Total Productive Maintenance Parameters Analysis of a Small Medium Indian Manufacturing Industry– A Case Study

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Abstract

World Class Manufacturing levels are the standards set for the industrial market which indicates the performance of the industry regarding world class levels. Total productive maintenance consists of 8 pillars which helps to reach at world class levels. The aim of this study is to find and analyze the Total Productive Maintenance parameters for the selected small medium Indian manufacturing industry's sponge iron unit and compare it with the world class manufacturing levels to obtain the present status of the industry's sponge iron unit with respect to world class manufacturing standards. The basic methodology used in this thesis consists of features such as plant visit, structured interviews, and use of the company's records. The result obtained were of 3 years data with average availability of 97.17%, average performance rate of 93.86%, the average quality rate of 100% and the average overall equipment effectiveness of 91.20%. Hence, it is concluded that the performance parameter lags compared to World Class Manufacturing levels and steps should be taken to improve this parameter as any small edge can provide the unit with better results and improved profits in this competitive market.

Keywords: Total Productive Maintenance (TPM), World Class Manufacturing (WCM), Overall Equipment Effectiveness (OEE)

1. Introduction

The term Total Productive Maintenance originated in Japan in 1971 as a technique to improve the machine's capability to perform, in long run. This part of paper deals with 5 sections:

1.1 Total Productive Maintenance

Total Productive Maintenance is equipment maintenance performed on a company wide basis. Total Productive Maintenance is basically a maintenance technique carried out by all employees through small group activities. [1]

Total Productive Maintenance is considered as the medical science of equipment and its primary objective is to develop a sense of ownership among the employees of the organization [2] i.e., the employees of the organization think of the machines and the organization as of their own and take responsibility accordingly. The focus of the industry should not be only on the equipment and machineries but also on the people of the organization [3]. Additionally, Total Productive Maintenance optimizes the life, reliability and equipment's functioning capability [4] [5], reducing the major losses and wastages also improving the productivity of the organization, safety and morale of the employees of the organization, quality of the produce and so on [6]. What Total Productive Maintenance is, is a maintenance technique in which following a series of 8 steps called Total Productive Maintenance pillars or principles takes place.

1.2 Total Productive Maintenance pillars

There are 8 Total Productive Maintenance pillars with a foundation 5S which is a Japanese concept and the 5S's are Japanese terms but are translated in equivalent English term for better ease of understanding which are mentioned below [7]:

1. Sorting – Sorting out of unnecessary items.
2. Set in order – Organizing the work place, everything has its own place concept is used.
3. Shining – Maintaining cleanliness in the work place.
4. Standardize- Setting a standard to work on.
5. Sustain- The set standards in previous step needs to be maintained.

Total Productive Maintenance pillars are centered towards reaching World Class Manufacturing levels. Figure 1 shows the house of Total Productive Maintenance with 8 pillars and foundation of 5S with the roof indicating World Class Manufacturing Levels.

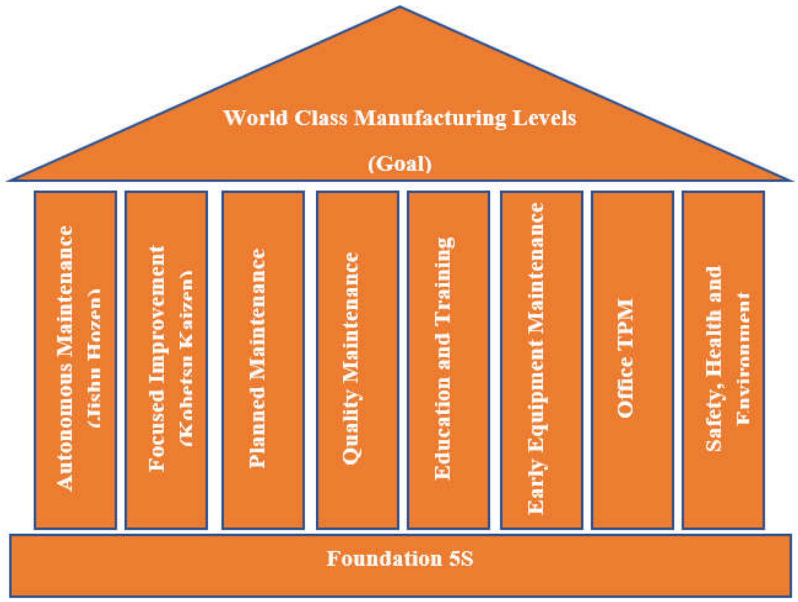

Figure 1. House of Total Productive Maintenance

1.3 Total Productive Maintenance Parameters

Total Productive Maintenance parameters are the tools to observe the equipment's capability of functioning. Total Productive Maintenance parameters indicates the health of equipment, quality of product, performance of the equipment and thus the organization. With these parameters we evaluate if the equipment is meeting the desired standards of World Class Manufacturing or not. There are 4 Total Productive Maintenance parameters which are as following:

