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Maximizing Overall Equipment Effectiveness in a Food Processing Industry: A Case Study

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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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Case Study

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ABSTRACT

In this study, TPM strategies were deployed to improve the production performance of a manufacturing facility. The OEE quantitative metric has been followed here to solve the underlying problem of reducing the frequency of machine failures and improving its operational efficiency. The results from the study show that the TPM implementation on the packaging machine has increased its OEE value from 48% to 74%, availability factor was raised by 19%; from 70% to 89%, the performance factor experienced an increase too, from the initial value of 70% to 84%, the reliability of the packaging machine increased from 38.91 hr. to 71.83 hr., and the downtime hour on the packaging machine drastically reduced from 834hr to 446 hr., which is about 46.52% hour reduction. The study further reveals that focused TPM implementation over a reasonable period of time can impressively enhance manufacturing performance.

Keywords: TPM; OEE; pareto analysis; JIPM; production losses.

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1. INTRODUCTION

Literature has revealed that manufacturing organizations globally are facing many challenges in order to be productively relevant in today's turbulent dynamic environment. As a result of these challenges, modern manufacturing organizations are now seeking effective and effectual maintenance practices to be well-off, and TPM has been widely reported in maintenance literature, as a potential production practice in the direction of maintaining performance and profitability of a manufacturing system. Total Productive Maintenance (TPM) is a team-based effort to build quality into equipment and to improve productivity by reducing the time lost due to breakdowns. It identifies the non-value added-activities within an organization and then, systematically creates solutions to eliminate the most wasteful ones. The operational strategies of TPM have proven capable of bringing a machine back to its original condition [1], as well as reducing expenses on capital investment [2]. The functional concept of TPM assigns maintenance responsibilities to the same people who operate that individual equipment. This maintenance concept advocates that equipment must operate at its designed speed, produce at the designed rate, as well as produce a quality product at these speeds and rates. Total Productive Maintenance also addresses causative factors for accelerated deteriorations, emphasizing on proactive and preventive maintenance actions to operationally improve the efficiency of equipment. In this maintenance approach, the maintenance teams are encouraged to start on small problem-solving projects and keep meticulous records of their progress once the teams are familiar with the TPM methodology [3]. This maintenance model has eight pillars of operation as shown in Fig. 1.

Each of these eight TPM operational pillars is assigned with a specific performance improvement tasks that linked chains of activities [4]. Total productive maintenance is aimed at reinforcing corporate structures by eliminating all losses through attainment of zero defects, zero failures and zero accident [5]. This maintenance approach according to [6] paves the way for excellent planning, organizing, monitoring and controlling practices through its unique eight pillar methodology. [7] Considered it appropriate to kick start TPM implementation with autonomous maintenance activities at the lowest operational level. Total productive maintenance takes a lot to consideration as it concerns the world's most acclaimed manufacturing priorities by reducing quality problem from unstable production, reducing unplanned stoppages, improve problem solving ability, and maintain customer's goodwill [8]. It takes 2 to 3 years for an enterprise to implement total productive maintenance (TPM) in a full swing [9], and the operational tool box used in TPM program consists of various problem-solving techniques such as fishbone analysis, Pareto analysis, the OEE metric analysis, etc. Among the tools used in TPM projects, OEE quantitative assessment metric has become the most conceptualized tool that is widely used in industries to picture current and historical levels of operational effectiveness. According to [3] OEE measurement is an effective way of analyzing the efficiency of a single machine. The OEE is broken down into three measuring metrics *viz.* Availability, Performance and Quality. The OEE metric availability and performance takes into account downtime losses, while the quality metric accounts for quality losses. In general, OEE is impacted by three categories of losses: downtime losses, speed losses, and quality losses [10]. The world-class OEE standard rate for availability factor is 90% performance factor 95% and quality rate of 99%. The recommended overall OEE rate, which is calculated as a product of the three rates, is 85%. TPM studies in an automotive industry have also resulted to a great reduction in associated production losses [11]. Similar benefits of TPM implementation have also been reported in an aerospace industry in 1996 by [12], a unionized aerospace industry supplier. Significant TPM implementation has also been reported in diverse industries such as food manufacturing industry [13] [14], electronic manufacturing company [2], brewery [15], [16] steel tube mills and rolling mills [17] [18] etc. In retrospect, TPM strategy has its own challenges, as innumerable barriers are encountered in real-life cases during TPM implementation [19], [20]. Most organizations fail in their attempts due to behavioral, cultural and bureaucratic challenges [21], lack of training, education, and organizational commitment [22];[5];[23], security doubts and ignorance [24]. Even in Nigeria, TPM is still misconstrued as a rigorous and time consuming maintenance approach [25], and most Nigerian industries operate productively less than 50% of the nominal functioning hours per year, due to high downtime, low spare-capacity to meet with the demands, and supply failures for input resources.

