipulated by MPVII. Efficient incorporation of all these procedures is expected to yield RI (smooth production operation), RII (reduction of production cost), RIII (satisfaction of customer's order), and so on.

3.4 Validation of Standard Operations and Procedures for Maintenance in Brewery Industry

Tables 2 and 3 show each vital equipment operating duration per month or batch, months where production operations were carried out, frequency of equipment failure, equipment failure rate [in number of failures per hour] (μ), Mean Time Between Failure in hours / failure (MTBF), equipment reliability (R_e) and failure probability (P_f) in Brewery A and B.

TABLE 2: Summary of equipment failure rate, Mean Time Between Failure, reliability and failure probability for Brewery A for 2021.

			Frequency of Equipment / Machine Failure									
S/N	**Equipment / Machine**	**Operating Hours/ Month**	**Feb**	**April**	**May**	**Aug**	**Sep**	**Oct**	**Failure Rate (μ) [failure / hr]**	**MTBF [hr/ failure]**	**Reliability (R_e)**	**Failure Probability (P_f) [per hr]**
1	Miller	7	0	0	0	0	1	0	0.0179	56.00	0.3679	0.6321
2	Mashing vessel	4	0	0	0	0	0	0	0.0000		1.0000	0.0000
3	Lauter/ Mash tun	8	0	0	0	0	0	0	0.0000		1.0000	0.0000
4	Hop boiler	7.2	1	0	0	0	0	0	0.0174	57.60	0.3679	0.6321
5	Whirlpooling vessel	3	0	0	0	0	0	0	0.0000		1.0000	0.0000
6	Heat exchanger(s)	4.4	0	0	0	0	0	0	0.0000		1.0000	0.0000
7	Flotation vessel	6	0	0	0	0	0	0	0.0000		1.0000	0.0000
8	Fermenter	323	0	0	0	0	0	0	0.0000		1.0000	0.0000
9	Bright tank	352	0	0	0	0	1	0	0.0004	2816.00	0.3679	0.6321
10	Filter	0.5	0	0	0	0	0	0	0.0000		1.0000	0.0000
11	Filling machine	5	0	1	0	0	0	0	0.0250	40.00	0.3679	0.6321
12	Sealing machine	6	0	0	0	0	0	0	0.0000		1.0000	0.0000
13	Labelling machine	5	0	0	0	1	0	0	0.0250	40.00	0.3679	0.6321
14	Packaging machine	6	0	0	0	0	0	0	0.0000		1.0000	0.0000

TABLE 3: Summary of equipment failure rate, Mean Time Between Failure, reliability and failure probability for Brewery B for 2021.

			Frequency of Equipment / Machine Failure									
S/N	**Equipment / Machine**	**Operating Hours/ Month**	**Feb**	**Apr**	**Sep**	**Oct**	**Nov**	**Dec**	**Failure Rate (μ) [failure / hr]**	**MTBF [hr/ failure]**	**Reliability (R_e)**	**Failure Probability (P_f) [per hr]**
1	Miller	7.3	0	0	0	0	0	0	0.0000	0.00	1.0000	0.0000
2	Mashing vessel	4.3	0	0	0	0	0	0	0.0000	0.00	1.0000	0.0000
3	Lauter/ Mash tun	9	0	0	0	0	0	0	0.0000	0.00	1.0000	0.0000
4	Hop boiler	7.1	0	0	0	0	0	0	0.0000	0.00	1.0000	0.0000
5	Whirlpooling vessel	2.8	0	1	0	0	0	0	0.0446	22.40	0.3679	0.6321
6	Heat exchanger(s)	4.2	0	0	0	0	0	0	0.0000	0.00	1.0000	0.0000
7	Flotation vessel	5.5	0	0	0	0	0	0	0.0000	0.00	1.0000	0.0000
8	Fermenter	321	0	0	0	0	0	0	0.0000	0.00	1.0000	0.0000
9	Bright tank	349	0	0	1	0	0	0	0.0004	2792.00	0.3679	0.6321
10	Filter	0.4	0	0	0	0	0	0	0.0000	0.00	1.0000	0.0000
11	Filling machine	6	0	0	0	0	0	0	0.0000	0.00	1.0000	0.0000
12	Sealing machine	5	0	0	0	0	0	0	0.0000	0.00	1.0000	0.0000
13	Labelling machine	6	0	0	0	0	0	0	0.0000	0.00	1.0000	0.0000
14	Packaging machine	5	1	0	0	0	0	0	0.0250	40.00	0.3679	0.6321

Note: Equipment/ machines shown here are regarded as essential one; Only those month where failures were observed are shown here; Ash / grey cells with zero and 1 are cells (months) where production operations were conducted; Zero means there was no failure of equipment/ machine while 1 means there was failure of equipment /machine; Number or frequency of equipment failure while on *n*th production operations (n_f); Total time used in *n*th production operations in hours (t); Equipment failure rate [in number of failure per hour] (μ); Mean Time Between Failure in hour/ failure (MTBF); Equipment reliability (R_e) and failure probability (P_f).

