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Maintenance Performance Evaluation and Downtime Analysis of Manufacturing Equipment in a Food Manufacturing Company

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

In food manufacturing, maintenance of manufacturing equipment is one of the most important essentials for an efficient manufacturing as this sector continuously face challenges that makes maintenance very critical due to the nature of manufacturing, thus as a result food manufacturing companies must add or modify their maintenance strategies in order to keep production running efficiently. The aim of this study is to carry out a maintenance performance evaluation and downtime analysis in a food manufacturing company and suggest areas for further improvement. In this study, an empirical case study was carried out in order to evaluate the maintenance performance and downtime analysis. Overall equipment effectiveness and Pareto analysis were used to carry out a maintenance performance evaluation and downtime analysis on the manufacturing equipment using three years historical data obtained from the food manufacturing company as an industrial case study. The study found that the average overall equipment effectiveness is 55.30% which is a low value when compared with Overall Equipment Effectiveness world standards, meaning that the manufacturing organisation is operating in an average condition and there is a required urgent improvement of maintenance policies and strategies, otherwise it will

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be difficult for the manufacturing organisation to sustain it. Thus it is necessary that in order to improve productivity, the manufacturing organisation under study should look into its manufacturing strategies so that urgent improvement of maintenance policies and strategies can be implemented and adopted.

Keywords: Maintenance performance evaluation; downtime analysis; overall equipment effectiveness; pareto analysis; availability.

1. INTRODUCTION

Globalization has increased the pressure on organizations and companies to operate in the most efficient and economical way. This tendency promotes that companies concentrate more on their core businesses, outsource less profitable departments and services to reduce costs [1]. Competition in manufacturing is increasing exponentially as customers are becoming more exigent and demand becomes increasingly random, this is why the development of industrial strategies (maintenance and production) has become obligatory for manufacturing firms in order to effectively reduce cost, [2].

The importance of maintenance is ever increasing as a result of the widespread automation of manufacturing systems and the capital expenditure allocated to it, thus making maintenance of manufacturing equipments an investment opportunity to be maximised and not a cost centre, [3]. The economic downturn continuously drives manufacturing organisations to seek for more efficient strategies to manage assets maintenance.

According to Turuna Seecharan, Ashraf Labib, [4] the effective maintenance of assets is a vital strategic task given the increasing demand on sustained availability of those assets used for manufacturing. This is essential as sudden failures of manufacturing equipments can be prohibitively expensive because they result in immediate lost production outcome, inefficient quality characteristics and poor customer satisfaction. In the food manufacturing sector, asset maintenance is one of the most important essentials for an efficient manufacturing in the sector as this sector continuously face challenges that makes asset maintenance very critical due to the nature of manufacturing, as a result manufacturing companies in the sector must add or modify these assets to keep it running efficiently thus enhancing production. This is causing food manufacturers to invest more on manufacturing assets than any other manufacturing sectors, [5].

The main focus for food manufacturers is to improve efficiency and profitability through the reduction of total manufacturing costs by optimizing operation processes and maintenance activities achieved through continuously improved machine reliability and a hands-on maintenance culture. Many studies [6,7,8], have discussed the economic implications of maintenance as it applies to food manufacturing industries showing how and effective maintenance policy affects productivity and profitability of a manufacturing process. Fig. 1 illustrates this relationship.

However, in Nigeria few manufacturers have the internal resources to implement such practical culture, [9]. Hence the aim of this study is to carry out a maintenance performance evaluation and downtime analysis in a food manufacturing company and suggest areas for further improvement.

2. METHODOLOGY

An empirical case study was carried out in order to evaluate the maintenance performance and downtime analysis. Overall equipment effectiveness was used to carry out a maintenance performance evaluation on the manufacturing equipments using three years historical data obtained from the food manufacturing company as an industrial case study.

