Experimental And Simulation of Failure Analysis of Machinery in Ab Breweries, Umuahia

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Abstract- Experimental and simulation of the failure analysis of machinery in AB breweries was investigated. Work study of the operation and production system were observed through data collection and analysis methods. Techno matrix Plant Simulation software were used to develop a conceptual simulate and validate the experimental and predicted data. Cleaning, Inspection, Lubrication and Tightening (CILT), and Kaizen processes were carried out, to optimize preventive maintenance strategies and to ensure evaluated system robustness. The production and operation system of the organization which involves varieties of sectors, machines, tools, and staff, were the cause of low productivity observed in the company, thereby struggling to meet the customer's demand. From the results obtained, it was observed that the bottleneck affecting the production is the filler and pasteurizer machines. The pasteurizer creates blockage due to an inefficient regulation of the labellers. From the different experiments conducted and remedies applied on the system from the methods, the inefficiency of the blockage of the pasteurizer was corrected, which decreased the production shift stoppages 5 minutes earlier, CILT result in 10 minutes less activities per shift in total, this is 92.96 minutes of the 480 minutes per shift. The CILT tasks over the operators were reduced, because the production balance in the new situation for labeler111 was at 52%, as against labeler112 at 48%. Implementing all the improvement strategies across the production line resulted in yearly savings of NGN338, 338,000.00 per line.

Indexed Terms- Breweries, Machine Failures, Technomatrix, Simulation, Kaizen, CILT

I. INTRODUCTION

The increasing need of beverages and beer made the business highly competitive in today's market, and AB Breweries, Umuahia needs to be among the best competitors. Different product brands penetrate the market where there is a competitive business, thereby customers' request differ in different tastes, decreasing the volume of the product demands, thereby increasing in variable costs as well as fixed costs. Introduction of new products and customers still demand same quality and services at an affordable price (Heineken, 2016). However, all these factors must be considered for AB Breweries, Umuahia to be on a continuous improvement and optimization of her production process and maintenance concept, which are aimed at maximizing the performance on the existing production lines. This ensures affordable operational cost, enhanced quality products and production wastes reduction, to stay ahead of the competitors. The utmost aim is to optimize the performance on the production lines, which in turn will optimize her production currently underutilized. Therefore, to get this job done, optimized preventive maintenance and regulated line technique must be applied and time wastages will be properly minimized, and give rise to higher line performance and productivity, thereby creating customer's satisfaction constantly in motion.

The recent situation in the AB Breweries, Umuahia production lines has indicated a painstaking study which is needed to see the industry blossom. Planned production stop is a situation where a machine is regulated to observe planned maintenance. Starvation is a scenario where the machine is not producing, caused by deficiency of processing material in the in-feed chamber part of the machine, mostly observed in preceding machines. Blockage is an observable fault in a machine where the discharge unit is being backup, mostly observed in succeeding machines. Short time failure issue involves when a machine generates fault within the space of five minutes, whereas long time failure involves a machine fault is observed for more than five minutes. The unknown type of machine failure situation involves where the cause of the failure cannot be ascertained or verified at that particular period.

Ramdeen and Pun (2015) stressed more on the importance of maintenance equipment and machineries in a production industry; they also incorporated the importance of raw materials and spare parts management, which affects the production capacities. Godwin and Achara (2016) investigated using industrial system as a case study, how manufacturers are being affected by unplanned failures such as machine defects, failure and breakdown, which reduced the annual percentage profit of the industry. Ogra *etal.* (2021), reduced the labour cost of a brewery from #108,000.00 to #67,000.00 of their yearly expenditure using reliability centered maintenance concept, which the research was concentrated on feed water pump and heat exchanger of the brewery, indicating that when the maintenance concept was adopted, the cost of purchasing spare parts is reduced. Wilson *et al.* (2020), used champions breweries as a case study, to investigate the effect of Total Production Maintenance (TPM) incorporated with the hybrid pillar model adopted by the company towards overall equipment effectiveness of the system, which observed an increase from 56.4 - 71.7% in effectiveness of the equipment was observed.

The alarming challenges in the market systems appear to be more in production quantities and new product brand high demands. This is the recent AB Breweries, Umuahia major challenge from other competitors. As a result, the current production strength of the industry cannot compete favorably with the other companies. To establish a favourable production framework needed to compete with other competitors, and also produce a new product fit enough to hit the market, huge capital is required to be invested in the system. However, mismanagement of this capital may cause bigger problem for the company if not properly invested. Hence, the issue is how to optimize effectively the production strength of the industry.

