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Reliability engineering principles and maintenance scheduling for plant recovery

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Abstract

Plant operation and management require data from which information can be extracted to determine the state of the plant, and predict its health and anticipated failure interval in the future. The data is lacking in most companies in Nigeria and sometimes when available are not organized in the proper form to extract useful information. This research described the use of reliability engineering principles to perform maintenance practice in a brewery industry. The operational data were obtained from the log book of the plant and subjected to reliability engineering analysis. The average reliabilities of the plant was: 0.431, 0.376, 0.434, 0.603 and 0.722 with average availability of 0.985, 0.986, 0.987, 0.988 and 0.996 respectively. The results show that reliability engineering principles can be used to determine the health and performance of the plant is highly suggested for adoption and implementation.

Keywords: Availability; Brewery; Downtime; Reliability; Recovery; Maintenance; Plant; Scheduling.

1. Introduction

Maintenance can be described as all actions which have the objective of returning a system back to its former state [1] [2]. Maintenance thus brings back the system quickly to its normal functional state and reduces equipment downtime, which is coat for a productive system.

The two different types of maintenance are breakdown mad preventive maintenance. In breakdown maintenance, there is no planned maintenance practice and the equipment or plant is allowed to run to failure, However, in preventive maintenance, the maintenance actions are scheduled in anticipation of plant breakdown either using statistical data or condition monitoring [3].Maintenance is carried out when there is obvious need which will increase the availability of the equipment in the system [4]. Preventive maintenance is the combination of all technical and associated actions intended to retain an item or system in or restore it to state in which it can perform its required function [5]. Equipment or asset failure are often caused by inadequate maintenance and inability to predict problems that may occur later during equipment usage [6].

The problem with most of our industries is the frequency with which installed machines and equipment breakdown [7]. This is the main reason why most of them are producing below the installed capacity thereby causing scarcity of goods and services. The general complaints advanced by these industries is the non-availability of spare parts. The industries generally wait until a breakdown occurs before they run around looking for spare parts. Statistically based maintenance is hardly practiced in our industries not to mention condition based maintenance.

[8]attributed this to lack of maintenance culture due to the following reasons: absence of support for maintenance by management with clear policy; non-recognition of maintenance by management as a vital activity in the organization,

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inadequate supply of spare parts, ineffective organization structure for maintenance, inadequate budget provisions for maintenance, poor or complete absence of maintenance planning resulting in fire-fighting situation in maintenance effort, sheer incompetence or limited knowledge of the plant on the part of the maintenance staff.

The main reason for setting up any industry is to satisfy the customers and provide social services and then make profit. [9] reported that although achieving this is directly the concern of the production department, it reflects back decisively on maintenance department. He maintained that maintenance department is not subservient to the production department and that all the manufacturing activities can only be effective if there is cooperation between the maintenance and production department. [10] emphasized that this cooperation must be two-way effort, as it is equally essential that the production department cooperated with the maintenance to gain its full support in the most expedient manner. Machine breakdown invariably and inevitably result in production loss.

To realize the objectives of setting up industry, the activities of the various departments have to be well organized and coordinated. This implies that different departments should be aware of the objectives which it was set up. The overall effect of this is to increase the profitability of the company. The essential objective of maintenance is to provide freedom from breakdown during manufacturing operations. [11], [12] reported that apart from this objective maintenance of equipment is also essential in order to : maintain the equipment at their maximum operating efficiencies, keep equipment in a satisfactory conditions for safe operations, reduce to a minimum, the cost of this maintenance consistent with the above items.

