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Efficiency Analysis Associated with Production Line in Champion Breweries Plc

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Abstract: This study analyses the production line system in Champion Breweries Plc in order to minimize production losses due to production downtime that hinders the system efficiency. In response to today's highly competitive business environment this has prompted businesses to analyse and improve their existing production systems for sustainability gains. The major problems identified in this study which hampered the productivity include: high efficiency losses, low throughput, low overall equipment effectiveness (OEE) and low productivity volume. Therefore, this study aims at developing a technical model for attaining optimal efficiency. Presented also, are findings from literature. Efficiency analysis of the line was performed using the OEE model, and as a result the disturbances that constitute production losses were studied, major efficiency losses were identified, and their root causes were investigated. Results showed that the OEE in existing production line of Champion Lager Beer was 61.5%; which is below the company's target. The OEE model for the existing production line was validated using theoretical validation techniques. The resulting validation model showed an improved OEE score with the validated OEE for Champion Lager Beer being 63.1%. Therefore, the achieved results in the validation model can easily be adapted after similar studies in order to achieve the company's target and also boost production capacity.

Key words: Competitiveness, production, efficiency, growth, improvement, productivity.

1. Introduction

The rapid industrialization witnessed in various emerging economies in the world has made the issue of optimum operation in service delivery very important. Although, the challenges of increasing production demands with the existing machinery and equipment have forced companies to show constant productivity improvements and to get the most advantage from existing machinery and equipment. The first step to achieve this aim is naturally the online monitoring of the processes/equipment and the interpretation of the operational data collected from these processes, so that the process/equipment optimization and cost-effective productivity opportunities can be identified. Experience and research have shown that a large number of companies and organizations that failed to break even have not followed the above-mentioned steps in pursuit of their companies' goal in terms of maintenance philosophy [1]. One persuasive cost that drags down productivity improvements, hence process optimizations are unplanned equipment and manufacturing process downtime. The high costs resulting from unplanned downtime have attracted attention to maintenance activities in plants. The maintenance of industrial machinery and equipment influences the entire operation of a plant, from equipment availability to product quality. The breweries sector in Nigeria is known to be the strength of the value-added processes in the Nigerian economy. In an increasingly competitive market place amongst the beverage industries, breweries in particular, show a clear and distinct need to improve their productivity operations [2]. Bottling plants are characterized by capital intensive and complex mass production [3] that involves significant asset (consists of several machines and materials flow) both in the investment and production phase. Champion Breweries Plc and

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Nigeria Bottling Company are not achieving the production target plan because the production lines are producing below its capacity and at low overall performance, due to various disturbances of the production system (that is frequent equipment downtimes, minor stops, speed losses, and starvation) which result in substantial production losses and that affect the productivity and financial performance of the company.

This paper proposes a technical model for attaining an optimal efficiency in Champion Breweries Plc and the Nigerian Bottling Company. This was achieved by developing a bottling line model using the overall equipment effectiveness (OEE) technique for improved production performance and by minimizing the bottling line problems as identified in the brewery plant. The bottling line performance index for the Brewery was also determined and methods of improving it have been recommended.

2. Performance Measurement

Performance measurement is an established concept that has taken on renewed importance in varieties of organizations [4]. Indeed, performance measurement systems historically developed as a means of monitoring and maintaining organizational control which is a process of ensuring that organizations pursue strategies that lead to achievement of overall goals and objectives [5]. In attempting to change focus of the organization, Brignall [6] suggested that performance measurement is a key agent of change in pursuit of optimum productivity gains. The development of performance measurement in management had followed a path that has been influenced by a general push to improve quality and service. For many organizations the justification has been acknowledged by senior management that lack of appropriate performance measurement can act as a barrier to change and improvement [7]. Maintenance is considered in this context as an integral part of the business process and in the past decade manufacturing organizations have been forced to shift their business models from closed system orientations to more open system-orientations due to drastic competitive forces [8]. The change in the industries strategic paradigm has made managers to get more interested in comprehending the contribution of maintenance towards total business goals. Today it has been acknowledged by many authors and practitioners that maintenance is a major contributor to the performance and profitability of manufacturing systems [9]. Therefore, performance measurement with a view to improving maintenance levels in an organization is important considering the value attached to maintenance practices in organizations.