II. METHODOLOGY

The research methods included: Production System Analysis: Conduct of work-study; process overview and data analysis of the production system of AB breweries, to understand the system problems and areas of focus in solving the existing problems. Application of Technomatrix Plant Simulation software to build a conceptual model to understand the dynamic behavior of the production systems to further discover bottlenecks in the system. Application of design of experiment to select best results or alternatives from the list of possible results of the12 experiments carried out. Application of Cleaning, Inspection, Lubrication and Tightening (CILT) and Kaizen to optimize Preventive Maintenance Strategies to ensure evaluated system robustness. Developing of Excel Spreadsheet Infer-face for easy data analysis and performance tracking.

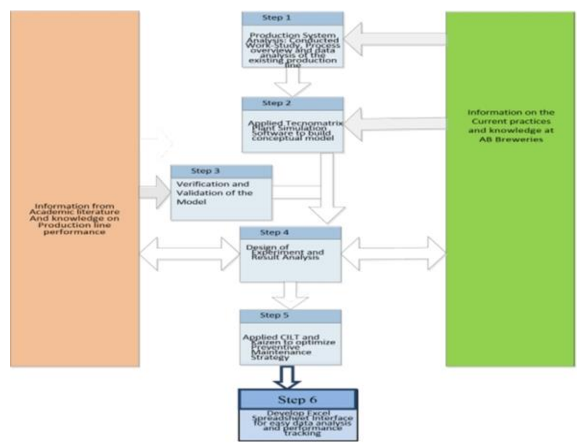

Figure 3.1: Research Design

- Production System Analysis

The research work was carried out in AB Brewery Industries. A work study was carried out from January 2020 to January 2023 to study the production system and obtain necessary data for evaluation. The brief overview of the production system was shown below

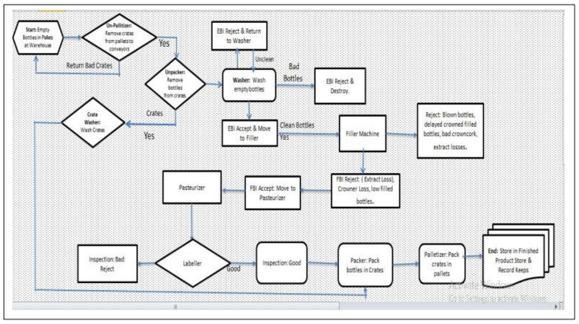

Figure 3.2: Flow Process of AB Brewery Packaging Line

Packaging Lines consists of returnable bottles, which means that they are recovered from the domestic market. The functioning of lines depends on the quality of the returned material. The Lines consists of several machines. A brief description of the functional critical machines are given below, in sequence from start to end. Thus, the production process starts at the de-palletizer and ends at the Palletizer. Also, machine event states for Filler were developed for machine analysis. On each row in table 3. 1, the total time of the state, the number of state occurrences, the minimum, average, and maximum event duration of the machine state, and the standard error of the event duration were presented.

Table 3.1: Machine event states for Filler in seconds

Machine State	Sum(s)	Number	Mean	Min	Max	Std Error
Running	22163	112	198	12	554	16
Internal Failure	1354	32	41	7	223	15
Starved for bottle	1742	27	65	53	242	24
Blocked by bottles	3117	59	53	23	139	19
Lack of Material	424	12	35	19	77	34
Total	28,800					

Machine Efficiency $= \frac{Running\ Time}{Running\ Time + Internal\ machine\ failure} = \frac{22163}{22163+13}$ = 94%. 3.1

Line Efficiency = $\frac{22163}{22163+(1354+1742+3117+424)} = 0.769 \approx 0.77$ 3.2

Line Availability = $A^{low} = \prod_{machine} \eta_{line}$ 3.3

Where Machine Efficiency = 94% and Line Efficiency = 77%.

The starved for bottle, blocked by bottles and lack of material are very important in the calculation of line efficiency. This is because production loss at Filler, which is the core machine, is the production loss of the production lines. From the table, a total 28,800 seconds were lost at the core machine due to the above machine states.

- V-graph Analysis

Core machine has machines on either side with extra capacity to restore the accumulation after a failure has occurred and the overcapacity increases for each machine going upstream or downstream from the core machine. The graph of the machine capacities has a 'V' -shape with the core machine at the base. The V -graph of a packaging line is basically a graph of the machine capacities in the sequence of the line. The V -graph can be expanded with the Mean Effective Rate of the machine, which gives the effective V-graph (using machine efficiencies). The actual line efficiency can also be shown. A more detailed V -graph shows a bar for each machine and the machine state totals are shown as bar segments of each machine bar. This V-graph gives an overview of the machine event summary for the machines of the line. The V graphs can help identify the bottleneck machine, as this is the machine which has many internal failures, and the preceding machine has a lot of block time and the succeeding machine has a lot of starve time.