A good maintenance policy is required for plant and equipment maintenance, A company can adopt any form of maintenance policy which it suits it. From the works of [9], [11].Condition Based maintenance has the capability in delivering the right kW to the customers [13]. The various forms of maintenance policies are: Replacement instead of maintenance-in this policy, the equipment is operated until it breaks down and then it is scrapped and a new one is bought. The maintenance engineer may discover that the cost of repair exceeds the cost of replacement for small, easily replaceable and cheap equipment. Sometimes, technological advancement causes some equipment to become obsolete rapidly, hence, it does not pay to design them to last when they fail; planned replacement-In the policy, the equipment is operated and then sold before it either breaks down or require expensive overhaul. This system is often applied in many branches of industry especially in those in which the equipment operates as an individual unit, small power plant, machines, etc. Some important advantages of this system is that it reduces down time caused by breakdowns and prevents costly overhauls while restricting maintenance function to lubrication, servicing, cleaning and adjustment; breakdown maintenance-in this policy, the equipment is allowed to operate until it breaks down and then repaired. In a situation where the cost of preventing failure of plant and equipment are more than the cost of breakdown, it is often justifiable financially to allow the machine to breakdown before carrying out ant maintenance. This system is usually applied where many items of the plant and equipment operate as individual units, or are separated from actual manufacturing process, so their failure would not immediately or greatly affect the overall production process or constitute a safety hazard. For example, a man operating a tailoring workshop may find it easier, cheaper and quicker, with less loss of production, to allow the sewing machines to breakdown then replaces them with repaired ones held in stock for such occurrences; preventive maintenance-the objective of this policy is to prevent failure before they happen. The benefits of this policy are: regular, simple preventive maintenance results in less down time than infrequent expensive and emergency maintenance, maintenance is carried out when it is most convenient to both production and maintenance personnel with the aim of incurring minimal losses; the volume of maintenance work is distributed evenly throughout the year thus reducing widely fluctuating demands upon the maintenance personnel; there will be greater plant availability because of fewer breakdowns; regular preventive maintenance ensures a high level of plant output, quality performance and efficiency [2]; downtime is reduced considerably since equipment needed are known and made available in advance; also effective control over weekly work allocation is enhanced since weekly workload is known; through a well-coordinated preventive maintenance programme, life expectancy of parts and materials can be determined. Equipment and plant depreciation rate can reduce with a good preventive maintenance application, functioning of machine parts can be determined with the aid of measuring devices employed in preventive maintenance activities. This will help in establishing a more accurate replacement period; Emergency maintenance –is the type of work carried out after a facility which no advance thought has been given has failed. Emergency repair is an undesirable occurrence. [14] is of the view that effectiveness of any maintenance department should not be judged by the vigour with which emergency repairs are carried out but by freedom of the factory from such emergencies. It is of the view that a good maintenance programme should reduce the number and intensity of emergency repairs to the point where no more than 15 percent of the total maintenance effort is devoted to emergency work. It is of my suggestion that this should be lower than 10%. However with current advancement in maintenance management such as reliability centered maintenance (RCM), the percentage should be reduced to 5 to 8%.Usually emergency breakdown has a serious consequence, especially to life and property; Shutdown maintenance- in this practice, the plant or equipment for instance a refinery is shutdown at a specified time interval determined by the company policy and serious maintenance work to be carried out.

Generally maintenance can be classified as planned or unplanned [12] [11]. [9] concluded that the main feature of an unplanned maintenance is that patching and unreliable maintenance is encouraged and rarely is the effort made to analyze and correct the root cause of failure.

[11] defined unplanned maintenance as the type of maintenance service that is generally used to tackle failure that has not been foreseen and which no advanced thought has been given. During an unplanned maintenance all the available resources are urgently utilized to restore a failed plant and equipment to its normal operational standard in shortest possible time. Planned maintenance on the other hand is the maintenance planning of the maintenance work. Planned maintenance is not a specific form of maintenance, but rather the application of maintenance tackled in a scientific manner. A good record is essential for a condition monitoring system to be successful [15] [16]. [13]. It is a maintenance work organized and carried out with fore though, control and records [16] Planned maintenance, be it replacement, breakdown or preventive provided that: the maintenance policy has been considered carefully, the application of the policy is planned in advance and the work is controlled and direct3d to conform to pre-arranged plan.

[14] concludes that the fundamental basis of any planned maintenance system is deciding in advance: the individual items of plant and equipment to be maintained, the forms methods and details of how each item is to be maintained the frequency at which these maintenance operation must be carried out, the method of administering the system and the method of analyzing the results.

[15] reported that in order to express these basic essential of planned maintenance in a manner that will form the structure of practical system, there must be: a schedule of all plant and equipment to be maintained, a complete schedule of all individual tasks that must be carried out on each item of the plant and equipment, a programme of events indicating when each task to be carried out, a method of ensuring that the work listed in the programme is done and a method of recording the results and assessing the effectiveness of the programme.

The benefits of planned maintenance guarantees greater plant and equipment. According to [17] planned maintenance is carried out when it is most convenient, hence it will cause the minimum loss of production. Also, excessive length of downtime is reduced in a planned maintenance system as plant and equipment are known in advance when necessary. Again planned maintenance which encourages regular, simple maintenance will result in less down time than frequent expensive maintenance; ensuring that regular simple servicing and adjustment of any equipment contained in the programme is not overlooked; ensuring that regular, simple servicing which is cheaper than sudden expensive stop gap repairs are undertaken.