2.1 Performance Measurement Practices

Furthermore, researchers have noted that performance measurement practices refer to activities done in efforts to measure performance in an organization [10] and these practices indicate where the organization is and where it is heading [11]. It functions as a guide as

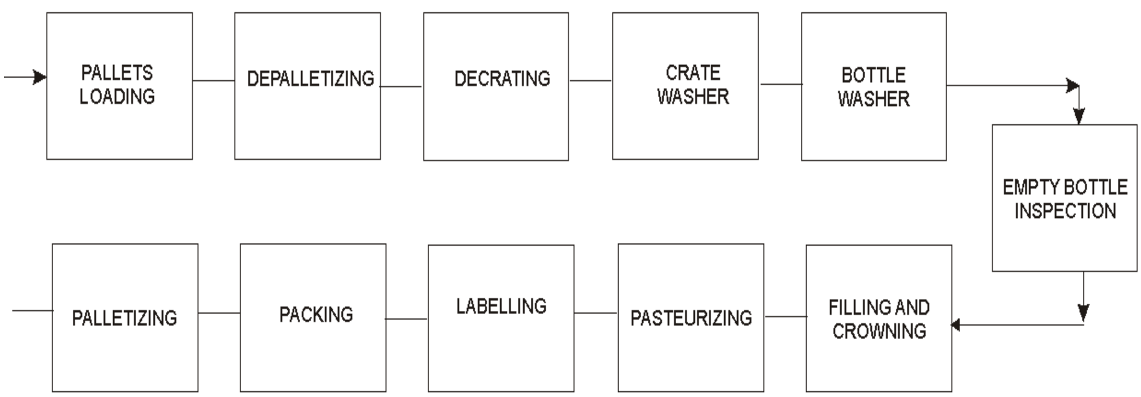

Fig. 1 Flow diagram of Champion Breweries Plc bottling line.

to whether the organization is headed towards achieving its goals. Traditional performance measurement practices focused on financial measures. However, they have faced various criticisms such as lack of strategic focus, measuring only one aspect, being historical in nature and not providing information for productivity measurement and improvements [11]. As such, on their own, they lack the ability to guide the firm in its efforts to achieve excellence. Modern performance measurement practices recognize the multi-dimensional views of performance measurement, link performance to strategy and present a balanced view of the system [12]. Modern performance measurement practices include use of balanced score card perspective, benchmarking, use of cleaner production, focusing on key performance indicators and total quality management (TQM) philosophy.

3. The Brewery Process

Brewing is the production of beer by steeping a starch source commonly (cereal grains), the most popular of which is barley in water and fermenting the resulting sweet liquid with yeast. The basic ingredients of beer are water and fermentable starch sources such as malted barley. Steps in the brewing process include malting, milling, mashing, lautering, boiling, fermenting, conditioning, filtering and packing [13]. There are three main fermentation methods, warm, cool and spontaneous action. Fermentation may take place in an open or closed fermenting vessel; a secondary fermentation may also occur in the cask or bottle as presented in Fig. 1.

3.1 Performance Measurement Systems Analysis

The following performance measuring systems were used to analyze the production line performance and recommend ways of improvement using OEE. The OEE measurement technique was developed from the total production maintenance (TPM) concept [14]. It is defined as measurement of total equipment performance. That is the degree to which the equipments such as boiler, bottle washer, labeler, decrater, heat exchange etc. are operating optimally [15]. The OEE technique is designed to identify loses against equipment effectiveness. These loses are activities that absorb resources but create no value. Theoretical validation method was utilized for analysis and validation of the data.

Mathematically:

$$\text{OEE} = A \times P \times Q \tag{1}$$

Where,

A = availability rate;

P = performance efficiency;

Q = quality rate.

