

Lean Six Sigma Approach to Improve Overall Equipment Effectiveness Performance: A Case Study in the Indian Small Manufacturing Firm

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Abstract: Due to increased competition in the global market, manufacturers are focusing on product quality, cost of the product and product delivery time. Every manufacturing firm exercises their new concepts and innovative ideas for continuous improvement in their business process in order to sustain in their market. Lean six sigma approach is the combination of lean methods and six sigma process tools and it is a well consolidated process for improving their processes. Many small sized manufacturing firms are yet unacquainted about the lean and six sigma process tools. Thus, a company should initiate a new quality system to continually improve and increase both their quality and performance efficiency. The case study was conducted in a Small and medium-sized pump manufacturing company and one of these machines had a poor OEE with a large variety. This led to on-time delivery problems which is a root cause for customer frustration. The poor OEE led to high costs in terms of rework and re-inspections of the products. Following a typical root cause analysis is made; the problems are removed and improved the Critical to Quality characteristics (CTQs) which have increased the OEE and reducing its variability. Tools such as Single Minute Exchange of Die (SMED), 5s and six sigma process tools were implemented to remove the root causes. The aim of this paper is to illustrate the use lean Six Sigma approach in the small and medium sized manufacturing firm to improve Overall Equipment Effectiveness (OEE).

Key Words: Lean Manufacturing (LM), Small Medium Enterprise (SME), Overall Equipment Effectiveness (OEE), Performance Measures.

1. INTRODUCTION:

SMEs are the backbone of the Indian manufacturing sector and became engine of economic growth in India. It is estimated that SMEs account for almost 40% of value addition in the manufacturing sector and 90% of industrial units in India. Small scale industry has been one of the major flat of India's economic development strategy since Independence. From very beginning India accorded high priority to small and medium enterprises (SMEs) and followed support policies to make these enterprises vibrant, visible and over time, these had become major contributors to the growth of GDP rate. At present, SME occupies a position of strategic importance in the Indian economic value due to its significant contribution in terms of employments, exports and outputs. SMEs industry accounts for 50% of total manufacturing exports and 40% of gross industrial value addition. More than 3.2 million units were spread all over the country producing about 8000 items, from very basic products to highly sophisticated products. SMEs are the biggest employment-providing area next to agriculture area, providing employment to 29.4 million people.

The growth of Indian SMEs are increased in the global market due to the large scale manufacturers who are outsourcing the products from the TIER2 [small firms] suppliers. In order to sustain TIER1 manufacturing contracts nowadays SME are focusing for the good quality of products and services. To assess this strategy, many SMEs owners or managers are focusing of their organization status to the next level. Here, the Lean, Six Sigma approach and OEE [Overall equipment efficiency] concepts are implemented to improve the performance level of the SMEs. This performance levels will increase the grade of the SMEs, so that the economic status of the particular concern would alternatively increased.

2. LITERATURE REVIEW:

2.1 SMEs IN INDIA

SME is an integral part of the Indian industrial unit. The feature of Small and Medium Enterprises (SMEs) are high labour absorption and less capital investment which has created unprecedented importance to this sector. The SMEs plays most important role in efficiently allocating the enormous labour supply and scarce capital by implementing labour intensive production processes.

2.2 Micro, Small and Medium Enterprises

The Micro, Small and Medium Enterprises Development facilitate the development of the enterprises and enhance their competitiveness. This act gives legal frameworks for “enterprise” which includes the manufacturing and services. In Table I the integration of the 3 tiers of the enterprises namely, medium, small and micro (Development Commissioner of MSME, 2009).

Table 1: Classification of firms

Category	Investment (Plant & Machinery)	Service
Micro Enterprises	< 25 lacs	< 10 lacs
Small Enterprises	< 5 crores	< 2 crores
Medium Enterprises	< 10 crores	< 5 crores

2.3 Importance of SMEs

Importance of SME is well understood by national economies. SMEs are capable of creating jobs with less amount of capital and in locations which makes SMEs attractive to policy makers. They remain as a heterogeneous group, in which different organizational structures ranking from proprietorship to corporate, engages in factories to service organizations activities and in some countries they differ from industry to industry. The SMEs development agencies such as Small Business Administration (SBA) of the US, SIDO (Small Industries Development Organization) in India and Small Business Service (SBS) of United Kingdom are the intermediaries set up by the Government (Chandra, 2004).