2. Materials and Methods

2.1. Models

The basic method for developing reliability engineering maintenance is the mean time before failure. The meantime to failure is sum of life divided by number of failure within that interval.

$$MBTF = \frac{S_L}{N_F} \quad \text{………………1}$$

where is sum of life and is the number of failure

The failure rate of a plant is given as:

$$\lambda = \frac{1}{MBTF} \quad \text{…………………2}$$

Reliability is the ability of a system to perform and maintain its function in routine circumstances. Therefore the reliability R is given as:

$$R = \exp^{=\lambda t}$$ ………………..3

Therefore reliability is concerned with reducing failure over time interval. Depending on the arrangement of equipment, it can be expressed in series or parallel as:

$$R_S = R_A x R_B x......R_N$$ …………..4

$$R_P = 1-(1-R_A)x(1-R_B)x....(1-R_N)$$ ……………..5

Another tool is the availability. It is concerned with the duration of uptime for operations and is a measure of how the system is alive.

$$A = \frac{Uptime}{Uptime + downtime}$$ ……………6

A plant maybe available but not reliable. However reliability implies a higher availability.

Maintainability is concerned with the duration of maintenance outages. An important parameter of merit is the meantime to repair (MTTR), which measures outages which includes: diagnoses, replacement and removal, trouble shooting, active repair, verification or testing that the repair is adequate.

$$M(t) = 1 - e^{-\mu t}$$ …………………7

$$\mu = \frac{1}{MTTR}$$ …………………8

2.2. Data Collection

Data was collected from different units spanning 5 years: match copper, match tone, wet kettle, match free out, storage tank unit, engine room, chiller 1 and 2, compressed air section, production unit, belt conveyor, tray, bottle washer, bottle instorer and filler and bottle labeler.

3. Results

Tables 1 to 5 show the equipment log for year one to five.

Table 1 Equipment downtime log for 2019

S/N	Equipment failed Date and hours	Equipment repaired date and hours	Failure hours	Failed Equipment	Remarks
1	20/1/2019 -9.00	26/1/2019-22.00	52	Match copper	
2	-	-	-	Match ton	
3	3/3/2019-13.00	2/4/2019-20.0	256	Wet kettle	
4	6/5/2019-9.00	8/5/2019-13.00	8	Match free out	
5	-	-	-	Storage tank	
6	7/8/2019-10.00	29/8/2019-19.00	198	Chiller 1	
7	10/8/2019-11.00	29/8/2019-19.00	152	Chiller 2	
8	-	-	-	Compressed air	

9	5/10/2019-7.00	31/10/2019-22.00	390	Belt conveyor	
10	10/10/2019-9.00	31/10/2019-22.00	273	Tray	
11	20/10/2019-13.00	31/10/2019-23.00	110	Bottles Washer	
12	6/11/2019-8.00	31/10/2019-15.00	63	Bottle instorer /filler	
13	12/11/2019-12.00	29/11/2019-20.00	136	Bottle labeller	
Number of failures					10

Table 2 Equipment downtime log for 2020

S/N	Equipment failed Date and hours	Equipment repaired date and hours	Failure hours	Failed Equipment	Remarks
1	12/1/2020 -12.00	29/1/2020-20.00	136	Match copper	
2	6/2/2020-8.00	15/2/2020-15.00	63	Match tone	
3	30/3/2020-9.00	31/3/2020-23.00	8	Wet kettle	
4	-	-	-	-	
5	10/4/2020-9.00	31/4/2020-22.00	273	Storage tank	
6	5/5/2020-7.00	30/5/2020-22.00	375	Chiller 1	
7	10/7/2020-11.00	29/7/2020-19.00	152	Chiller 2	
8	-	-	-	Compressed air	
9	7/9/2020-10.00	29/9/2020-19.00	198	Belt conveyor	
10	6/10/2020-9.00	8/10/2020-13.00	8	Tray	
11	3/11/2020-13.00	25/11/2020-20.00	154	Bottle washer	
12	21/11/0-6-8.00	25/11/2020-21.00	52	Bottle instorer/ filler	
1	6/12/2020-11.00	18/12/2020-18.00	84	Bottle labeller	
Number of failures					11