Considering the production process of Champion Breweries Plc,

Let, x = operating time (min);

y = loading time (min);

m = downtime (min);

n = theoretical cycle time (min);

a = actual output (units);

b = defect amount (units);

c = total production (units).

$$\text{Availability rate } (A) = \frac{\text{operating time}}{\text{loading time}} \times 100 \tag{2}$$

$$\text{This further implies that } (A) = \frac{x}{y} \times 100 \tag{3}$$

Also, performance efficiency (P)

$$= \frac{\text{theoretical cycle time (h)} \times \text{actual output (h)}}{\text{operating time (h)}} \tag{4}$$

Hence,

$$P = \frac{n \times a}{x} \times 100 \tag{5}$$

Quality rate (Q)

$$= \frac{\text{Total production} - \text{Defect amount}}{\text{Total production (units)}} \times 100 \tag{6}$$

But,

$$Q = \frac{c - b}{c} \times 100 \tag{7}$$

Then,

$$\text{OEE} = \frac{n \times a}{x} \left(\frac{x}{y}\right) \left(\frac{c - b}{c}\right) \times 100 \tag{8}$$

An OEE score of 100% represents perfect production that is to say that all the equipments are functioning optimally. An OEE score of 85% is regarded as world class [16]. But in the case of a low OEE score, say 40%, the production of the brewery will be low and thus adequate steps must be taken to reduce the losses such as equipment failure, idling, minor stops and process defects, which actually affect the effectiveness of the production process.

4. Findings

A systematic approach was also used to gather data of all the manufacturing machines within different types of processes and products. Data were collected manually by embarking on interview sessions with staff on hourly, daily and weekly basis. The following data were collected from the production line of Champion Lager Beer:

(1) Time loss for machine downtimes;

(2) Time loss for set ups and product changeover;

(3) Time loss for component stoppage time and micro downtimes;

(4) Time loss for preventive maintenance (planned down time);

(5) Time loss for resources lack;

(6) Planned and final output;

(7) Production volume;

(8) Quality lost time;

(9) Sensor position;

(10) Conveyor length;

(11) Machine cycle time;

(12) Machine speed, and

(13) Production rate.

The data collected were analyzed over different production shift teams, different product types, different time schedules and different production parameters of line.

4.1 Production Line Analysis

The collected data were analyzed in parts beginning with the production line down times of Champion Lager Beer. This was stratified per day for six months (June-November, 2019) and after the determination of OEE score—when it was possible—each index (Availability, Performance and Quality) was compared to company's target and world class target.

Table 1 shows the production down time losses in the production line of Champion Lager Beer in six months.

Table 1 Down time losses of Champion Lager Beer in six months.

S/N	Down time loss factor	Down time losses (h)	Cumulative (%)
1	Set up and adjustment	99.14	18.42
2	Machine break downs	243.14	45.2
3	Complexity (flavor changes)	82.01	15.2
4	Component stoppages	95.87	17.8
5	Services stoppages	9.25	1.72
6	Size changes	4.26	0.79
7	Labor losses	4.71	0.88
	Total down time losses	538.38	

Further information is provided in Table 2.

Table 2 Shut down time losses of Champion Lager Beer in six months.

S/N	Shut down time loss factor	Shut down time losses (h)	Cumulative (%)
1	Clean in place (CIP)	172.2	17.05
2	Warehousing	178.5	17.67
3	Planned maintenance	435.3	43.10
4	Trials	4.25	0.42
5	Services equipment down	70.20	6.90
6	Planned stoppages	14.90	1.50
7	Planning	8.60	0.90
8	Planned meetings	4.50	0.45
9	House-keeping	10.50	1.03
10	External services	115.5	11.44
	Total shut down time losses	1,014.45	

4.2 The OEE Model Development

The following calculations were used in the course of the study:

$$\text{Loading Time} = \text{Total Shift Time} - \text{Shut Down Losses} \quad (9)$$

$$\text{Operating Time} = \text{Loading Time} - \text{Down Time Losses} \quad (10)$$

$$\text{Net Operating Time} = {\text{Gross Production}}/{\text{Base Quantity}} \quad (11)$$

$$\text{Value Added Oper. Time} = \text{Net Operatng Time} - \text{Quality Lost Time} \quad (12)$$

$$\text{Availability} = {\text{Net Operating Time}}/{\text{Loading Time}} \quad (13)$$

$$\text{Performance} = {\text{Net Operating Time}}/{\text{Operating Time}} \quad (14)$$

$$\text{Quality} = {\text{Value Added Oper. Time}}/{\text{Net operating Time}} \quad (15)$$

$$\text{Capacity Utilization} = {\text{Loading Time}}/{\text{Calendar Time}} \quad (16)$$

$$\text{Asset Utilization} = {\text{Value Added Oper. Time}}/{\text{Base Quantity}} \quad (17)$$

$$\text{OEE} = \text{Availabilty} \times \text{Performance} \times \text{Quality} \quad (18)$$

Using the values in Tables 1 and 2 to analyze for the OEE, it was determined that the OEE of the existing production line of Champion Lager Beer is 61.5%.