Overall equipment effectiveness (OEE) according to [10,11] takes into account, the availability rate, quality rate and performance rate of manufacturing equipments and products and is represented as:

$$\text{OEE} = \text{Availability x Performance Rate x Quality Rate} \quad (1)$$

Where availability accounts for losses as a result of equipment failure, setup and adjustment and is calculated as the ratio of operating time to loading time and is calculated as follows:

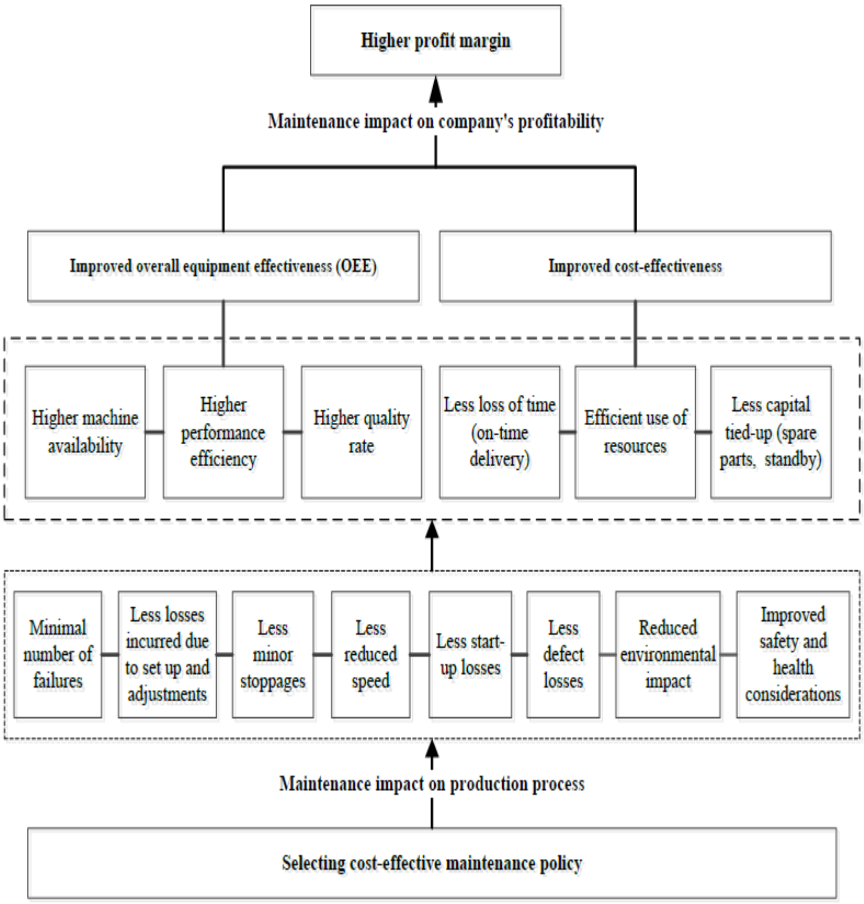

Fig. 1. Relationship between maintenance and company's profits margins
Source: Al-najjar and Gomiscek, [12]

$$\text{Availability} = \frac{\text{Plannedruntime} - \text{Planneddowntime}}{\text{Plannedruntime}} \times 100 \qquad (2)$$

And performance rate accounting for losses due to idle time and minor stoppages and is calculated as ratio of net operating time to operating time and is calculated as follows:

$$\text{Performance rate} = \frac{\text{Total Actual amount of product}}{\text{Target amount of product}} \times 100 \qquad (3)$$

Quality rate factors in the defects in process and reduced yield and is defined as ratio of valuable operating time to net operating time and is calculated as follows:

$$\text{Quality rate} = \frac{\text{Processed Quantity} - \text{defective quantity}}{\text{Processed quantity}} \times 100 \qquad (4)$$

The world class OEE will serve as a benchmark to evaluate the maintenance performance for the manufacturing organisation and to improve the maintenance policy and affect the continuous improvement in the manufacturing systems. This benchmark guide is shown in Table 1. In analysis, if the calculated OEE is equal to world class OEE it is interpreted as that the manufacturing organisation is in good condition and if the OEE is less then it means that there is a required urgent improvement of maintenance policies and strategies otherwise it will be difficult for the manufacturing organisation to sustain it.