Table 3 Equipment downtime log for 2021

S/N	Equipment failed Date and hours	Equipment repaired date and hours	Failure hours	Failed Equipment	Remarks
1	-	-	-	Match copper	
2	7/2/2021-10.00	28/2/2021-19.00	189	Match tone	
3	7/3/05-9.00	16/4/2021-13.0	40	Wet kettle	
4	3/4/2021-13.00	25/407-20.00	154	Match free out	
5	21/5/2021-8.00	25/5/2021-21.00	52	Storage tank	
6	6/6/2021-11.00	18/6/2021-18.00	84	Chiller 1	
7	-	-	-	Chiller 2	
8	-	-	-	Compressed air	
9	12/7/2021-12.00	29/7/2021-20.00	136	Belt conveyor	
10	6/9/2021-8.00	15/9/2021-15.00	63	Tray	

11	20/10/2021-13.00	31/10/2021-23.00	110	Bottles Washer	
12	10/11/2021-9.00	31/11/2021-22.00	273	Bottle instorer /filler	
13	5/12/2021-7.00	30/12/2021-22.00	375	Bottle labeller	
Number of failures					10

Table 4 Equipment downtime log for 2022

S/N	Equipment failed Date and hours	Equipment repaired date and hours	Failure hours	Failed Equipment	Remarks
1	15/1/2022 -10.00	26/1/2022-20.00	110	Match copper	
2	-	-	-	Match tone	
3	-	-	-	Wet kettle	
4	3/3/2022-9.00	2/4/2022-15.00	186	Match free tone	
5	7/8/2022-10.00	29/8/2022-19.00	152	Storage tank	
6	-	-	-	Chiller 1	
7	-	-	-	Chiller 2	
8	-	-	-	Compressed air	
9	10/8/2022-11.00	29/8/2022-20.00	198	Belt conveyor	
10	-	-	-	Tray	
11	3/11/2022-13.00	25/11/2022-20.00	154	Bottle washer	
12	6/11/2022-12.00	15/11/2022-16.00	36	Bottle instorer/ filler	
13	10/7/2022-8.00	29/7/2022-14.00	114	Bottle labeller	
Number of failures					7

Table 5 Equipment downtime log for year 2023

S/N	Equipment failed Date and hours	Equipment repaired date and hours	Failure hours	Failed Equipment	Remarks
1	-	-	-	Match copper	
2	7/9/2023-10.00	29/9/2023-19.00	198	Match tone	
3	3/11/2023-13.00	25/11/2023-20.00	154	Wet kettle	
4	-	-	-	Match free tone	
5	-	-	-	Storage tank	
6	6/12/2023-11.00	18/12/2023	8	Chiller 1	
7	6/10/2023-9.00	8/10/2023-13.00	8	Chiller 2	
8	21/11/2023-8.00	25/11/2023-21.00	52	Compressed air	
9	-	-	-	Belt conveyor	
10	-	-	-	Tray	
11	-	-	-	Bottle washer	
12	-	-	-	Bottle instorer/ filler	
13	-	-	-	Bottle labeller	

Tables 6 to 10 show the equipment reliability and availability for five years.

Table 6 Equipment reliability and availability for 2019

Equipment	**Match copper**	**Match tone**	**Wet Kettle**	**Match Free Out**	**Storag e tank**	**Chiller 1**	**Chiller 2**	**Compresse d Air section**	**Belt Conveyo r**	**Tray**	**Bottle Washe r**	**Bottle Filler/ Instore r**	**Bottle Labelle r**
Study interval	8760	8760	8760	8760	8760	8760	8760	8760	8760	8760	8760	8760	8760
Uptime	8708	8760	8504	8752	8760	8562	8608	8760	8370	8487	8650	8697	8624
Downtime	52	-	256	8	-	198	152	-	390	273	110	63	136
No. of failure	1	-	1	1	-	1	1	-	1	1	1	1	1
MBTF	8708	-	8504	8752	-	8562	8608	-	8370	8487	8650	8697	8624
Failure rate	0.00014	0	0.00017	0,0001 4	0	0.0001 6	0.0001 6	-	0.00019	0.0001 7	0.00015	0.00014	0.00015
Reliability	0.295	1	0.235	0.293	1	0.254	0.252	1	0.203	0.236	0.273	0.296	0.274
Unreliability	0.705	0	0.765	0.707	0	0.746	0.748	0	0.797	0.764	0.727	0.704	0.726
Availability	0.994	1	0.970	0.999	1	0.977	0.982	1	0.955	0.968	0.987	0.992	0.984
Unavailability	0.006	0	0.003	0.001	0	0.023	0.018	0	0.045	0.032	0.013	0.008	0.016