2.4 Contribution of SMEs

Contribution of individual SMEs are in small numbers but they had collectively emerged as a dominant player in the national economies. The major importance of Small and Medium Enterprises in India is due to maximum number of units and the employment opportunities. This area plays a important role in the development and employment to minorities, rural people and also to women. The sector is to employ about 59 million people in over 26 million units throughout the country.

2.5 Lean Manufacturing

Ultimate goal of lean is to identify all types of waste present in the Current process and to take necessary steps to eliminate the waste. Lean production and Lean maintenance utilizes techniques and principles that improve efficiencies of value, operations, product development, suppliers and customers relations that requires less space, less human effort, less relations that requires less space, less human effort, less capital and less time to make products with fewer defects which are compared with the previous system of mass production (Paul M. Gibbons, Stuart C. Burgess). Lean maintenance works that is to be carried out by application of TPM, Kanban, 5S, and And on with less waste, less maintenance space, less human effort, less investment in tools, and less inventory, and in less time. Total productive maintenance (TPM) is a methodology to increase the availability of the existing equipment and increases maximum effectiveness of equipment, tidier, neat and clean work place hence it reduces the further capital investment. Maintenance in the manufacturing firms is none productive since it does not generate cash directly. Industry must produce goods of the right quantity and quality for the customers and able to deliver them at the right time. For this plant or equipment must operate accurately and efficiently.

2.6 Why OEE in SMEs?

In modern manufacturing firm Effectiveness of equipment plays a major role to less the number of rejections and achieve the higher productivity. In the current dynamic and challenging environment, reliable manufacturing equipments and OEE are the main components for increasing performance and profitability of manufacturing systems. Maintenance may be breakdown, corrective, preventive, etc. Maintenance planning consist two things, first is to plan the maintenance schedule in advance and second is the maintenance for different types of failure in the Industry.OEE needs three key performance measurements: Availability, Performance Rate and Quality Rate for the calculation. The OEE focuses on improving the performance of machinery and processes by identifying those performance opportunities that will have the greatest impact to the bottom line.OEE is ratio of actual equipment output to its theoretical maximum output. OEE measurements are defined as:

- (a) Availability or uptime (downtime: planned and unplanned, tool change, tool service,etc.)
- (b) Performance Efficiency(actual vs. design capacity) and

(c) Rate of quality output(defects and rework)

2.7 TPM

Total Productive Maintenance is a Japanese concept. Total Productive Maintenance has been developed on the basis of productive methodologies and maintenance concepts. TPM concept was first introduced by M/s Nippon Denso Co. Ltd. of Japan. Total Productive Maintenance is an innovative approach of maintenance used to optimize equipment effectiveness eliminates breakdowns and promotes independent maintenance by involving total workforce. Total Productive Maintenance concept is used to maintain the equipment in best possible to avoid unexpected breakdowns, speed losses, and quality defects. Zero accident, Zero defects, and Zero breakdowns are the three ultimate goals of TPM (Nakajima, 1988; Willmott, 1994; Noon et al., 2000). The main goal of Total Productive Maintenance program is to bring maintenance labour and production labour together. A Total Productive Maintenance program typically enlarges the responsibility of production workers for detecting machine breakdown, performing basic maintenance, and keeping work areas clean and controlled I.P.S. Ahuja, J.S. Khamba, (2008). The basic exercises of Total Productive Maintenance implementation are often called the elements or the pillars of TPM. The main eight pillars of Total Productive Maintenance include independent maintenance; determined maintenance; planned maintenance; education and safety, health and environment training; office tpm; development management; and quality maintenance; (Ireland and Dale, 2001; Shamsuddin et al., 2005; Rodrigues and Hatakeyama, 2006). The eight pillars of Total Productive Maintenance implementation plan for Small Medium Enterprises are as shown in Figure 1.