Pareto Analysis is used in this case study for downtime analysis, it uses simple bar chart to categorize and help establish priorities [14]. According to Pareto analysis, around 20% of the downtime factors cause 80% of total downtime in manufacturing organisations. It is also a process of identifying the most important priority to that requires improvements [14]. To identify these downtimes, a Pareto chart was used.

Table 1. World class goals for OEE

OEE factor	World class rate (%)
Availability	>90.0%
Performance rate	>95%
Quality rate	>99%
OEE	85%

Source: Jain, Bhatti, and Singh, [13]

3. RESULTS AND DISCUSSION

Necessary data was collected from three years historical maintenance records (production data, records of equipment faults and failures, and factory maintenance compliance sheet) and through twelve months direct observation of manufacturing machines and maintenance activities in a food and beverage manufacturing company based in Anambra state, Nigeria. Data obtained were analysed to interpret the OEE indicators using equations 1, 2, 3 and 4 and are reported in Table 2 and 3:

From Table 3 the average (Mean value of three years observation) overall equipment effectiveness is 55.30% which is a low value when compared with OEE world standards as illustrated in Fig. 2. This means that the manufacturing organisation under study is in an average condition and there is a required urgent improvement of maintenance policies and strategies otherwise it will be difficult for the manufacturing organisation to sustain it.

The average availability for the year under study when compared with the accepted world standards was found to be comparatively lower as illustrated in Fig. 2,

In order to identify the causes behind these findings in Fig. 3, an analysis of downtime in these years is required using Pareto analysis. Availability is reversely proportional to downtime, and to identify the downtimes that have caused around 80% of total downtime, Pareto chart was drawn.

