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ABSTRACT

In this study, the machine breakdown pattern in Brewery “A” in Eastern Nigeria situated in Onitsha Anambra state has been considered. In the first step of this study, structured questionnaires were produced and administered to target audience for primary data collection. The brewery has limited newsletters, annual reports and bulletins that were used in addition for the reviews. The machines used in the packaging department and its breakdown data over a period of twelve months were gathered and from this, the frequency of breakdown of the machines were established and the data analyzed. The analysis was done by evaluating bottleneck machine breakdowns for different work stations in the production plant, and the effects of breakdown on system output. As a result of the study, critical rates of machine breakdown, which have affected system output, were determined. The frequency of machine breakdown, downtime and maintenance failure problems were also identified. Data collected were analyzed and model for optimization developed. Root cause analysis tools–fishbone and “5why” were used to eliminate the frequent occurring machine breakdown. Mean Time to Failure (MTBF), Availability, and Mean Time to Repair (MTTR) values for the various production lines were evaluated before and after root cause analysis. The result shows that a percentage increase of 13.66%, 10.62% and decrease of 46.42% respectively were obtained which indicated improved Factory efficiency, machine availability and compliance to plan. Also, Exponential distribution model was used to calculate the failure rate and reliability of the machines using the reliability measures result obtained after root cause analysis technique was applied to each failure. A reliability of 99.7% was obtained.

Keywords: Problem solving; Root cause analysis; 5why; Fishbone analysis; Downtime/breakdown; Availability.

1. Introduction

Every conversion process keeps seeking for the most efficient way of utilizing resource inputs in order to optimize the process and production which in turn reduces unit cost (Meyers and Stewart 2005). In production plants, there are so many unplanned stoppages during production leading to downtime example machine breakdowns, raw material unavailability etc. No matter the circumstance, the production company has to meet customer’s demand to be in business or they will face loss of their customers, so it is important to deal with all forms of downtime before it starts impacting on the business.

Manufacturing business is very unstable in nature and can face various setbacks or challenges which can affect output and performance entirely. These setbacks includes machine breakdown which is the area of concentration in this work. Machine breakdown is an important factor in production facility therefore production planners must be cautious during maintenance scheduling and planning to completely eliminate machine stoppage during production by improving the machine’s reliability and availability, by so doing, timely production targets are met and the machine will invariably always be in good condition making it easier and safer to work with.

According to Globerson and Parson (2013), the key elements in manufacturing system are machines, and its breakdown can drastically affect performance of the manufacturing system. Adler (2000) also emphasized that what a machine breakdown stops a production process, the workstation at which this breakdown occurred is regarded as a critical station for the breakdown. Considering this critical workstation, the parts or output of this station can be reserved in a buffer area so that production can still continue in case of breakdown of such station.
Principally downtime (from any source) can be reduced to the barest minimum without affecting or compromising the quality and performance of the output (whether product or services). To be in business, manufacturing companies should adopt a way or system of keeping downtime in check and thereby improve efficiency, productivity and the organization at large Niebel et al., 2008.

2. Materials and Methods

2.1. Materials

The materials used for this research include the following:

- Oral interview/interaction with some selected staff of in the brewery Onitsha.
- Use of the company’s journals/magazines/bulletins and data storage systems.
- Use of the libraries.
- Research on internet.
- Maintenance log sheets.

2.2. Data collection

Data Collection is very vital in this research study. Inaccurate data can impact on the results of a study leading to invalid results. Machine failure, downtime and maintenance history is vital for investigating the Root Cause of a problem.

Data also gives the basis for:

- Defining the current performance.
- Identification of root cause.
- Measuring progress.
- Testing effectiveness of solutions.

2.2.1. Aim of the data gathering

1. Evaluate the data to establish what happened as it occurred.
2. Look at how it happened.
3. Establish why it happened.

2.2.2. Failure

The data about the causes of breakdown were also collected in form of:

i. Breakdown time.

ii. Repair hours, inspection time and maintenance action taken.

iii. Parts changed.
iv. The data also include reasons for failure related to machine, material, process, environment etc. These information, after analysis, will be useful in the availability improvement attempt.