1. Availability: It refers to equipment availability which is basically the ability of the equipment to run and perform for the planned time.
2. Performance Rate: It is the ability to function at full designed potential excluding any type of speed loss.
3. Quality Rate: It indicates the amounts of good pieces produced.
4. Overall Equipment Effectiveness (OEE): It is used to indicate the health of the equipment and therefore the health of the unit.

In this study Total Productive Maintenance parameters for the sponge iron unit is calculated.

The equations of these 4 parameters are given in figure 2

Figure 2. TPM Parameters [8]

1.4 Total Productive Maintenance Importance

Total Productive Maintenance helps to eliminate or reduce the six-big losses faced by any typical manufacturing industry (figure 3) improving the Overall Equipment Effectiveness [9]:

Six-major losses	Equipment Failure
	Set-up and adjustment loss
	Idling and minor stoppages
	Reduced Speed
	Defective Products
	Reduced Yield

Figure 3. Six Big Losses [1]

Total Productive Maintenance is generally used in the process of striving towards [9]

- Zero Defects
- Zero Breakdown
- Zero Accidents
- Zero dust and dirt

There could be other benefits of implementing Total Productive Maintenance also, like zero wastages, improving morale of the workers, improving skill level of the workers etc. Working on these targets helps the effectiveness of the equipment increase automatically and which in turn improves the productivity of the unit.

1.5 World Class Manufacturing levels

World Class Manufacturing levels are the benchmark values of the Total Productive Maintenance parameters, and it becomes one of the target of the industries wanting to implement Total Productive Maintenance to reach that value. The minimum values of Total Productive Maintenance parameters for an industry to be called world class were given by [1] well known as the father of Total Productive Maintenance, by his work experience in different industries. These values are as follows:

Table 1. World Class Manufacturing levels

Total Productive Maintenance Parameters	World Class Manufacturing levels
Availability	90%
Performance Rate	95%

Quality Rate	99%
Overall Equipment Effectiveness	85%

Of course, it should be noted that these values were obtained by Nakajima's observation in Japanese industries in his period but it is still considered as the benchmark of World Class Manufacturing levels.

Effective implementation of Total Productive Maintenance has already been proven to be beneficial in this highly competitive era with very less investments [10] [11].

This paper deals with finding and analyzing the Total Productive Maintenance parameters of the selected small medium Indian manufacturing industry's sponge iron department and comparing it with World Class Manufacturing levels to obtain the present status of the unit.

2. Methodology

10 steps methodology is followed in this paper:

2.1 Problem Identification:

Total Productive Maintenance is a maintenance technique that is used worldwide for reaching or managing the World Class Manufacturing levels which can be measured by using Total Productive Maintenance parameters. This paper is centered towards finding and analyzing the Total Productive Maintenance parameters of the selected small medium manufacturing industry's sponge iron department. The study was conducted in a small medium Indian manufacturing industry's sponge iron unit which have not implemented Total Productive Maintenance yet in the unit and the entire industry.

2.2 Research Design:

The upcoming steps were planned and scheduled in this step.

2.3 Industry Selection:

Industry ABC, a small medium Indian manufacturing industry is a Power and Ispat limited industry which produces different steel products and produces direct reduced iron or DRI more commonly known as Sponge Iron from which the steel products are manufactured. Among the different plants the sponge iron unit is selected.

The industry visited is referred in this paper as ABC industry as requested by the industry itself. The ABC industry when asked about being named in the paper asked to remain anonymous, when inquired about it they mentioned some previous cases of data theft and were still recovering from the bad naming of the industry and were also concerned over the competitors and therefore being extra cautious they asked us to perform our research but not to share the industry's name anywhere.

The sponge iron department consists of 2 rotary kilns of designed 350 TPD (tons per day) capacity of producing sponge iron. Therefore, net ideal output of the production unit is 700 TPD.