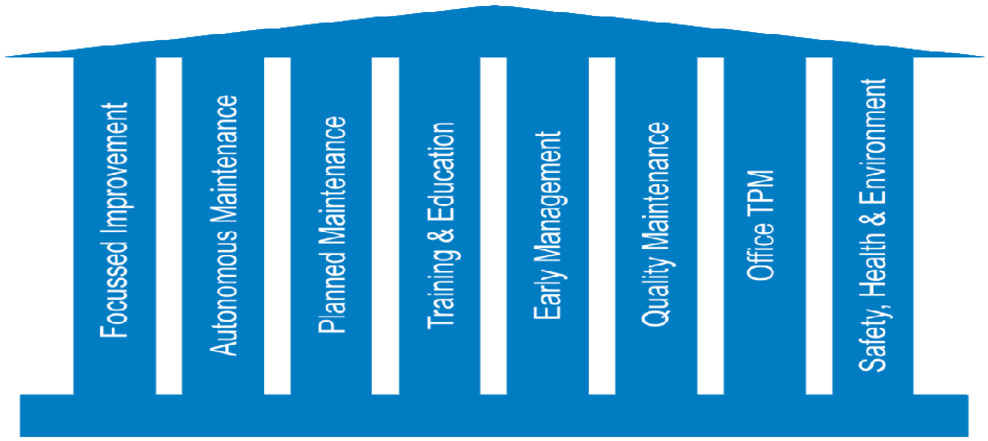

Fig. 1. Eight pillars of TPM

2. RESEARCH METHODOLOGY

The research was carried out in a food manufacturing company, majoring in the production of noodles, and was conducted over a period of nine months. The organization operates three shifts a day, and the study was limited to bottleneck operation and the identified bottleneck machine in this study was the noodle packaging machine. The criterion for selecting the bottleneck machine was based on the equipment that immediately increases output yield. The OEE measurement metric was used to analyze the equipment effectiveness on the bottleneck machine, and the baseline study was conducted with a six month data. A TPM program was introduced on the machine, after which readings were taken to ascertain the level of improvement. All the production parameters needed to assess the overall equipment efficiency were gotten through the use of a questionnaire, direct observations and measurements. The three OEE rates were determined individually, after which the OEE was calculated as the product of the three rates. The equipment reliability of the observed machine was also analyzed using machine reliability function.

$$\text{Availability (A) \%} = \frac{\text{Active time} - \text{downtime}}{\text{Active time}} \quad (1a)$$

OEE loss under availability rating is categorized as downtime loss (breakdown, set-up / adjustment loss), and could be in the form of unplanned maintenance hours, equipment failures, material shortages, machine changeover, tooling damage and process-warm-up

$$\text{(A)\%} = \frac{\textit{Operating time}}{\textit{Active time}} \quad (1b)$$

Where,

$$\text{Operating time} = \text{Active time} - \text{downtime} \quad (1c)$$

$$\text{Actual output} = \frac{\textit{Operating time}}{\textit{Actual cycle time}} \quad (2)$$

Performance (P) %=
Operating speed coefficient x Net operating rate (3a)

Where,

$$\text{Operating speed coefficient} = \frac{\textit{Ideal cycle time}}{\textit{Actual cycle time}} \quad (3b)$$

$$\text{Net operating rate} = \frac{\textit{Ideal cycle time}}{\textit{Actual cycle time}} \text{x } 100 \quad (3c)$$

OEE loss under performance rating is categorized as speed loss. In operation, this category of loss could be as a result of products that are not well feed into machine, component jams, product flow stoppage, poor level of machine operator's training, aged equipment, and tooling wear.

$$\text{Quality (Q) \%} = \frac{\textit{Ideal cycle time}}{\textit{Actual cycle time}} X\ 100 \quad (4)$$

The OEE loss under quality category could be as a result of tolerance adjustment, warm-up process, incorrect assembly, rejects and rework.