Figure 1 Eight Pillars of Total Productive Maintenance

3. CALCULATION OF OEE:

3.1 Overall Equipment Effectiveness

OEE accounts three major components as they are,

- Availability,
- Performance Rate,
- Quality Rate.

OEE percentage can be seen as the snapshot of the current production efficiency of equipment, line or cell.

$$\text{OEE} = \text{Availability} \times \text{Performance Rate} \times \text{Quality Rate}$$

a. Availability:

Availability takes downtime loss into account.

$$\text{Availability} = \frac{\text{Operating Time}}{\text{Planned Run Time}} \times 100 \%$$

Here, the planned time is the total time that a machine to produce,

Therefore

$$\text{Production Time} = \text{Available Time} - [\text{Break Time} + \text{Stet up}]$$

During the available period, machine may be not operating for a number of reasons: planned interval breaks in production schedule, planned maintenance break, preventative resting time, lack of works and others. Therefore, if there is any planned downtime, that should be eliminated from the available time and what is left is the active time.

b. Performance Rate:

The performance only depends the gross operating time. A property of the gross operating time is that the speed exceeds zero limit at any time. In the gross operational time there are no down time losses. The performance factor is a measure for the speed losses.

$$\text{Performance Rate} = \left[\frac{\text{Total Pieces}}{\text{Operating Time}} / \text{Ideal Run Rate} \right] \times 100 \%$$

c. Quality Rate:

During the total operational time, no down time or speed losses occur. It is not certain that the total produced output is exact quality specifications. To increase insight, the quality factor is defined:

$$\text{Quality Rate} = \left[\frac{\text{Total Output} - \text{Average Reject}}{\text{Total Output}} \right]$$

4. SURVEY ANALYSIS:

We made a survey at the pump industry to find the on going process and in order implement the OEE concept with mobile maintenance to increase the production efficiency and minimize the time of the production system. We had made two surveys on the industry one is before implementing the OEE concept and another one is after implementing the OEE concept with mobile maintenance, the following calculations shown in table II are OEE calculation made before installation of mobile maintenance.

Table 2. OEE Calculaton before installation of Mobile Maintenance

Item	Data
Shift Length	8 hours = 480 min.
Short Breaks	2 @ 15 min. = 15 min.
Meal Break	1 @ 30 min. = 30 min.
Down Time	80 minutes
Ideal Run Rate	20 pic per hour
Total Pieces	90 pieces
Reject Pieces	19 pieces

Planned Production Time = [Shift time - Breaks] = [480 – 60] = **420 min**

Operating System = [Planned Production Time – Down Time] = [420 -80] = **380 min**

Good Pieces = [Total pieces – Rejected pieces] = [90 – 19] = **71 pieces**

Table iii gives the detailed calculation of the Availability, performance, quality and OEE in the unit. It show us the details before installation of the mobile maintenance. Here we had calculated availability using operating time and panned production time. And the performance using the total pieces, operating time, nad ideal time rate, and quality by good pieces to the total pieces.

Table 3. Calculaton before installation of Mobile Maintenance

Availability	Operating Time / Planned Production Time
	340 minutes / 420 minutes
	0.8095 (80.95%)
Performance	(Total Pieces / Operating Time) / Ideal Run Rate
	(90 pieces / 340 minutes) / 20 pieces per hour
	0.8021 (80.21%)
Quality	Good Pieces / Total Pieces
	71 / 90 pieces
	0.7888 (78.88%)
OEE	Availability x Performance x Quality
	0.8095 x 0.8021 x 0.788
	0.5121 (51.21%)