Table 3 shows the 6 months production process losses of Champion Lager Beer. In the production process, about 1,010.01 hours was shut down losses (SDL), 538.01 hours was in down time losses (DTL), 270.02 hours was performance losses (PL) and 50.55 hours was observed as quality lost time.

In this study, Fig. 2 shows the contribution of the production losses in the production line of Champion Lager Beer.

Table 3 Production line losses of Champion lager beer.

S/N	Production losses	Time (h)	Cumulative (%)
1	Shut down losses	1,010.01	54.0
2	Down time losses	538.01	28.8
3	Performance losses	270.02	14.5
4	Quality lost time	50.55	2.7
	Total	1,868.59	

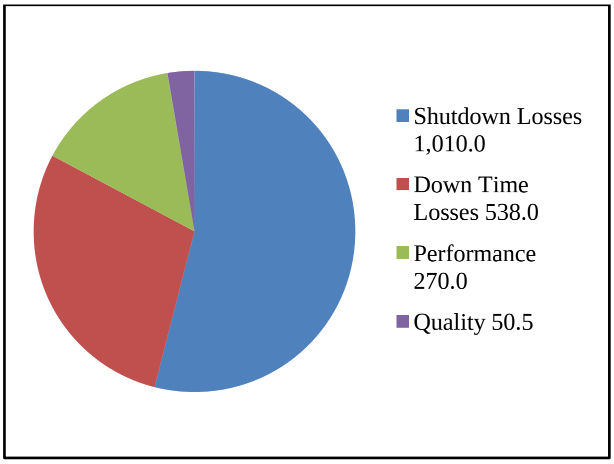

Fig. 2 Contribution of the production losses for Champion Lager beer.

Source: Authors compilation.

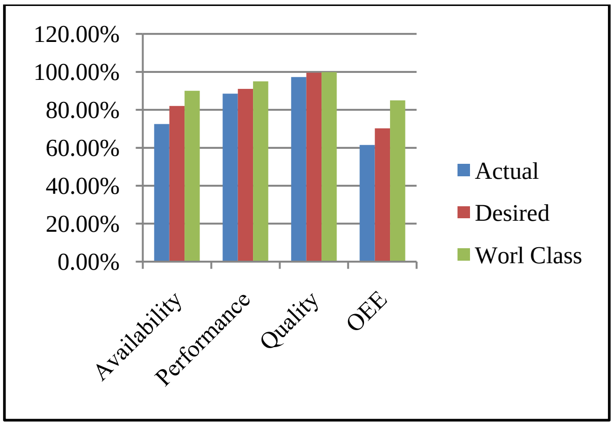

Fig. 3 Target, actual and world class OEE rating.

Source: Authors compilation.

The availability and performance show that there is an excessive down time loss that decreases the production line performance. So, there is room for improvement.

Fig. 3 presents the six months availability, performance, quality and OEE rating.

The OEE (61.5%) is below company target (70.0%) by 9%. Enhancing towards the target and world class OEE rating would mean a huge improvement in productivity. The production line analysis was performed to identify the production losses and their sources therefore, the quality is within target.

4.3 Proposed Breweries Validation Model

The existing production line of Champion Lager Beer shows high availability losses and low OEE. To improve the OEE and equipment downtimes, a theoretical validation technique was carried on the existing production lines. As a result, the OEE was improved.

4.4 Theoretical Validation for Champion Lager Beer in Six Months

The following data were collected from the existing production line of Champion Lager Beer. From Table 3, a total shutdown time loss is 1,010.1 h. To theoretically validate the existing model, changing the logic of production parameters (shutdown losses, downtime losses, performance losses) improves the OEE [17].

Table 4 The production line analysis using Champion Breweries Plc.

S/N	Parameter	Existing line (time in h)	Validation model (time in h)	Difference (h)
1	Calendar time	4,320.00	4,320.00	0.00
2	Working time	3,984.00	3,984.00	0.00
3	Loading time	2,974.02	2,969.55	4.45
4	Operating time	2,438.00	2,431.17	6.38
5	Net operating time	2,167.20	2,160.71	6.49
6	Value added operating time	2,116.26	2,110.16	6.10

Therefore, the validated OEE was calculated from Eqs. (13)-(18) and 63.12% was achieved.