OEE = Availability x Performance rate x Quality rate (5)

$$\text{MTBR (mean time between repair)} = \frac{\textit{Total Operating time}}{\textit{number of failures}}$$

3. RESULTS AND ANALYSIS

Six months data on the packaging machine operational history was gathered prior to TPM implementation to ascertain the OEE baseline value before the TPM implementation, as presented in Table 1. After the baseline study was undertaken and documented, the organization embarked on total productive maintenance exercise. At first, before the TPM implementation exercise, Five whys-approach was used to identify the potential causes of machine failures, after which the machine operators engaged in minor maintenance tasks in the form of preventive maintenance actions such as cleaning, inspection, adjustment, alignment, lubrication, etc., at the start of every shift. These actions were able to eliminate most of the common causes of failures, improve OEE rates and value, as seen in Table 2, and increased the reliability of the packaging machine, as seen in Table 3. Common failures identified with the bottleneck machine before and after TPM Implementation were grouped into categories in accordance to JIPM (Japan Institute of Plant Maintenance) procedures, and were roughly presented in Tables 4 and 5 respectively. Comparisons on the OEE rates, machine reliability, and observed failure category before and after TPM implementation were graphically represented in Figs. 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11.

Fig. 2 represents comparative OEE factors of the packaging machine before and after TPM implementation with respect to the world class recommended values. As labeled in the column chart above, the OEE rates before TPM implementation are 70% for availability factor, 70% for performance factor, 99% for quality factor and 48% for the OEE value. After TPM implementation, the availability factor was raised by 19%; from 70% to 89%, the performance factor experienced a 14% increase, from initial value of 70% to 84%. The quality rates increased by 1% after TPM compared with the 99% before the TPM implementation, and the Overall equipment effectiveness value increased by 26%, from 48% to 74%. Mean time before repair (MTBR) value which is a direct measure of reliability was tabulated in Table 3, and Fig. 7 graphical showed that the reliability of the machine increased by 84.6% from 38.91 hr. to 71.83hr. The downtime hour of the packaging machine drastically reduced from 834hr. to 446hr., which is about 46.52% hour reduction.

Table 1. OEE factors before TPM implementation

Month	Performance (%)	Quality (%)	Availability (%)	OEE (%)
Oct.	69.4	96.5	74.9	50.2
Nov.	70.6	97.6	66.9	46.1
Dec.	71.1	99.2	70.4	49.7
Jan.	69.2	98.9	76.3	52.2
Feb.	72.4	99.5	63.9	46.0
Mar.	66.8	99.0	69.8	46.2
Average (%)	$\sum = 70$	$\sum = 99$	$\sum = 70$	$\sum = 48$

Table 2. OEE factors after TPM implementation

Month	Performance (%)	Quality (%)	Availability (%)	OEE (%)
Jun.	83.1	99.7	81.3	67.4
Jul.	85.3	99.5	92.7	78.7
Aug.	84.6	99.6	96.3	81.1
Sept.	86.0	99.8	83.5	71.7
Oct.	84.0	99.8	88.9	74.5
Nov.	83.9	99.9	90.8	76.1
Average (%)	$\sum = 84$	$\sum = 100$	$\sum = 89$	$\sum = 75$

Table 3. MTBR and Downtimes values before and after TPM implementation

Production parameters	Active time (Hr.)	No. of recorded failures	Down time (Hr.)	MTBR (Hr.)
Before TPM	3,735	96	834	38.91
After TPM	3,735	52	446	71.83