The Total Productive Maintenance parameters are calculated for the sponge iron unit as the performance of the organization of manufacturing sponge iron depends on the performance of the sponge iron unit.

2.4 Plant Visit:

Plant visit helped to understand the details of functioning of the sponge iron plant and helped to understand the day to day routine and work culture owned by the sponge iron unit.

2.5 Structured Interview:

Interviews with the different managers, staff members of different departments helped to obtain and understand the data essential for the study. The ideal capacity of the kiln to produce sponge iron, the type of maintenance technique used in the industry, causes of breakdown of the rotary kiln, etc. were obtained in this step.

Preventive and Breakdown maintenance techniques is used in the industry. Only using preventive maintenance cannot help avoiding breakdowns [1]. The target of the unit is to be able to run for out of 12 months at least 11 months keeping the unit down for at least 30 days.

2.6 Data Collection:

Year wise data were collected in the structured interview step and was obtained from the company's records. The more the data the accurate the result will be and since data of 3 years were complete up to date and usable, therefore data of 3 years was selected.

2.7 Collected Data Analysis:

Data obtained from the company is analyzed.

2.8 Parameter calculation from Data obtained:

The already mentioned Total Productive Maintenance parameters are calculated in this step.

2.9 Parameter comparison with World Class Manufacturing levels:

The Total Productive Maintenance parameters are compared with World Class Manufacturing standards.

2.10 Calculated data analysis:

The calculated Total Productive Maintenance parameters are analyzed in this step.

3. Results and Findings

3.1 Collected Data Analysis:

- Available Time Analysis:

The analysis done in this section is based upon collected data. The collected data are mentioned in table 2, 3 and 4.

Table 2. Data Collected Regarding Availability

Year	Total time in a year (Hours)	Planned Downtime (Hours)	Planned Production Time (Hours)	Unplanned Downtime (Hours)	Actual Operating Time (Hours)
2014-15	8640	720	7920	288	7632
2015-16	8640	720	7920	240	7680
2016-17	8640	720	7920	144	7776

The planned production time is the difference between the Total Time allotted (Total time in a year) to the planned downtime. Actual Operating time is the difference between the time the sponge iron unit is allotted to operate (Total time in a year) to the time the sponge iron unit was down (Total Downtime i.e., planned and unplanned).

The kilns or the sponge iron unit needs to perform for 12 months but for ease of functioning, planned downtime of 30 days is taken and the unplanned downtime is the excess time the unit was down.

Since preventive maintenance technique is used in the industry the planned downtime of 30 days is kept must.

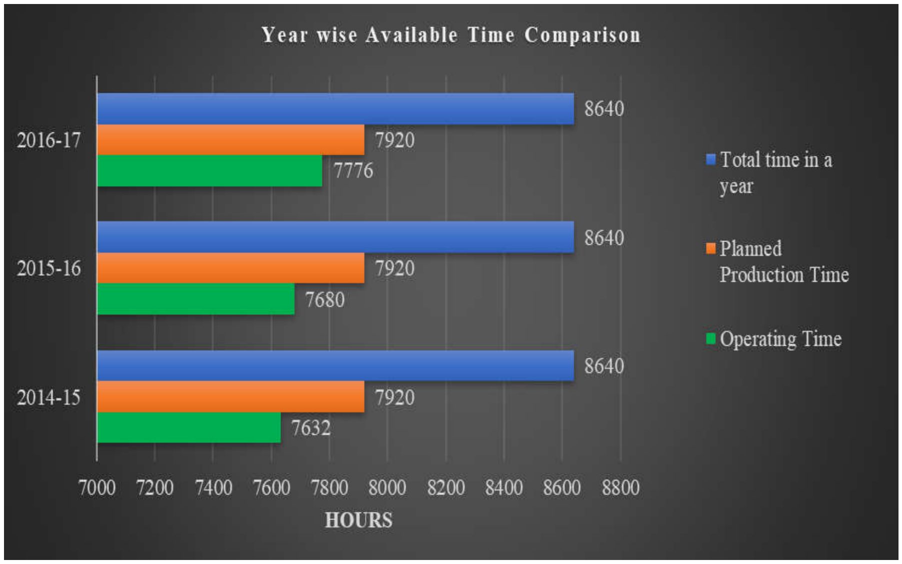

Figure 4. Available Time Comparison

Figure 4 represents the comparison of available time in the sponge iron unit for different years.