The V -graph creates a line view instead of viewing the machines and buffers separately; this means that machine interaction can be seen on a global level. It also helps to identify the bottleneck machine of the packaging line.

The data needed to create the V-graph are:
Line component system, i.e., a description of the machines of the line and where they are connected.

Capacities for each machine
Mean Effective Rate (MER) of each machine, or machine efficiency of each machine to calculate the MERs

Mean Effective Rate, = ɳ∗ 3.4

Where ŋis machine efficiency = machine capacities
The machine with the lowest M.E.R. is called the bottleneck machine, i.e. the machine with the lowest effective production capacity. In keeping with the design this should be the core machine. The mean effective rate of the bottleneck machine gives the upper limit of the efficiency.

The bottleneck machine is then identified as the machine which transforms backup into starvation, i.e., the previous machine is blocked and the next machine is idle, whereas the machine itself has few starvation and backup, but a lot of failures (or loss of speed). Filler is the core machine.

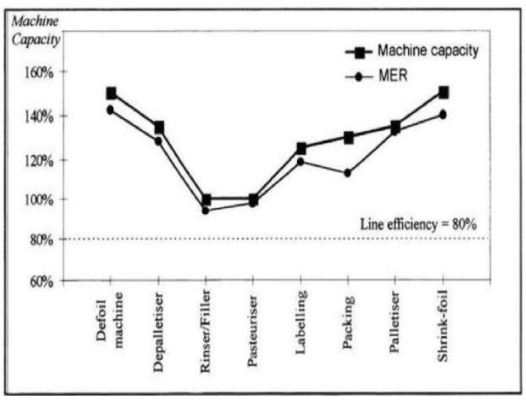

Figure 3.3: V-graph: Machine capacities, MER and Line efficiency

The main use of the V -graph is the overview it gives of the machines and buffers of the line. It is a tool to detect exceptions and bottlenecks. The V-graph is useful in comparing different packaging lines.

Statistical Analysis. Pareto, Cause and Effect Analysis were used to identify the distribution of the machine behavior, external and planned downtime.

Pareto Analysis: Machine Breakdown, Planned and External downtime were collected from production lines 1, 2 & 4 from week 38 to week 52. The raw data were grouped in external machine and planned downtime. Again, it was grouped in 4M (Machine, Method, Material and Man) after which Pareto graph was plotted to know the area of focus in tackling the problems of downtime.

Cause and Effect Analysis: The machine breakdown, external downtime and planned downtime were re-grouped into 4M (Machine, Method, Man and Materials) to analyze the effect of each component on the production loss and production line inefficiency. Week 38 to Week 52 of machine breakdown, planned downtime and external downtime were used.

Correlation Analysis: The running time against production output is calculated to establish worthiness to consider the impact of running time, which is independent variable on the production output. The coefficient of determination is also calculated to establish the percentage of output problems known and that of unknown. Equation created was for a single variable because running time is compared with production output at a constant nominal speed. The correlation t in the equation is used to find the relationships between independent variables and dependent variable.

$$r = \frac{n\sum xy - \left(\sum x\right)\left(\sum y\right)}{\sqrt{n\left(\sum x^2\right) - \left(\sum x\right)^2}\sqrt{n\left(\sum y^2\right) - \left(\sum y\right)^2}} \quad 3.5$$

Coefficient of Determination r^2
Coefficient of determination enables us to identify the percentage of the problems known and the percentage of the problems unknown.

Performance Measurement
OEE was used in this research to measure machines efficiency for productivity improvement. Machine inefficiencies were grouped into three categories for analysis and better understanding of the manufacturing process.

- OEE/OPI Calculation

OEE = Availability x Performance x Quality 3.6

$$\text{Availability} = \frac{Running\ Time}{Total\ Time} * 100\% \quad 3.7$$

$$\text{Performance} = \frac{Total\ Count}{Target\ Count} * 100\% \quad 3.8$$

$$\text{Quality} = \frac{Good\ Count}{Total\ Count} * 100\% \quad 3.9$$

$$\text{OEE} = \frac{Final\ Machine\ Run\ Time}{Planned\ Machine\ Run\ Time} * 100\% \quad 3.10$$

OPI Analysis. OPI was used to measure the performance of the production lines and the entire organization relating to the production output and set production targets.