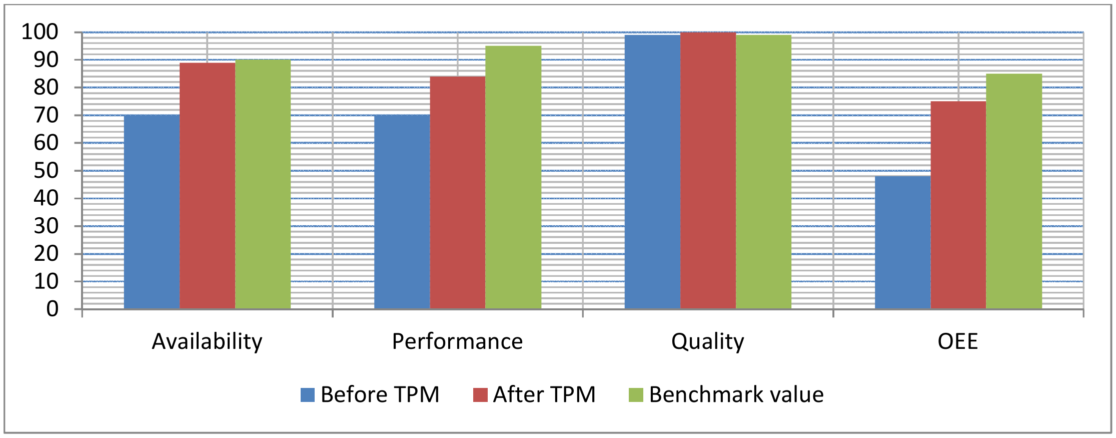

Fig. 2. Graphical representation of the OEE values before and after TPM in relation to world class benchmark values