Table 7 Equipment reliability and availability for 2020

Equipment	**Match copper**	**Match tone**	**Wet Kettle**	**Match Free Out**	**Storage tank**	**Chiller 1**	**Chiller 2**	**Compressed Air section**	**Belt Conveyor**	**Tray**	**Bottle Washer**	**Bottle Filler/ Instorer**	**Bottle labeller**
Study interval	8760	8760	8760	8760	8760	8760	8760	8760	8760	8760	8760	8760	8760
Uptime	8624	8697	8650	8760	8487	8385	8608	8760	8562	8752	8650	8606	8674
Downtime	136	63	110	-	273	375	152	-	198	8	154	52	84

No. of failure e	1	1	1	-	1	1	1	-	1	1	1	1	1
MBTF	8624	8679	8650	-	8487	8385	8608	-	8562	8752	8606	8708	8676
Failure rate	0.00015	.000014	0.00015	0	0.00017	0.00019	0.00016	0	0.00016	0.00014	0.00016	0.00014	0.00015
Reliability	0.274	0.296	0.274	1	0.263	0.203	0.252	1	0.254	0.293	0.252	0.296	0.274
Unreliability	0.726	0.704	0.726	0	0.737	0.797	0.748	0	0.748	0.707	0.748	0.705	0.726
Availability	0.984	0.992	0.987	1	0.968	0.957	0.982	1	0.977	0.999	0.982	0.994	0.990
Unavailability	0.016	0.008	0.013	0	0.032	0.043	0.018	0	0.023	0.001	0.018	0.006	0.001

Table 8 Equipment reliability and availability for 2021

Equipment	**Match copper**	**Match tone**	**Wet Kettle**	**Match Free Out**	**Storage tank**	**Chiller 1**	**Chiller 2**	**Compressed Air section**	**Belt Conveyor**	**Tray**	**Bottle Washer**	**Bottle Filler/ Instorer**	**Bottle labeller**
Study interval	8760	8760	8760	8760	8760	8760	8760	8760	8760	8760	8760	8760	8760
Uptime	8760	8571	8720	8606	8706	8676	8760	8760	8624	8697	8650	8487	8385
Downtime	-	189	40	154	52	84	-	-	136	63	110	273	375
No. of failure	-	1	1	1	1	1	-	-	1	1	1	1	1
MBTF	-	8571	8720	8606	8708	8676	8760	8760	8624	8697	8650	8487	8385
Failure rate	0	0,00016	0.00014	0,00016	0.00014	0.00015	0	0	0.00015	0.00014	0.00015	0.00017	0.00019
Reliability	1	0.253	0.295	0.252	0.295	0.272	1	1	0.274	0.296	0.273	0.236	0.203
Unreliability	0	0.747	0.705	0.748	0.705	0.728	0	0	0.726	0.704	0.727	0.764	0.793
Availability	1	0.978	0.995	0.994	0.994	0.990	1	1	0.984	0.992	0.987	0.968	0.957
Unavailability	0	0.022	0.005	0.006	0.006	0.001	0	0	0.016	0.008	0.013	0.032	0.043

Table 9 Equipment reliability and availability for 2022

Equipment	Match copper	Match tone	Wet Kettle	Match Free Out	Storage tank	Chiller 1	Chiller 2	Compressed Air section	Belt Conveyor	Tray	Bottle Washer	Bottle Filler/ Instorer	Bottle labeller
Study interval	8760	8760	8760	8760	8760	8760	8760	8760	8760	8589	8760	8605	8760
Uptime	8650	8760	8760	8574	8660	8760	8760	8760	8589	8760	8605	8724	8624
Downtime	110	-	-	186	152	-	-	-	171	-	155	36	114
No. of failure	1	-	-	1	1	1	-	-	1	-	1	1	1
MBTF	8650	8760	8760	8574	8660	8760	8760	8760	8589	8760	8605	8724	8646
Failure rate	0.00015	0	0	0,00016	0.00016	0	0	0	0.00016	0	0.00016	0.00014	0.00015
Reliability	0.273	1	1	0.253	0.253	1	1	1	0.253	1	0.252	0.294	0.273
Unreliability	0.727	0	0	0.747	0.748	0	0	0	0.747	0	0.748	0.706	0.727
Availability	0.987	1	1	0.978	0.982	1	1	1	0.980	1	0.982	0.995	0.986
Unavailability	0.013	0	0	0.022	0.018	0	0	0	0.002	0	0.0018	0.005	0.014