Experimental Verification and Validation through Simulation Model

Verification tool used is Technomatrix Plant Simulation, which is an animation package. When experiment was running, AB Bottles (ABBs) were seen as movable units, in animated form. These animations helped to know when the beer bottles stuck on a certain conveyor. When this is the case, it indicates that there is a bug in the model otherwise the AB Bottles (ABBs) will move to the next conveyor. Validation was checked through the comparisons of the output of the model with the input, which should be equal if no beer bottles remain in the system or conveyors. Final verification of the simulation model was checked on how the system is sustained regarding the output, when there is a change in the input variables.

III. RESULT AND DISCUSSION.

During the production system analysis, work-study was carried out from January 2020 to January 2023 to study production line 1, 2 and 4. Process and data analysis were carried out to understand the existing production problems and the following results were obtained:

sTable 4.1: Machine capacities, machine efficiencies, MER.

S/N	Machines	$C_{mac\ h\%}$	$\eta_{mac\ h\%}$	$MER_{mac\ h\%}$
1	Depalletizer	135 ↑	97	131
2	Washer	110	98	99
3	Filler (Core Machine)	100	98	98
4	Pasteurizer	100	99	99
5	Labeller	125	95	119
6	Packer	130	93	121
7	Palletizer	135 ↓	96	130

Source: AB Breweries

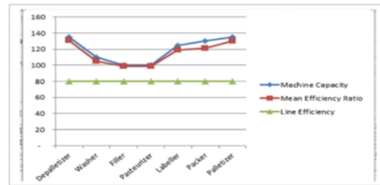

Figure 4.1: MER, Machine Capacity and Line Efficiency

- Process Analysis Result and Discussion

In Table 4.1, and Figure 4.1, the result of the process analysis reveals that functioning of lines depends on the quality of the returned and input materials, capacities of different machines especially the core machine with corresponding conveyors and the functioning of the buffer. Analysis revealed that Filler, Pasteurizer and Labeller are the most important machines of the production lines. Pasteurizer and Filler have the same production capacities, and are regarded as the core machines; all other machines around them have continuous increase in capacities from the core machines towards downstream and upstream of the production lines as shown in Table 4.1. The analysis also revealed that any loss on the core machines cannot be recovered since it has the lowest production capacities across the production lines. Three operations were carried out at the Filler, which includes crowning, filling, and CILT activities, and are inherent to problems which can further reduce the existing capacities of the core machines. Starvation, Blockage, and longtime failure of core machines should be avoided to increase the overall efficiency of the line and ensure maximum utilization of existing production capacities, which is the main focus of these studies.

Table 4.2: Machine Events of Filler

Machine State	Sum(s)	Number	Mean	Min	Max	Std Error
Running	22163	112	198	12	554	16
Internal Failure	1354	32	41	7	223	15

Starved for bottle	1742	27	65	53	242	24
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Total	28,800					

Table 4.3: Total Production Output compared with Running Time of Line 1, 2,and 4

Line 1, 2 & 4 Running Time compared with Production Output in Cartons Units

	LINE 1		LINE 2		LINE 4		COMBINED		
Week	Runing hour	Line 1	Runing hour	Line 2	Runing hour	Line 4	Running Hour	Cus	
Wks	hrs	Cus	hrs	CUS	hrs	CUS	hrs	Cus	
30	139	57,336	136	72,149			275	129,485	129
31	139	66,342	96	44,350			235	110,692	111
32	63	27,283	70	27,566			133	54,849	55
33	84	37,234	67	34,170			151	71,404	71
34	83	37,732	70	38,331			153	76,063	76
35	111	51,049	81	42,221			192	93,270	93
36	167	74,873	168	81,362	55	25,521	390	181,756	182
37	66	34,203	72	39,763	64	35,993	202	109,959	110
38	111	50,048	115	45,496	69	66,925	295	162,469	162
39	102	43,386	120	54,288	73	42,100	295	139,774	140
40	118	54,578	116	45,710	117	87,286	351	187,574	188
41	135	70,364	112	59,028	144	121,049	391	250,441	250
42	101	46,953	87	46,180	81	94,788	269	187,921	188
43	138	68,901	129	66,040	125	147617	392	282,558	283
44	138	71,404	144	74,576	80	103187	362	249,167	249
45	99	50,102	116	67,893	74	120071	289	238,066	238
46	155	68,225	133	80,009	131	127293	419	275,527	276
47	140	61,121	140	76,512	84	113266	364	250,899	251
48	113	56,595	132	72,599	145	130169	390	259,363	259
49	130	75,919	139	75,623	121	133200	390	284,742	285
50	149	70,962	148	80,703	90	112468	387	264,133	264
51	144	62,212	148	80,047	140	153135	432	295,394	295
TOTAL	2,625	1,236,822	2,539	1,304,616	1,593	1,614,068	5,548	3,311,237	3,311