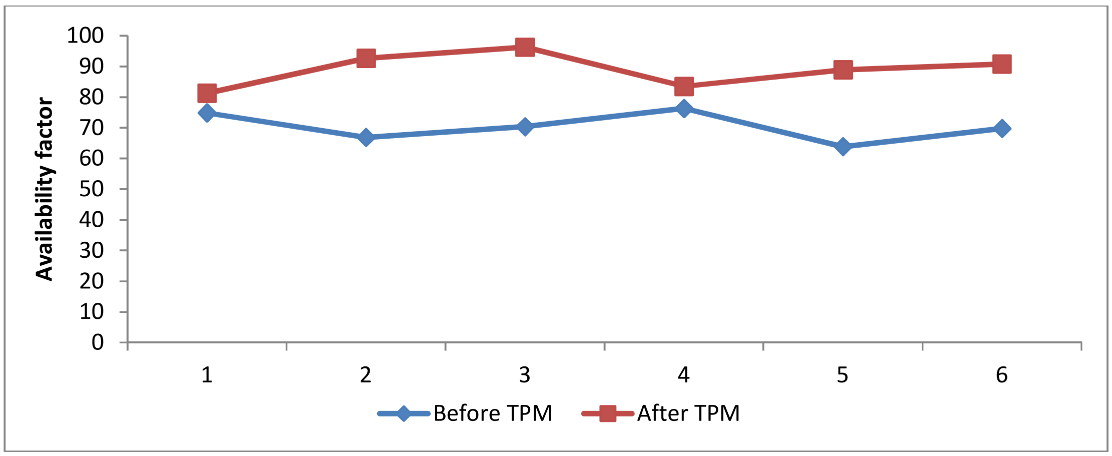

Fig. 3. Graphical appraisal on the availability factor before and after TPM

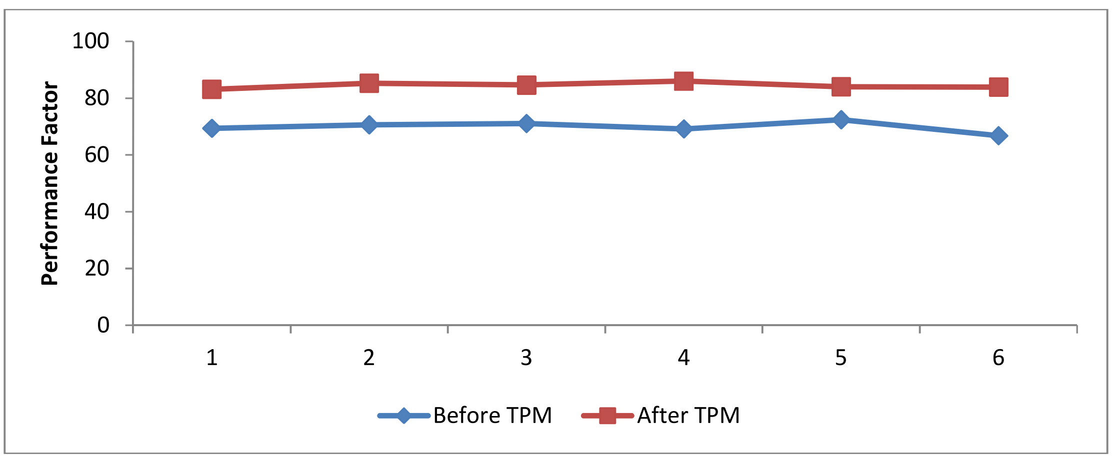

Fig. 4. Graphical appraisal of the performance factor before and after TPM

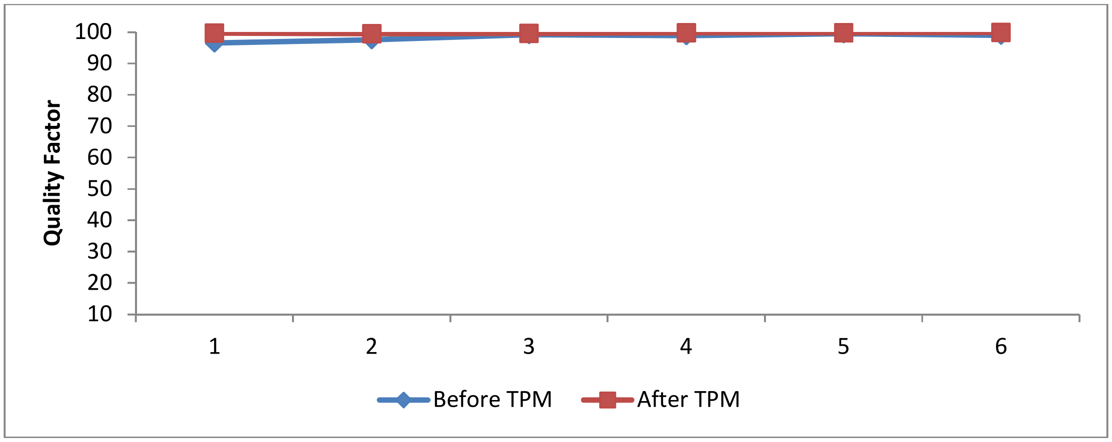

Fig. 5. Graphical appraisal on the quality factor before and after TPM

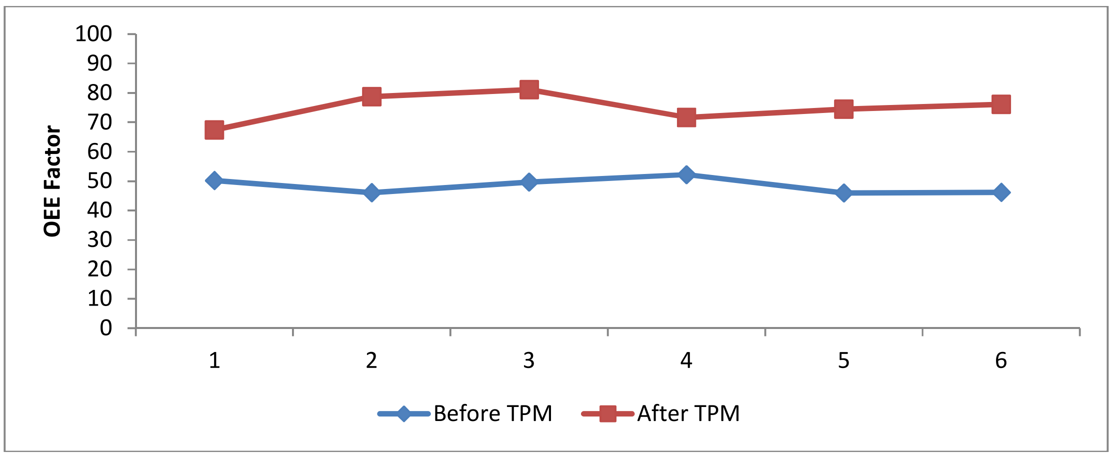

Fig. 6. Graphical Comparison of OEE values before and after TPM Implementation

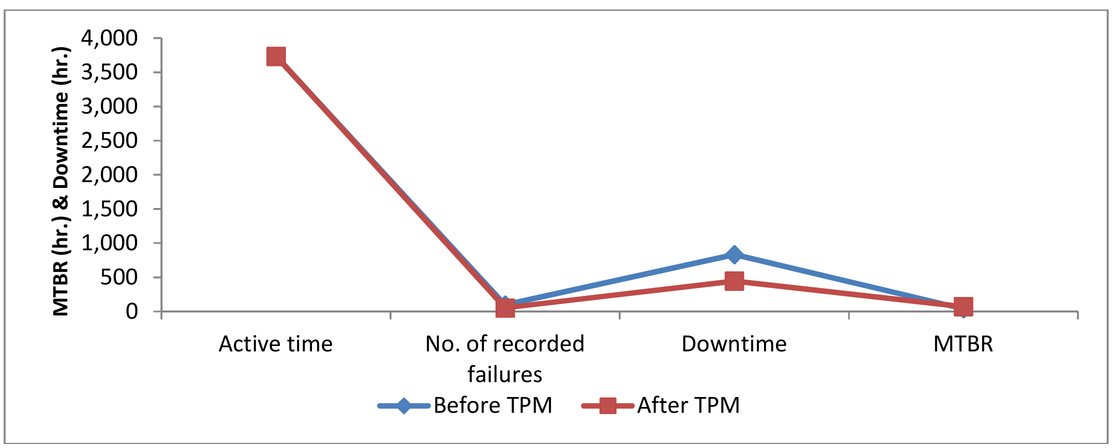

Fig. 7. MTBR (hr.) and Downtime (hr.) before and after TPM Implementation

The equipment failures recorded within the observed period were grouped into four JIPM (Japan Institute of Plant Maintenance) failure categories such as unchecked deterioration, basic condition neglect, inadequate skill level and operation standards not followed. Under JIPM fail category, the basic condition of neglect occurs when tool is not maintained to the proper standard, for example broken covers, leaking water lines on electronic components, missing cable clamps. Unchecked deterioration is similar to basic condition neglect but in this case, there is no recommended scheduled PM to prevent the failures or any checks to detect problems, for example, motors that have worn brushes or failing torque, drive belts that are frayed or have damaged teeth, pumps that have worn internal parts and now rattle or vibrate. In the penultimate category, which is the inadequate skill level, machine faults and failures are caused when the operators use the equipment wrongly. Last on the category is when operating standards are not followed or has been followed incorrectly.

Most common example is when the wrong type of parts are used or reused despite the instruction to use the new one every time, use of wrong screws, and when joints that should have been lubricated have been missed.

The downtime hours and number of fails are used to sort the categories before and after TPM Implementation, see Figs 8 and 9. Before the TPM implementation, as depicted in Fig. 8, represents the percentage of failures and accrued downtime for the four failure categories. Fig. 9; also depicts the percentage of failures according to JIPM categories and the accrued downtime after the TPM implementation. All the measurement parameters were clearly represented in a clear Pareto chart, as shown in Figs. 10 and 11, thereby analyzing all the failures and accrued downtime before and after TPM Implementation.

The time to carry out the repairs which is the main consideration in this study as it gives a better idea of how the failures are impacting production, hours of downtime was used to sort the categories as shown in Figs. 8 and 9. After the TPM implementation, basic condition neglect now becomes the focal JIPM failure category that was used to prioritize maintenance attention because it has the largest impact in terms of number of fails, and down time hours. Followed by unchecked deterioration level ranking second in failure and downtime order, after which inadequate skill level and operating standard not followed.