From the figure 4 it can be observed that the downtime has been exceeded from the planned downtime in all the years only by a little but exceeded and reduced the actual operating time.

- Plant performance analysis:

Table 3. Data Collected Regarding Plant Performance

Year	Plant Capacity (MT)	Target Production (MT)	Actual production (MT)
2014-15	255500	210000	195900
2015-16	255500	220000	208060
2016-17	255500	240000	224900

MT = Metric Tons

The plant capacity is calculated using the designed cycle of the unit i.e., 700 tons per day, since the unit is to run for 365 days, then the ideal capacity of the plant becomes 365 times 700 i.e., 255500 tons.

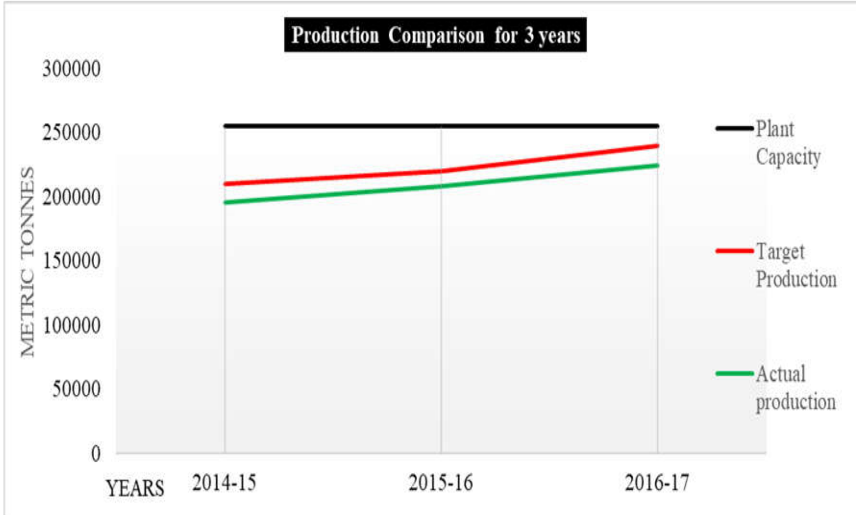

Figure 5. Production Comparison

Figure 5 represents the comparison of production in the unit for different years.

It can be seen from figure 5 that the sponge iron department was very close to the target they set in terms of production. Also, it can be noticed that the target production does vary but increasing in nature and so is the actual production which indicates the progressive nature of the sponge iron department.

- Quality Analysis:

Table 4. Data Collected Regarding Quality

Year	Defective products
2014-15	Nil
2015-16	Nil
2016-17	Nil

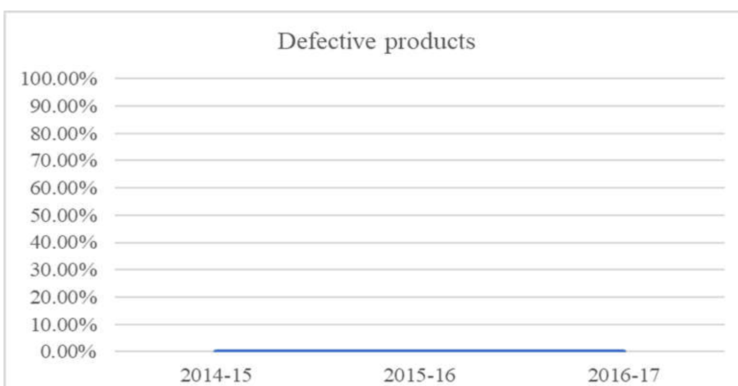

Figure 6. Defective Products Comparison

Figure 6 represents the number of defective products produced in different years.

3.2 Parameter calculation from Data obtained:

The Total Productive Maintenance parameters calculated with the help of the collected data from tables 2, 3 and 4 using the equations mentioned in figure 2 is given in table 5

Table 5. Data Calculated

Year	Availability (%)	Performance rate (%)	Quality Rate (%)	Overall equipment effectiveness (%)
2014-15	96.36%	93.29%	100.00 %	89.89%
2015-16	96.97%	94.57%	100.00 %	91.71%
2016-17	98.18%	93.71%	100.00 %	92.00%
Average	97.17%	93.86%	100.00 %	91.20%

3.3 Parameter Comparison with World Class Manufacturing levels:

The Total Productive Maintenance parameters calculated in table 5 is compared with World Class Manufacturing levels which are mentioned in table 1

Figure 7 shows that the availability of the unit for 3 years with World Class Manufacturing standards, the first 2 years the availability was lower than 3rd year but all in all above the World Class Manufacturing levels and therefore the average value is also higher than the World Class Manufacturing value. Also, it should be noted that the availability is increasing with year.