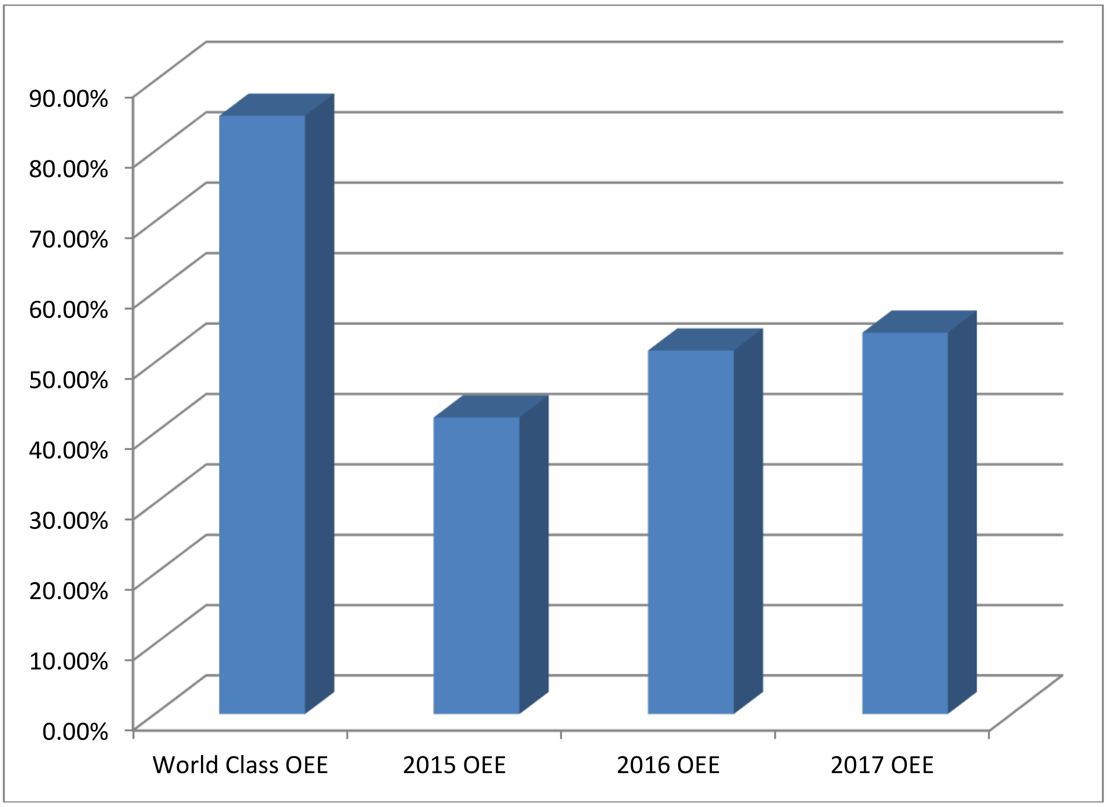

Fig. 2. Benchmark of case study OEE to world standards

Table 2. Monthly OEE measurements

Months	Variables								
	2015			2016			2017		
	Availability%	Performance%	Quality%	Availability%	Performance%	Quality%	Availability%	Performance%	Quality%
January	73.10	73.40	93.70	67.90	73.60	83.70	75.86	84.30	90.73
Febuary	72.70	60.40	93.40	75.78	79.40	95.70	73.08	81.78	88.39
March	76.60	73.10	94.80	77.20	80.10	95.44	70.88	80.00	86.00
April	75.60	79.70	92.00	76.60	78.80	93.31	72.46	81.23	87.88
May	73.50	80.90	91.90	70.80	83.90	91.05	74.70	83.66	89.42
June	45.20	66.30	70.60	66.87	73.30	90.66	78.00	85.30	92.07
July	26.70	49.30	80.70	77.87	79.30	90.70	76.40	84.63	91.42
August	70.40	84.40	91.20	72.46	74.70	90.10	69.60	74.84	85.25
September	70.30	83.40	90.20	72.76	73.47	90.00	69.80	74.92	85.73
October	68.60	73.20	88.90	78.43	73.20	94.05	72.90	81.73	87.22
November	52.30	72.90	72.50	77.56	65.90	92.47	77.37	84.00	91.49
December	67.90	73.60	83.40	78.60	73.60	91.32	78.50	85.52	92.36

Table 3. Monthly OEE measurements (Cont'd)

Months	Overall equipment effectiveness %		
	2015	2016	2017
January	50.27	41.82	58.02
Febuary	40.01	57.58	53.34
March	53.08	59.01	48.77
April	55.43	56.32	51.72
May	54.64	54.08	55.88
June	21.15	44.43	61.25
July	10.62	56.00	59.11
August	54.18	48.76	44.40
September	52.88	48.11	44.83
October	44.64	53.99	51.97
November	27.64	47.26	59.44
December	41.67	52.82	62.00