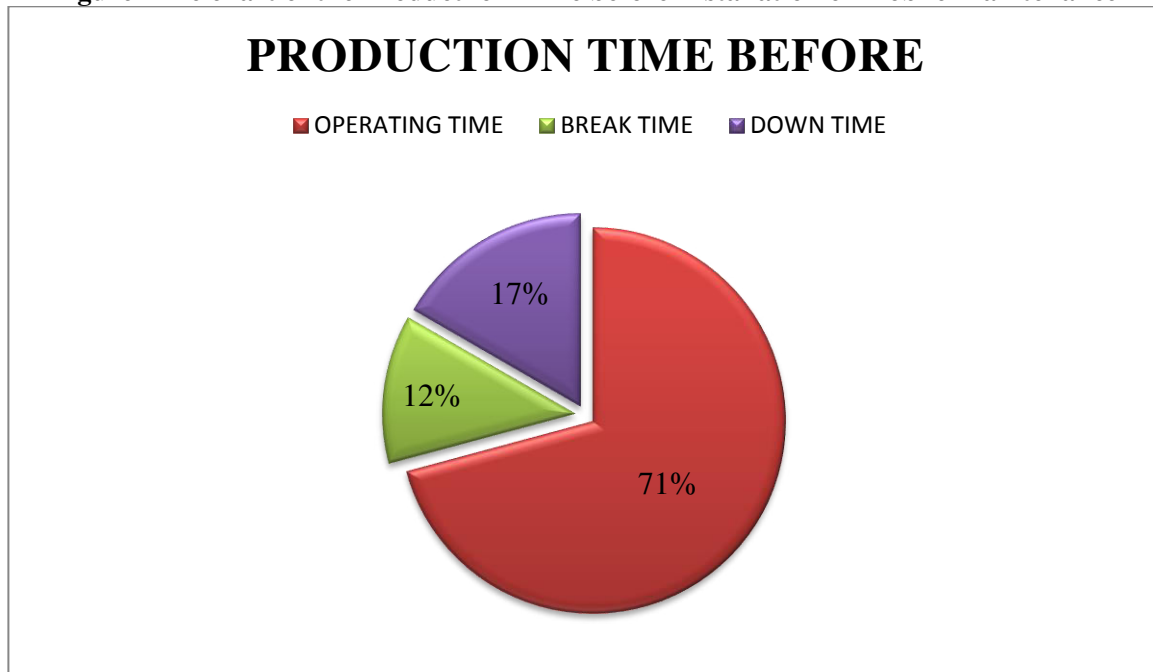
Figure 2 Pie chart of the Production Time before Installation of Mobile Maintenance

Figure 2 represent the percentages of the operating time, break time, down time of the process involved in SME before the installation of mobile maintenance. Here the total operating time is 71% , break time is 12% and the down time is about 17%.Here the downtime is due to the machine breakdown.

5. MOBILE MAINTENANCE:

The aim is to have trouble free machines and equipments that produces defect free products for total customer satisfaction. Researchers proposed that mobile maintenance has got the place along with maintenance planning. Maintenance may be preventive, breakdown, corrective, etc. Now-a-days, Mobile maintenance is the new generation concept which is adapted especially by Small Medium Enterprises. SMEs is have few numbers of machines which requires very less maintenance as compared to large industries. Other maintenances such as breakdown, corrective, preventive maintenance program are suited for large industries but SMEs needs less maintenance when compared to large industries. These SMEs needs only a preventive or mobile maintenance more Offaly and sometimes require breakdown maintenance. The main differences between preventive maintenance and mobile maintenance is that the preventive maintenance is have a pre determined schedule of each equipments on the industrial floor but mobile maintenance is does not have schedule. In Mobile Maintenance the maintenance personals are roaming along with a trolley of tools and spare parts on the shop floor to check any machine at any time and try to identify the defect or fault and also train the machine operators how to find the defect and how to eliminate these types of defects. SMEs as well as some large industries is also using the mobile maintenance. Mobile maintenance is one of the pillars of the model in TPM for Small medium enterprises. Researchers are implementing this type of mobile maintenance concept in this case study. One of the researcher has found that few SMEs are most probably using this mobile maintenance along with other maintenance like preventive strategy..

5.1. Installation Of Mobile Maintenance:

Mobile maintenance concept requires a little numbers of maintenance person with a trolley with some important tools, specific standard of nuts and bolts, grease, brushes, safety cloth and important spare parts, screws, oils, etc. Mobile maintenance personals with trolley will move on the floor to oil, grease, clean the machineries regularly and also to maintain the machines so that unplanned downtime of machineries will reduce as shown in table iv. This maintenance is a very important strategy, especially in SMEs. Industrial floor area of small medium enterprises are low, so that mobile maintenance team can easilycheck and maintain each and every machine quickly.