Table 4. JIPM failure categories before TPM implementation

S/N	JIPM Category	Number of fail	Downtime (Hr.)	(%) fail	Cumulative (%) fail	(%) downtime	Cumulative (%) downtime
1	Unchecked deterioration	29	279	30.21	30.21	33.45	33.45
2	Basic condition neglect	30	313	31.25	61.46	37.53	70.98
3	Inadequate skill level	15	198	15.63	77.09	23.74	94.70
4	Operating Standard not followed	22	44	22.92	100	5.30	100
Total		96	834	100		100	

Table 5. JIPM failure categories after TPM implementation

S/N	JIPM category	Number of fail	Downtime (Hr.)	(%) fail	Cumulative (%) fail	(%) downtime	Cumulative (%) downtime
1	Unchecked deterioration	10	89	19.20	19.20	19.09	19.09
2	Basic condition neglect	13	111	25.00	44.20	23.82	42.91
3	Inadequate skill level	16	147	30.80	75.00	31.55	74.46
4	Operating Standard not followed	13	119	25.00	100	25.54	100
Total		52	466	100		100	

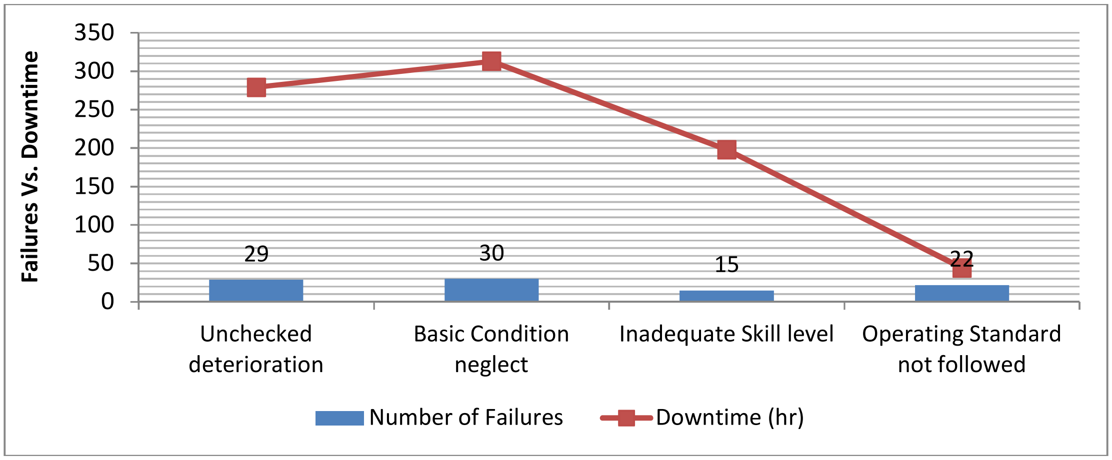

Fig. 8. Analysis of failures before TPM implementation

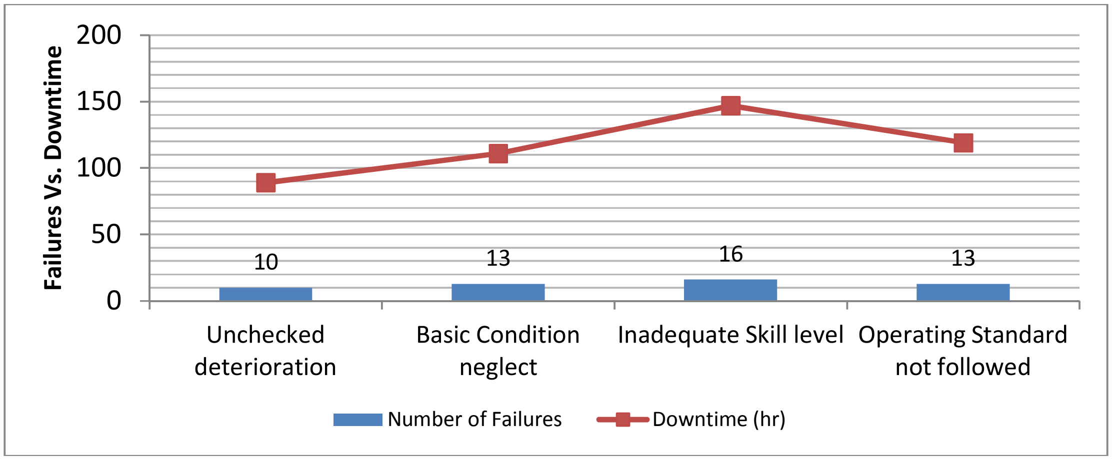

Fig. 9. Analysis of failures after TPM implementation

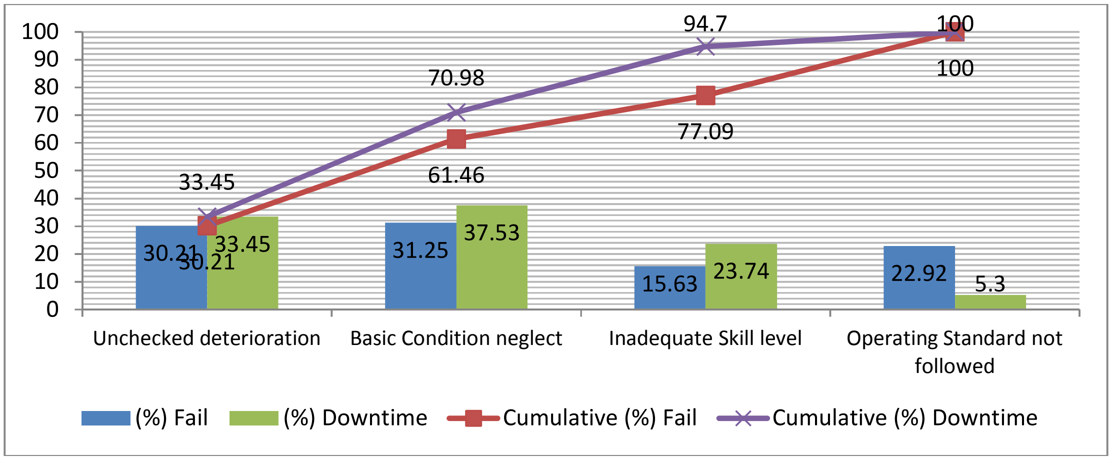

Fig. 10. Pareto chart of all the fails and accrued downtime before TPM implementation