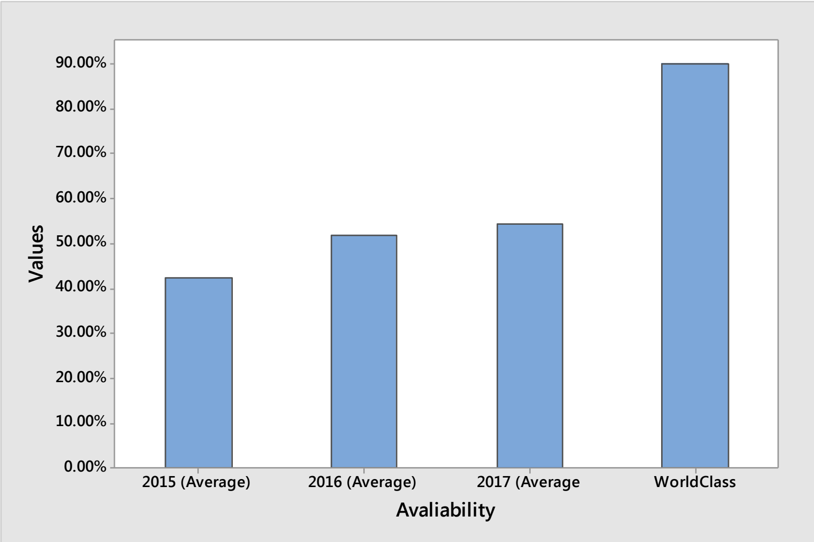

Fig. 3. Average availability benchmark

Table 4. Downtime factors

Downtime factor	Downtime minutes	Percentage	Cumulative percentage
Scheduled Maintenance	42723	40.82	40.82
Equipment Failures/Breakdown	25398	24.26	65.08
Waiting for materials to arrive	19856	18.93	84.01
Maintenance job meetings	9723	9.29	93.3
Waiting for maintenance instruction and orders	5153	4.92	98.22
Miscellaneous activities	1797	1.71	100.00