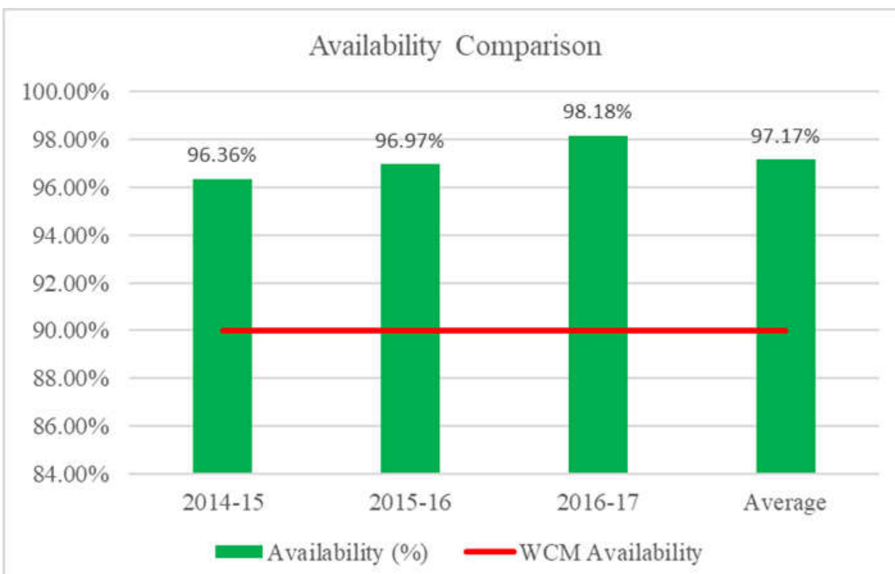

Figure 7. Availability Comparison

Figure 8 shows the variation of performance rate with World Class Manufacturing levels, the average value of performance rate is quite low than the World Class Manufacturing level and performance rate never crossed the World Class Manufacturing line in this case, it was better in 2nd year then it went down again.

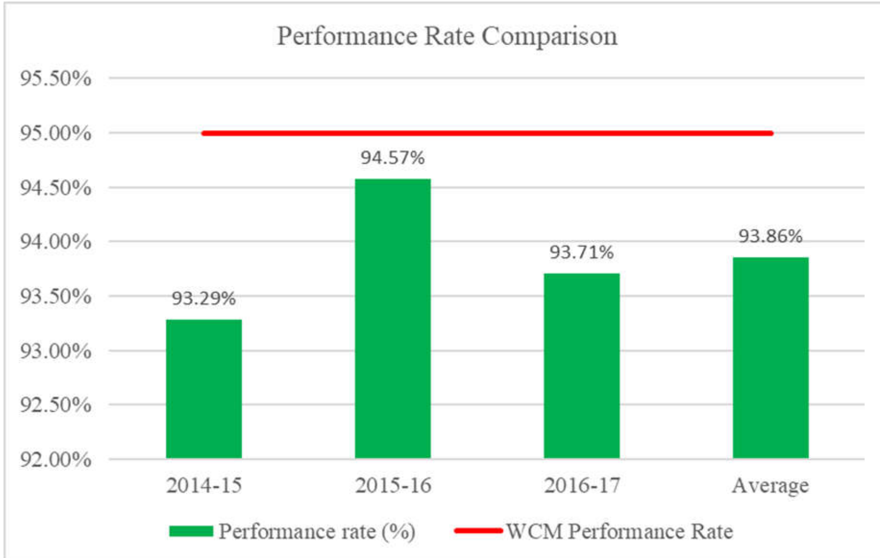

Figure 8. Performance Rate Comparison

Figure 9 shows the comparison of quality rate of the industry to the World Class Manufacturing quality rate which is 100% since no defective products is formed.