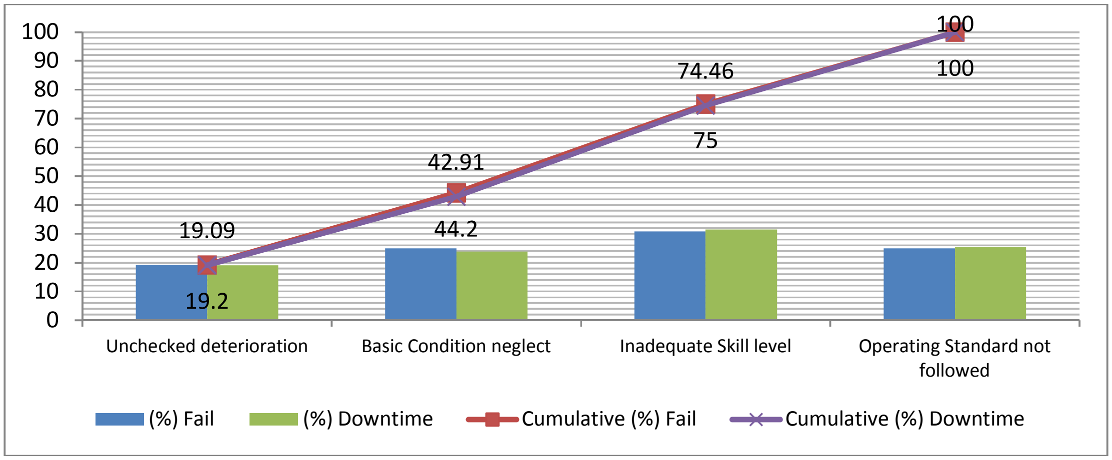

Fig. 11. Pareto chart of all the fails and accrued downtime after TPM Implementation

4. CONCLUSIONS

The study was conducted in a food processing industry that specialized in the manufacture of noodles of different sizes and flavors. Noodle packaging machine was studied and analyzed, using TPM maintenance strategy. The OEE value and the equipment reliability reports have shown a peak progression. However, as observed in the study, the two world class manufacturing strategies JIT and EI are in their nascent stage in the organization. These two strategies needs to be explored and supported to further narrow some maintenance gaps. The employee's involvement (EI) should cut-across intra-functional units and the company's maintenance goals should be targeted to failures that need the biggest improvement. In conclusion, the OEE value after TPM Implementation is quite impressive and this study has shown that with a dedicated improvement culture in the organization, attaining the world class OEE benchmark is not far-fetched.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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