From Table 2, miller for Brewery A only failed once in September, 2021, and μ of 0.0179 failures / hour, MTBF of 56 hours, R_e of 0.3679 and P_f of 0.6321. Hop boiler was faulty in February, 2021 and had 0.0174 failures / hour, 57.6 hours MTBF, 0.3679 R_e and 0.6321 P_f. In September, 2021, bright tank failed and recorded 0.0004 failures / hour, 2816 hours MTBF, 0.3679 R_e and 0.6321 P_f. In April and August, 2021, filling and labelling machines respectively, developed fault and recorded 0.025 failures / hour, 40 hours MTBF, 0.3679 R_e and 0.6321 P_f.

Similarly, Tables 3, packaging machine for Brewery B was once faulty in February, 2021, and had μ of 0.025 failures / hour, MTBF of 40 hours, R_e of 0.3679 and P_f of 0.6321. Whirlpooling vessel had a fault in April, 2021 and recorded 0.0446 failures / hour, 22.4 hours MTBF, 0.3679 R_e and 0.6321 P_f. In September, 2021, bright tank also failed and recorded 0.0004 failures / hour, 2792 hours MTBF, 0.3679 R_e

and 0.6321 P_f. Meanwhile, MTBF is a measure of how reliable equipment is. The higher the MTBF, the more reliable the equipment is, while failure probability shows the extent to which equipment can fail while on operation for certain period *t*. In a study conducted by Iselin (2015), it was found that the prediction of the MTTF of the manufacturing system's component could reduce cost of production. However, the observed values of these parameters in the present study, for instance, failure rate of miller indicates that for every one hour of operation there is that tendency to have 0.0179 failures, and it could be operated for 56 hours before the equipment might be faulty again but with only 36.8% reliable and 63.2% unreliable.

As observed, it would take a longer time for bright tank to fail while filling and labelling machines may be unlucky to withstand failure for a short period of 40 hrs. It again noted that all the faulty equipment had the same R_e and P_f, the reason was that they had failed once (that is, n_f = 1). Generally, out of 14 major types of different equipment used, only five (5) were once faulty in Brewery A and three (3) malfunctioned in Brewery B, and probably they were rectified in time without causing delay in production operation as could be inferred from the responses. However, the less number of failures might have been as result of the proactive standard operations and procedures for maintenance instituted in both breweries to curb equipment breakdown. This is in consonant with the report of Bolu (2015).

IV. Conclusion

In an attempt to improve the efficiency and performance of the brewery production, standard operations and procedures for maintenance were developed using two breweries (A and B) in Nigeria were as representative samples. The results showed that instrument content validity (0.989), reliability (1.00), response and return rate (100%) were excellent. However, equipment failure rate ranged from 0.0004 – 0.025 for 5 out of 14 equipment in Brewery A and 0.0004 – 0.0446 for 3 out of 14 equipment in Brewery B; max Mean Time Between Failure recorded for A and B from bright tank were 2816 and 2792 hours/ failure; equipment reliability values were 0.3679 each for Brewery A and B; and failure probability had commendable values of 0.6321.

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APPENDIX

Appendix I: Standard operations and procedures for maintenance in brewery industry.

1.	Do you carry out maintenance on your brewery facilities?	*Yes [ ] * No [ ]
2.	If ***Yes*** in item in 1, how often?	*After each batch of production [ ] * Once a month [ ] *Twice a month[ ] *Quarterly [ ]
3.	What kind of maintenance do you practise?	*
4.	Do you often pay for its cost as need arises?	* Yes [ ] *No [ ]
5.	Do you clean and sanitize your facilities as part of maintenance procedure? *If **Yes**, explain briefly.*	*Yes [ ] *No [ ] * *
6.	Indicate the frequency of equipment failure and total time for running such equipment between Jan., to Dec., 2021.	* * *
7.	Do you have experts or team of maintenance engineers in your brewery?	*Yes [ ] *No [ ]
8.	How long does take it to response to equipment breakdown?	*
9.	Do you have sufficient spare parts for replacement in your inventory in case of failure?	*Yes [ ] * No [ ] Any other comment:……………………………………
10.	Briefly explain standard maintenance operations and procedures you normally carried out in your brewery based on facilities management.	* * * *