5. Conclusion

As a result of applying theoretical validation, the OEE of the production line of Champion Lager Beer was improved. The OEE of champion lager beer has been increased from 61.5% to 63.12%.

Based on the achievable results, the following conclusions are drawn.

OEE of the production line of Champion Lager Beer is below target management plan by 9%. The identified reason for lower OEE is due to lower line availability and line performance in view of higher manufacturing efficiency losses. Also, other reasons for lower availability are due to excess machine breakdown, longer set up and adjustment and frequent component stoppage. The main reasons for lower performance are due to higher losses, and frequent short stoppage time.

OEE model for existing production line of Champion Lager Beer was validated using theoretical validation technique. The validated model shows an improved OEE value of 63.1% against 61.5% which is the value for the existing production line. Thus, company can meet expected demand; reduce production cost, increase production capacity to boost its competitiveness and performance. Therefore, it can be concluded that the production line efficiency analysis and validation model are beneficial to the company.

References

[1] Hornsey, I. S. 2010. *A History of Beer and Brewing*. Cambridge University Press.

[2] Jeffries, M., et al. 2003. "A New Approach to Process Control for a Bottling Plant." *Journal of Material Processing Technology* 132 (1): 123-7.

[3] Bierbooms, R. 2012. "Performance Analysis of Production Lines: Discrete and Continuous Flow Models." *International Journal of Operations Research and Management* 9 (3): 325-45.

[4] Camarata, J. B., and Camarata, M. R. 2000. "Towards an Integral Model: Perdormance Measurement in Non-profit Organization." *Journal of Operation Management* 2 (4): 55-94.

[5] Nani, A. J., Dixon, J. R., and Vollman, T. E. 1990. "Strategy Control and Performance Measurement." *Journal of Cost Management* 8 (2): 56-73.

[6] Brignall, S. 1992. "Performance Measurement Systems as Change Agents." *Journal of Operation Research* 8 (6): 72-94.

[7] Biticti, U. S., Turner, T., and Begemann, C. 2000. "Dynamics of Performance Measurement Systems." *International Journal of Operations and Production Management* 20 (6): 692-704.

[8] Parida, A., and Chattopadhyay, G. 2008. "Development of a Multi-criteria Hierarchical Framework for Maintenance Measurement (MPM)." *Journal of Quality in Maintenance Engineering Operation Management* 13 (3): 241-58.

[9] Maggard, B. N., and Rhyne, D. M. 1997. "Total Productive Maintenance: A Timely Integration of Maintenance." *Journal of Production and Inventory*

Management 2 (9): 6-11.

[10] Neely, A., Gregory, M., and Platffs, K. 2005. "Performance Measurement System Design: A Literature Revere and Research Agenda." *International Journal of Operations and Production Management* 25 (12): 1228-63.

[11] Rose, K. H. 1995. "A Performance Measurement Model, Quality Progress." *Journal of Operation Management* 9 (6): 308-20.

[12] Neely, A., Mills, J., Platts, K., Richard, H., Gregory, M., and Bourne, M. 2000. "Performance Measurement System Design: Developing and Testing a Process Based Approach." *International Journal of Operation Production Management* 20 (10): 119-32.

[13] Mirsky, S. A. 2007. "Ale's Well with the World." *Scientific American Journal* 2 (24): 54-60.

[14] Nakajima, S. 1998. *Introduction to TPM: Total Productive Maintenance*. Cambridge, MA: Productivity Press.

[15] Williamson, R. M. 2019. "Using Overall Equipment Effectiveness: The Metric and the Measures: Strategic Work Systems, Inc. Columbus." Accessed May 13, 2019. https://www.swpitcrew.com.

[16] Naveen, K., and Dalgobind, M. 2013. "Productivity Improvement through Process Analysis for Optimizing Assembling Line in Packaging Industries." *Global Journal of Research in Engineering* 9 (13): 1-17.

[17] Harrison, R., and Counsell, S. 2000. "Theoretical Validation and Empirical Evaluation of Object-Oriented Design." *Journal of Industrial Engineering* 20: 199-201.