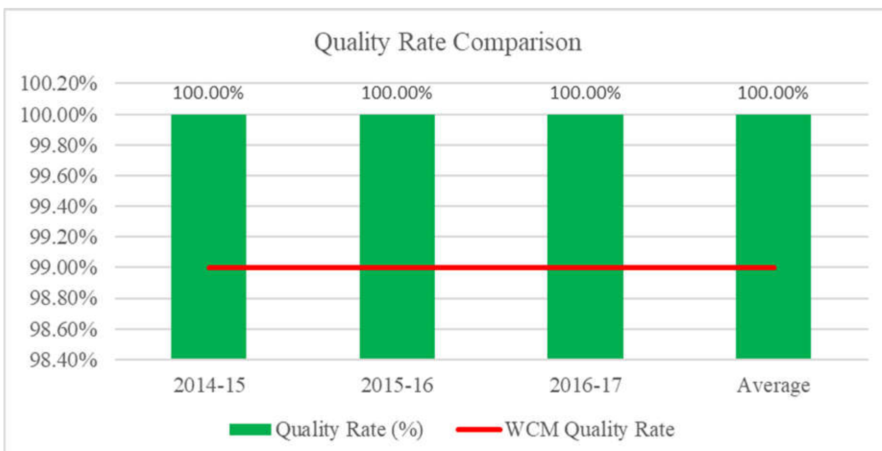

Figure 9. Quality Rate Comparison

Figure 10 indicates that the OEE of the unit varies for different years but stays above the World Class Manufacturing level OEE and it can be noted that OEE is growing with year.

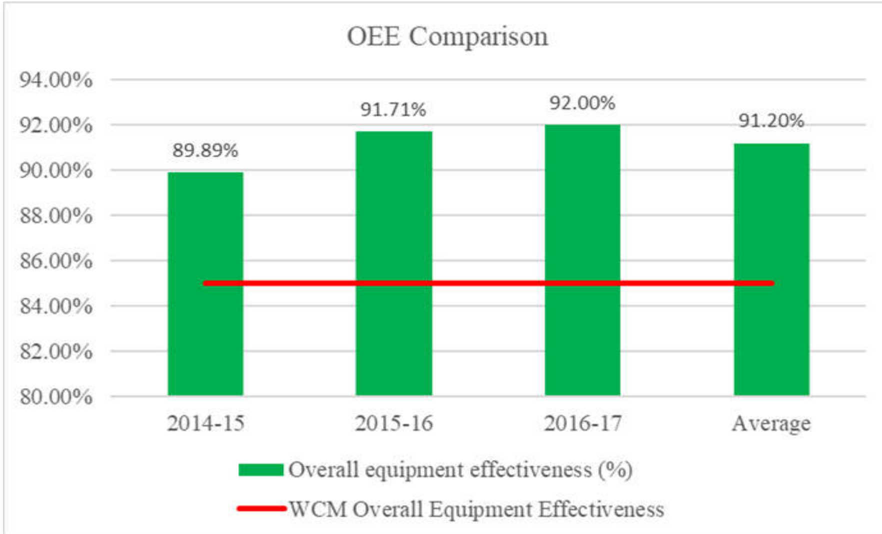

Figure 10. OEE Comparison

3.4 Calculated Data Analysis:

All the data calculated were of the sponge iron department of the selected industry.

From the table 5, the average availability of 97.17%, average performance rate of 93.86%, the average quality rate of 100% and the average OEE of 91.20% when compared with World Class Manufacturing levels seems to be above the World Class Manufacturing standards.

The availability, quality rate, and overall equipment effectiveness satisfies the World Class Manufacturing level and more but out of the 4 parameters performance rate is only parameter which remains below World Class Manufacturing standards.

Availability for different years as mentioned in figure 7 and 11 shows that it varies less but stays above World Class Manufacturing levels with an average of 97.17%.

Performance Rate from figure 8 and 11 shows less variation but under World Class Manufacturing levels with an average of 93.86%.

Table 6. TPM parameters and WCM Level Comparison

Total Productive Maintenance Parameters	2014-15	2015-16	2016-17	World Class Manufacturing levels	Average
Availability (%)	96.36%	96.97%	98.18%	90.00%	97.17%
Performance rate (%)	93.29%	94.57%	93.71%	95.00%	93.86%
Quality Rate (%)	100.00%	100.00%	100.00%	99.00%	100.00%
Overall equipment effectiveness (%)	89.89%	91.71%	92.00%	85.00%	91.20%

Quality Rate from figure 9 and 11 show 100% quality of the products in 3 years above the World Class Manufacturing levels giving an average of 100%.