Production Output compared with Running Time: Lines 1, 2, and 4 show individual line production output result compared with running time. The standard deviation was 58 cartons per hour, with an average of 511 cartons per hour for the 22 weeks productions. The range of hourly production was 208 cartons. Further values show that Line 4, week 45 recorded 1,623 cartons per hour while week 36 recorded 464 cartons per hour as the highest and lowest production per hour respectively. The standard deviation was 316 cartons per hour, with an average of 1,005 cartons per hour for the 16 weeks productions. The range of hourly production was 1,159 cartons. Combined production output against running time was analyzed. The standard deviation was 80 cartons per hour, with an average of 189 cartons per hour for the 22 weeks productions. The range of hourly production was 224 cartons. From the analysis results of Line 1, 2, and4,

Production Line 1 and 2 has relatively low Standard deviation and range compared with line 4. Line 1 and 2 runs on regulated lines while line 4 runs on unregulated line. Speed loss was recorded more on line 1 and 2 while total downtime was very high in line 4 but productions was at its peak when machine was running. In unregulated line, machine can be producing at 100% or not producing at 0%, while in regulated lines, speed of machines automatically adjusts its speed to cope with starvation, blockage and minor stoppages. It is now important to ascertain if there is proportionality or correlation between running time and production output to analyze production system problems that are causing high running time against production output in line 1 and 2 and high downtime on the part of line 4. Again, coefficient of determination was employed to determine the percentage of problems in correlation, which is known and that which is unknown.

CONCLUSION

The first objective of the studies, which is the discovering of bottleneck machines and prioritizing problems areas, were achieved by analyzing and grouping production system data to find the existing problems and area of focus in addressing the current problems. Development of conceptual simulation that led to the discovering of the causes of imbalance in the outputs of line 1 and 2, and high machine breakdown of unregulated line 4 was realized. The conceptual simulation revealed the constraints to the production performance of individual lines which include the followings; Lines 1 and 2 which run on regulated continuous speed mode (0, 25, 50, 75,and 100%). Machines automatically adjust its speed to cope with minor failures, starvation and blockages, thereby increasing the production flow and speed losses of the production system. It is also revealed that the continuous flow guaranteed safety of equipment and reduces machine downtimes than system with frequent minor stoppages and downtimes.The efficiency of the regulation between the pasteurizer and labellers decreased production shifts and stops on average of 77.96 minutes earlier, in the new situation, because the throughput of the production line is increased, and therefore more products can be produced at the same time. The inefficiency of the blockage of the pasteurizer is corrected, which decreased the production shifts stops 5 minutes earlier, CILT result in 10 minutes less activities per shift. In total this is 92.96 minutes of the 480 minutes per shift. The CILT tasks over the operators are reduced, because the production balance in the new situation is LABELER111: 52% against LABELER112: 48%.

Reference table 4.34, implementing all the improvement strategies across the production line resulted in yearly savings of NGN338, 338,000.00 per line.

Development of a methodology that discovered the hidden bottleneck in the system studied can be applied in other breweries. An easy and effective excel spreadsheet-based platform for evaluating the performance of AB Breweries production lines in order to enhance the company's competitive advantage was successfully introduced.

REFERENCES

[1] Godwin, H.C. and Achara, O. M. (2016).Optimum Maintenance Strategy for Paint Manufacturing Industries: a case study. *International Journal of Advanced Engineering Technology*.

[2] Heineken, N. S. V (2016). HNS nieuws special. *Heineken Nederland Supply Zoeterwoude*, 1-12

[3] Subramaniam, S.K., Husin, S.H., Yusop, Y., and Hamidon, A. H. (2017). Machine Efficiency and Man Power Utilization on production Lines. *Proceedings of the 6th WSEAS International Conference on Circuits, Systems, Electronics, Control & Signal Processing*.

[4] Willmott, P. and McCarthy, D. (2021). TPM a route to world-class performance.*Oxford. Boston. Butterworth-Heinemann*

[5] Wein, L. M. and Chevalier, P.B (2022). A broader view of the job shop scheduling problem. *Management Science*, 1018-1025.