The data used for this work is data collected from the maintenance archive/record in brewery company Onitsha, and also information provided by the maintenance team and specialists

### 3. Results & Discussions

#### Table 1.0. Downtime Sources, Frequency and its Degree of Occurrence

<table>
<thead>
<tr>
<th>Downtime source</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine</td>
<td>17318</td>
<td>18216</td>
<td>17571</td>
<td>21811</td>
<td>20811</td>
<td>15516</td>
<td>18061</td>
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<td>18584</td>
</tr>
<tr>
<td>Operational (man)</td>
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<td>0</td>
<td>0</td>
<td>5</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>27</td>
</tr>
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<td>Materials (CAN, bottle, crate, label, crown cork etc)</td>
<td>175</td>
<td>277</td>
<td>180</td>
<td>21</td>
<td>115</td>
<td>228</td>
<td>217</td>
<td>101</td>
<td>156</td>
<td>108</td>
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<tr>
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<td>72</td>
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<td>162</td>
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<td>Program/software error</td>
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<td>12</td>
<td>0</td>
<td>4</td>
<td>10</td>
<td>41</td>
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<tr>
<td>Others (jam, trip, dirt carryover etc)</td>
<td>50</td>
<td>44</td>
<td>13</td>
<td>51</td>
<td>62</td>
<td>38</td>
<td>66</td>
<td>75</td>
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![Figure 1.0.](image-url)
Table 2.0. Maintenance Cost (From August 2015 to July 2016)

<table>
<thead>
<tr>
<th>Month</th>
<th>Maintenance cost in naira (#)</th>
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<tbody>
<tr>
<td>August</td>
<td>10,863,792.93</td>
</tr>
<tr>
<td>September</td>
<td>10,072,550.51</td>
</tr>
<tr>
<td>October</td>
<td>13,360,266.22</td>
</tr>
<tr>
<td>November</td>
<td>15,388,173.04</td>
</tr>
<tr>
<td>December</td>
<td>12,825,811.26</td>
</tr>
<tr>
<td>January</td>
<td>19,735,682.48</td>
</tr>
<tr>
<td>February</td>
<td>21,975,705.88</td>
</tr>
<tr>
<td>March</td>
<td>19,607,159.38</td>
</tr>
<tr>
<td>April</td>
<td>12,023,906.46</td>
</tr>
<tr>
<td>May</td>
<td>13,485,335.19</td>
</tr>
<tr>
<td>June</td>
<td>18,929,708.97</td>
</tr>
<tr>
<td>July</td>
<td>14,836,231.43</td>
</tr>
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Table 3.0. Bottling Line 1 Machines, their break down pattern and down time record over a year period