Overall equipment effectiveness from figure 10 and 11 shows variation among them but stays above World Class Manufacturing standards with an average of 91.20%.

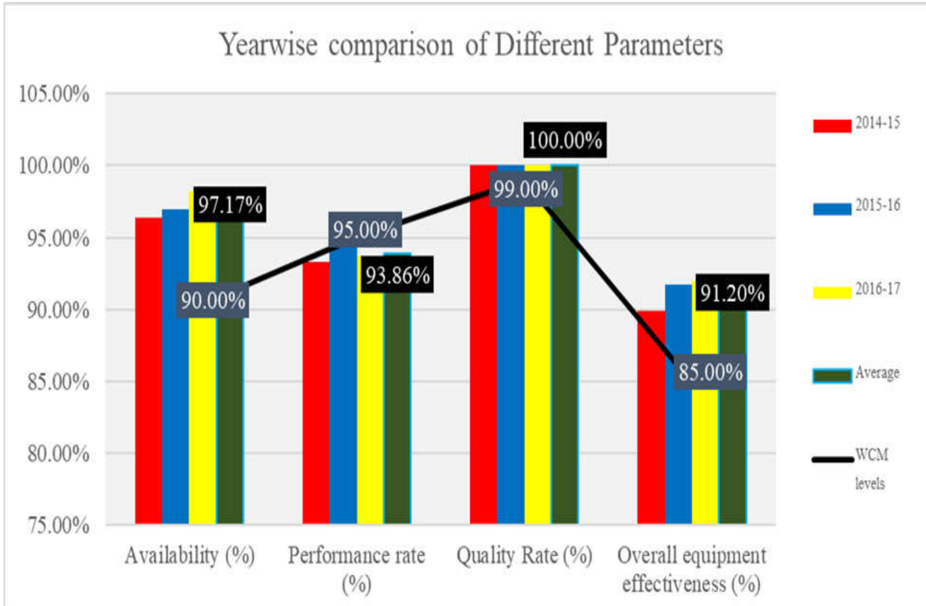

Figure 11. Year Wise Comparison of TPM Parameters

In the figure 11 World Class Manufacturing is represented by a line and years and their average is represented by columns. The World Class Manufacturing line passes through the column representing the standard for that parameter.

4. Discussions

4.1 Availability

The plant needs to operate for 12 months but 30 days of downtime is planned to avoid harmful stresses on the kilns, but as it is seen from figure 4 the actual planned time for production gets reduced due to the reason that unplanned time exceeds and adds to the total time for downtime which is undesirable. Total Productive Maintenance in this case can help to manage the unplanned downtime and keep it under check also Total Productive Maintenance can help to lower the planned downtime resulting in higher availability. Now from table 5 and figure 7 it can be observed that the availability of the year 2014-15 is the lowest at 96.36% and almost similar in 2015-16 at 96.97% and in 2016-17 it is the highest at 98.18% which are all above the World Class Manufacturing standard for availability and the average of these 3 years is at 97.17%, this group of data indicates that the availability of the unit varies but stays above the World Class Manufacturing standard comfortably and reaches World Class Manufacturing always. Total Productive Maintenance helps the plant availability to stay above the World Class Manufacturing availability standards.

4.2 Performance Rate

Figure 5 shows that the actual production reaches close to the target production and shows that the target production as well as the actual production is increasing per year which indicates the progressive approach of the industry. This data helps to know that the industry is very effective in terms of production but figure 8 on other hand shows that the World Class Manufacturing Performance Rate never was crossed in those 3 years, the performance rate was 93.29% in year 2014-15, rose a little bit at 94.57% in year 2015-16, again fell to 93.71% in year 2016-17, with an average of 93.86% never crossing 95%, the World Class Manufacturing mark for the performance rate. This indicates that the kilns in the unit does very well when it comes down to production but the optimum speed at which the kiln should be running it doesn't reach there. Total Productive Maintenance helps the industry to perform at full optimum speed and maximizes the equipment effectiveness and can manage the performance rate above the World Class Manufacturing levels.

4.3 Quality Rate

The number of defective products, from table 4, is obtained as nil.

The quality rate as shown in figure 9 becomes constant at 100% in the absence of any defective products for all the years and surpasses the World Class Manufacturing line.