Table 10 Equipment reliability and availability for 2023

Equipment	Match copper	Match tone	Wet Kettle	Match Free Out	Storage tank	Chiller 1	Chiller 2	Compressed Air section	Belt Conveyor	Tray	Bottle Washer	Bottle Filler/ Instorer	Bottle labeller
Study interval	8760	8760	8760	8760	8760	8760	8760	8760	8760	8760	8760	8760	8760
Uptime	8760	8562	8606	8760	8760	8752	8752	8705	8708	8760	8760	8760	8760
Downtime	-	198	154	-	-	8	8	52	-	-	-	-	-
No. of failure	-	1	1	-	-	1	1	1	-	-	-	-	-
MBTF	8760	8562	8606	8760	8760	8752	8752	8708	8760	8760	8760	8760	8760

Failure rate	0.00016	0.00016	0	0	0	0.00014	0.00014	0.00014	0	0	0	0	0
Reliability	1	0.254	0.252	1	1	0.293	0.293	0.295	1	1	1	1	1
Unreliability	0	0.746	0.748	0	0	0.707	0.707	0.705	0	0	0	0	0
Availability	1	0.977	0.982	1	1	0.999	0.999	0.994	1	1	1	1	1
Unavailability	0	0.023	0.018	0	0	0.001	0.001	0.006	0	0	0	0	0

Table 11 shows the average reliability and availability values of the plant.

Table 11 Average reliability and availability value of the plant

Year	Average Reliability	Average Availability
2019	0.431	0.985
2020	0.376	0.986
2021	0.434	0.987
2022	0.603	0.988
2023	0.722	0.996
Overall average	0.513	0.988

4. Discussion

Tables 1 to 5 show the equipment log taken for five years from 2019 to 2023, indicating date and time the equipment failed, date and time it was repaired and the actual down time, The major equipment of the brewery industry captured for this study include: match copper, match tone, wet kettle, match free out, storage tank, chiller 1 and 2, compressed air section, belt conveyor, tray, bottle washer, bottle instorer and filler and bottle labeler. Also the number of failures per year are indicated. In Tables 1,2,3,4 and 5 the number of failures are: 10, 11, 10, 7, 7 and 5 respectively. From the available data, equipment reliability and availability for each year was computed. For each year in Tables 6,7,8,9 and10 the uptime, downtime, number of failures for each equipment are presented. The mean time before failure (MTBF), failure rate, reliability, unreliability, availability and unavailability results are presented. In Table 11 the average reliability of the plant is presented. In the 2019, 2020, 2021, 2022 and 2023 the average reliabilities was: 0.431, 0.376, 0.434, 0.603 and 0.722.The overall average reliability of the plant in Table is 0,513, which is low. The average availability of the plant in the years was: 0.985.0.986, 0.987, 0.988 and 0.996 respectively with the overall average availability of 0.988. The lowest average reliability of the plant was in 2020, while the lowest average availability was 0.985 in 2019. In practice reliability is an important index than availability. A plant may be available and yet unreliable. Take for an instance the voltage supply from the mains of the power holding company in Nigeria sometimes maybe less than 150V. In this case even though the power is available, it is not reliable and cannot be used to run most equipment. This is similar to what we have in Table 11. Even though the availabilities are high, but in most cases the reliabilities remain very low. This can also be explained that since the plant has many components, if one critical component is down, even if the others are available, the reliability of the plant is going to reduce drastically. The reliability of this plant is low. For instance in 2019, the average reliability was 43% indicating a loss of 53%. It means 53% loss of revenue and 53% loss of market share, which will lead to the reduction in the profit margin of the company. By the use of reliability principle the performance of the brewery plant has been evaluated and this will enable the management to take critical decision for plant recovery to boost our ailing economy.

5. Conclusion

Reliability principles is very effective in determining the health and performance of a plant. Using this technique, the reliability of this plant from the computations are low and require improvement for proper plant recovery. It is hereby recommended that the company should carry out self- assessment using reliability principle presented here to lift itself from waters.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest is to be disclosed.

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