<table>
<thead>
<tr>
<th>Machine/ Downtime incurred (mins)</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
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</thead>
<tbody>
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<td>249</td>
<td>181</td>
<td>262</td>
<td>193</td>
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<td>128</td>
<td>170</td>
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<td>127</td>
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<td>233</td>
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<td>212</td>
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<td>175</td>
<td>168</td>
<td>159</td>
<td>173</td>
<td>148</td>
<td>157</td>
<td>123</td>
<td>106</td>
<td>154</td>
<td>1183</td>
</tr>
<tr>
<td>Pallet magazine</td>
<td>40</td>
<td>17</td>
<td>54</td>
<td>16</td>
<td>70</td>
<td>55</td>
<td>69</td>
<td>56</td>
<td>102</td>
<td>33</td>
<td>159</td>
<td>17</td>
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<tr>
<td>Crate conveyor</td>
<td>37</td>
<td>34</td>
<td>46</td>
<td>122</td>
<td>18</td>
<td>37</td>
<td>154</td>
<td>109</td>
<td>123</td>
<td>44</td>
<td>69</td>
<td>106</td>
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<tr>
<td>Bottle conveyor</td>
<td>255</td>
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<tr>
<td>Packer</td>
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<td>209</td>
<td>241</td>
<td>268</td>
<td>270</td>
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<td>174</td>
<td>162</td>
<td>198</td>
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<td>175</td>
<td>162</td>
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<td>Unpacker</td>
<td>447</td>
<td>359</td>
<td>182</td>
<td>355</td>
<td>277</td>
<td>319</td>
<td>452</td>
<td>313</td>
<td>285</td>
<td>177</td>
<td>184</td>
<td>464</td>
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<tr>
<td>Crate washer</td>
<td>179</td>
<td>183</td>
<td>113</td>
<td>172</td>
<td>209</td>
<td>216</td>
<td>177</td>
<td>185</td>
<td>162</td>
<td>152</td>
<td>138</td>
<td>173</td>
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<tr>
<td>Bottle washer</td>
<td>258</td>
<td>309</td>
<td>352</td>
<td>388</td>
<td>371</td>
<td>358</td>
<td>260</td>
<td>359</td>
<td>318</td>
<td>264</td>
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<td>Filler</td>
<td>2372</td>
<td>1300</td>
<td>1269</td>
<td>1311</td>
<td>1362</td>
<td>1481</td>
<td>1533</td>
<td>1540</td>
<td>1451</td>
<td>1316</td>
<td>438</td>
<td>1515</td>
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<tr>
<td>Empty bottle inspector</td>
<td>147</td>
<td>146</td>
<td>150</td>
<td>175</td>
<td>108</td>
<td>131</td>
<td>239</td>
<td>176</td>
<td>138</td>
<td>144</td>
<td>105</td>
<td>152</td>
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<tr>
<td>Full bottle inspector</td>
<td>102</td>
<td>110</td>
<td>97</td>
<td>148</td>
<td>116</td>
<td>129</td>
<td>133</td>
<td>154</td>
<td>162</td>
<td>184</td>
<td>175</td>
<td>116</td>
</tr>
<tr>
<td>Full crate inspector</td>
<td>48</td>
<td>20</td>
<td>59</td>
<td>162</td>
<td>83</td>
<td>179</td>
<td>156</td>
<td>108</td>
<td>137</td>
<td>44</td>
<td>66</td>
<td>40</td>
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<tr>
<td>Video jet (for coding)</td>
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<td>140</td>
<td>136</td>
<td>104</td>
<td>16</td>
<td>29</td>
<td>437</td>
<td>153</td>
<td>116</td>
<td>145</td>
<td>179</td>
<td>188</td>
</tr>
<tr>
<td>Pasteurizer</td>
<td>129</td>
<td>136</td>
<td>187</td>
<td>152</td>
<td>329</td>
<td>326</td>
<td>148</td>
<td>176</td>
<td>179</td>
<td>168</td>
<td>174</td>
<td>47</td>
</tr>
<tr>
<td>Labeller</td>
<td>871</td>
<td>583</td>
<td>742</td>
<td>651</td>
<td>718</td>
<td>577</td>
<td>950</td>
<td>500</td>
<td>471</td>
<td>586</td>
<td>612</td>
<td>347</td>
</tr>
</tbody>
</table>
Table 4.0. Downtime Sources, Frequency and its Degree of Occurrence

<table>
<thead>
<tr>
<th>Downtime source</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
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<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
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</thead>
<tbody>
<tr>
<td>Machine</td>
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<td>16236</td>
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<td>17666</td>
<td>18584</td>
</tr>
<tr>
<td>Operational (man)</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>27</td>
</tr>
<tr>
<td>Materials (CAN, bottle, crate, label, crown cork etc)</td>
<td>175</td>
<td>277</td>
<td>180</td>
<td>21</td>
<td>115</td>
<td>228</td>
<td>217</td>
<td>101</td>
<td>156</td>
<td>108</td>
<td>138</td>
<td>115</td>
</tr>
<tr>
<td>Accident</td>
<td>0</td>
<td>0</td>
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<td>2</td>
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<td>0</td>
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<tr>
<td>Utilities supply</td>
<td>215</td>
<td>305</td>
<td>117</td>
<td>205</td>
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<td>59</td>
<td>65</td>
<td>72</td>
<td>137</td>
<td>149</td>
<td>162</td>
<td>138</td>
</tr>
<tr>
<td>Program/soft ware error</td>
<td>12</td>
<td>34</td>
<td>15</td>
<td>0</td>
<td>33</td>
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<td>12</td>
<td>0</td>
<td>4</td>
<td>10</td>
<td>41</td>
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<tr>
<td>Others (jam, trip, dirt carryover etc)</td>
<td>50</td>
<td>44</td>
<td>13</td>
<td>51</td>
<td>62</td>
<td>38</td>
<td>66</td>
<td>75</td>
<td>49</td>
<td>22</td>
<td>61</td>
<td>17</td>
</tr>
</tbody>
</table>

The production department runs on a 24hours daily production plan (except on maintenance day) and this is divided into a three shift plan, one runs during the day (7am-6pm) and the other at night (7am-6pm) while one is on off duty.