It was a quite interesting fact to note that the sponge iron department never produces any defective products. When interviewed about this matter it was made clearer.

The sponge iron produced in the rotary kiln in the chosen industry is of 2 grades, grade A and grade B among which most desirable being grade A. The rotary kilns in the production unit produces grade A mainly and rarely produces grade B.

Now from the selling and consuming point of view, grade A is the demand, and the output produced from the kiln has an overall grade of grade A, if any lot consists of grade B it is in negligible amount and does not affect the overall grade of the lot and therefore no defective products is produced. Hence the defective products percentage becomes zero.

4.4 Overall Equipment Effectiveness

The OEE is the parameter calculated with the help of the above 3 parameters, it represents the health of the equipment and therefore the health of sponge iron department. Figure 10 shows the OEE calculated for year 2014-15 is 89.89%, for year 2015-16 is 91.71%, for year 2016-17 is 92.00% and the average of these values is 91.20% which indicates the health of the kilns in the sponge iron unit and therefore the health of the sponge iron unit. Also, all the overall equipment effectiveness values crossed the World Class Manufacturing level for Overall equipment effectiveness which indicates an excellent plant performance and implementing Total Productive Maintenance will only help these parameters to maintain for long time.

5. Conclusion

The question this paper was dealing with an objective of calculating and analyzing the Total Productive Maintenance parameters for the selected small medium Indian manufacturing industry, the answer to this question can be obtained from this case study. The conclusions that can be obtained from this study are as follows:

- Three parameters are above World Class Manufacturing standards but performance rate parameter is below in comparison with World Class Manufacturing levels, which shows excellent product quality, excellent availability, excellent overall equipment effectiveness but a less expected performance rate compared to World Class Manufacturing level.
- This study reveals that although Total Productive Maintenance is not implemented in the selected sponge iron department it is applicable in this sponge iron department since not all the Total Productive Maintenance parameters are fulfilled by the department i.e., performance rate, that means there is a room of improvement in these parameters which an effective implementation of Total Productive Maintenance can provide.
- It can be observed that the variation of the Total Productive Maintenance parameters among it selves is low and with World Class Manufacturing levels these parameters are quite close or above (figure 11) meaning the industry is performing quite well as well which conforms with the point of the managers of the sponge iron unit that the industry do not experience losses, which indicates another point that when implementation of Total Productive Maintenance pillars takes place it should be implemented at slow pace giving time to the departments to adjust with the new philosophy introduced, so that no abrupt change in the Total Productive Maintenance parameters occurs. Implementation of the Total Productive Maintenance should be such that, the lagging Total Productive Maintenance parameter grow and reach to World Class Manufacturing levels but not at the cost of decrease in other parameters as that can affect the company’s performance.

The market is full of competition and any small edge over the competitors is always desirable and any techniques that does that, should be applied but since the selected industry is a small medium manufacturing industry, it might cost more in the process of complete Total Productive Maintenance pillars implementation compared to the profit it will gain in upcoming years i.e., instant financial loss could be more than the long time profit obtained after the implementation of Total Productive Maintenance as indicated by [12] since the industry is already performing well, not to all the desired levels of World Class Manufacturing but very close.

Also considering the Total Productive Maintenance parameters, there is no doubt that there is room of improvement in the parameters specifically performance rate parameter and therefore, if that goal is achieved it will execute the satisfactory level of Total Productive Maintenance implementation in the industry's sponge iron department which in turn, improves the productivity, work culture, working environment conditions etc. and hence the profits of the industry [9].

Therefore, the overall conclusion is that the company is under performing, as can be observed from the performance rate parameter regarding world class levels and can consider taking partial implementation of Total Productive Maintenance i.e., implementing only few pillars at a time will be helpful as, Total Productive Maintenance implementation is a difficult and time-consuming process [12] [13] [14]. Almost 2 to 3 years can be consumed for total implementation of Total Productive Maintenance and up to 5 years in some cases and might take more if no urgency is shown as stated by [15]. Partial implementation of Total Productive Maintenance can help the sponge iron department improve the lagging Total Productive Maintenance parameter without any concern of financial or economic loss as mentioned for Small Medium Enterprise's by [12]. No urgent need of implementation of all the Total Productive Maintenance pillars but implementing some of the pillars slowly step by step can help the industry reach above and maintain all the World Class Manufacturing levels comfortably, in this case particularly the performance rate parameter can certainly be improved.

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