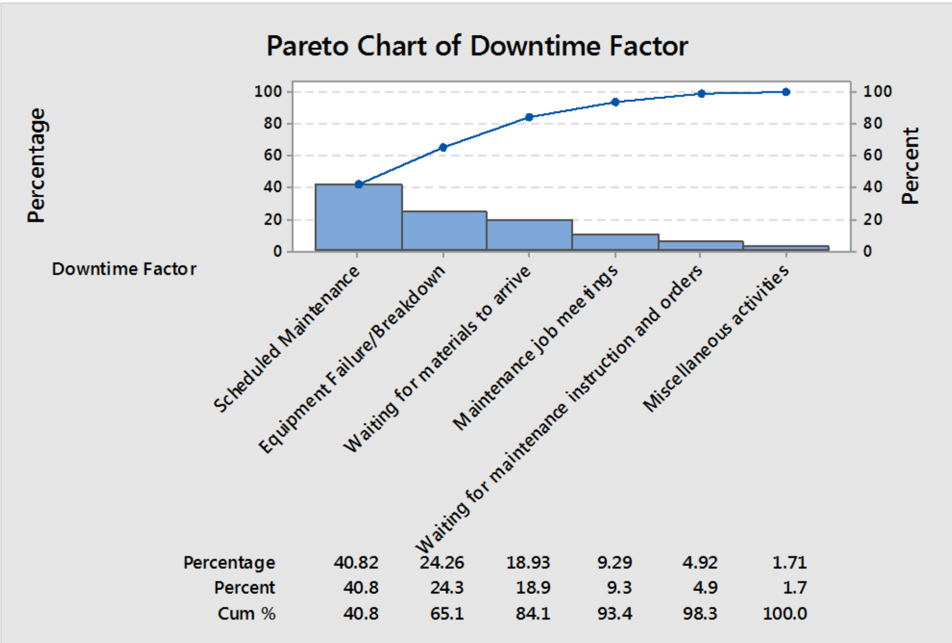

Fig. 4. Downtime analysis

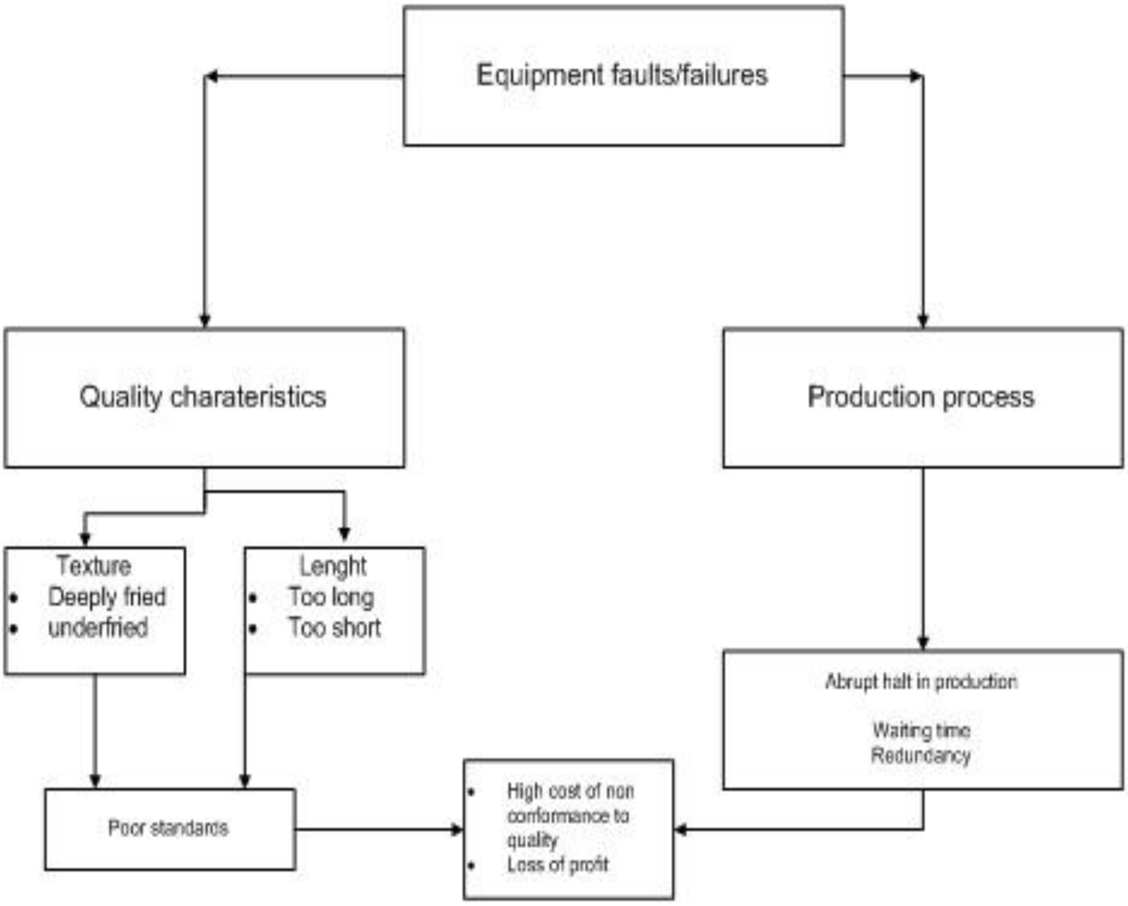

Fig. 5. Faults/Failures and implications

Table 4 identified the causes of downtime during a manufacturing process and the total duration in the industrial case study and through prioritization of the causes via a pareto chart shown in Fig. 4 it was obtained that scheduled maintenance, equipment failures and breakdown and waiting for materials to arrive have caused 84% of the total downtime. Whereas scheduled maintenance and equipment failures and breakdown was unavoidable, they could be reduced with effective maintenance strategy. The manufacturing organisation under study adopts corrective maintenance as its preferred maintenance strategy only, which can be described as a reactive, firefighting strategy. The information obtained from the maintenance team of the organisation was that most faults and failures can be fixed manually by the maintenance team in a relatively short period of time. But, there have been incidents and occasions where breakdowns resulted in long unavailability of the manufacturing equipments and machines as can be seen in the months of June and July 2015 in Table 3. Also observed was the effect of faults and failures on the manufacturing process as depicted in Fig. 5.

4. CONCLUSION

In conclusion, maintenance performance evaluation and downtime analysis is an important area in implementing continuous improvement programs to improvethe manufacturing process and consequently overall equipment effectiveness (OEE) is one of the acceptable maintenance performance evaluation methods that are popular in the manufacturing industries to assess the equipment's effectiveness and performance. It is necessary that in order to improve productivity, the manufacturing organisation under study should look into its manufacturing strategies so that urgent improvement of maintenance policies and strategies can be implemented and adopted thus enhancing productivity levels in the manufacturing organisation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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