With 22 days production time period, the maximum production time per period is calculated thus:

Max production time (in seconds) = 22 x 24 x 60 x 60 x 60 = 190800s.

From the data gathered and tabulated above, it was established that:

1. The main source of down-time are machines

2. In all the production lines, the machine with the highest down time (unplanned stop during production) are the filler, labeler and the pasteurizer (in their order of occurrence)

3. The stoppage of one machine causes the entire production line (other machines) to be idle

Therefore the Root cause analysis for downtime minimization was focused on these machines addressing their common/frequent causes of failure.

As earlier discussed, Root-cause Analysis is a method used to fix a problem of non-conformance in order to get to the —root cause of the problem. It is aimed at correcting or eliminating the cause, and prevent the problem from resurfacing. Root Cause is the factor that, when it is gotten right, the problem disappears and doesn’t come back.
4. Conclusion

This project was carried out on the machines in the production line of Intafact beverages Onitsha, and all repeated breakdowns were analyzed along with the critical parts, which has been under breakdown condition is also identified and analyzed. Also the reason for the breakdown has been analyzed and some of the tools of root cause analysis like 5-why analysis, fish bone diagram were implemented to identify the actual cause of the breakdown. By this analysis and methods, the root causes of the machine breakdowns were identified. This in turn helped to develop and improve a new preventive maintenance checklist for the machine. This method is used to prevent the failure of equipment before it actually occurs. The average availability of critical machine like the filler after root cause analysis is increased by 10.62%. Also the average MTBF of the critical machine after root cause analysis is increased by 13.66% and MTTR is decreased to 46.42% respectively. After root cause analysis there is an improvement in the maximization of planned productivity. This is because of proper diagnosis of the existing system and by employing proper preventive maintenance schedule. Therefore whenever a breakdown occurs, the root cause of the breakdown has to be identified. Then some efforts should be made to improve this system using root cause analysis and counter measures, such that similar type of breakdown can be reduced.

Therefore this work resulted in:

1. Reduced machine downtime during production.
2. Increased machine availability.
3. Increase in machine/factory efficiency by an increased MTBF and decreased MTTR.
4. Increased Overall Equipment Effectiveness (OEE).
5. Improved safety and quality conditions.
6. Improved Factory efficiency.
7. Improved Adjustable factory efficiency.
8. Improved Machine efficiency.
9. Improved Compliancy to plan.
10. Improved Line efficiency.
11. Improved Operating efficiency.

Further results achievable at the long run as a result of this work which will include but not limited to:

1. Reduced overtime costs and more economical use of maintenance workers due to working on a scheduled basis instead of a crash basis to repair breakdowns.
2. Timely, routine repairs circumvent fewer large-scale repairs.
3. Reduced cost of repairs by reducing secondary failures.
4. Identification of equipment with excessive maintenance costs, indicating the need for corrective maintenance, operator training, or replacement of obsolete equipment.
5. Parts stocking levels can be optimized.
5. Contribution to Knowledge

With the results achieved in this work, facts have been established that effective Root Cause Analysis can minimize machine failure during production. Tasks as little as cleaning has shown to have an impact on the performance and availability of machines.

6. Recommendation

For future further research, condition monitoring as an effective tool in reliability Engineering can also be explored in the quest to cut down on unwanted machine stoppage during production (down time) because of its predictive nature. In the cause of this work it was noted that this is yet to be fully utilized and implemented. If this will be implemented together with an effective root cause analysis tool, the company will meet and surpass its target thereby improving on its key performance indicators.

Also a mechanism for downtime documentation should be developed in order to track every second of production time wasted, for example software should be installed in machine’s program to enable it capture every stoppage and prompt the operator to input reason for stopping before starting up again, with this accurate downtime tracking will be established instead of relying on operator alone for reporting downtime. This will give more detailed downtime information especially in terms time which has economical implication on the company.

Declarations

Source of Funding

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Competing Interests Statement

Authors have declared no competing interests.

Consent for Publication

The authors declare that they consented to the publication of this research.

Authors’ Contributions

All the authors took part in literature review, analysis, and manuscript writing equally.

References