Table IV OEE Calculation after installation of Mobile Maintenance

Item	Data
Shift Length	8 hours = 480 min.
Short Breaks	2 @ 15 min. = 15 min.

Meal Break	1 @ 30 min. = 30 min.
Down Time	45 minutes
Ideal Run Rate	22 pic per hour
Total Pieces	110 pieces
Reject Pieces	15 pieces

Calculation for shift

Planned Production Time = [Shift Length - Breaks] = [480 - 60] = **420 minutes**

Operating Time = [Planned Production Time - Down Time] = [420 - 45] = **375 minutes** **Good Pieces** = [Total Pieces - Reject Pieces] = [110 - 15] = **90 pieces**

Table v gives the detailed calculation of the Availability, performance, quality and OEE in the unit. It show us the details after the installation of the mobile maintenance. Here we had calculated availability using operating time and panned production time. And the performance using the total pieces, operating time, nad ideal time rate, and quality by good pieces to the total pieces

Table V Calculation before installation of Mobile Maintenance

Availability	Operating Time / Planned Production Time
	375 minutes / 420 minutes
	0.8928 (89.28%)
Performance	(Total Pieces / Operating Time) / Ideal Run Rate
	(110 pieces / 375 minutes) / 22 pieces per hour
	0.7999 (79.99%)
Quality	Good Pieces / Total Pieces
	95 / 110 pieces
	0.8636 (86.36%)
OEE	Availability x Performance x Quality
	0.8928 x 0.7999 x 0.8636
	0.6168 (61.68%)

Figure 3 Pie chart of the Production Time after Installation of Mobile Maintenance

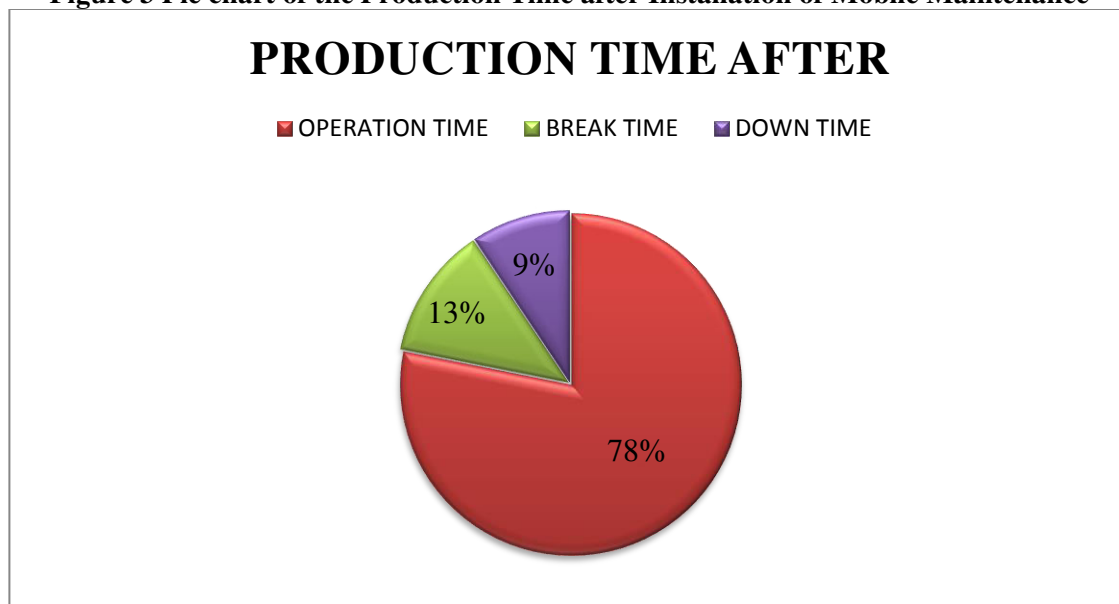


Figure 3 represent the percentages of the operating time, break time, down time of the process involved in SME after the installation of mobile maintenance. Here the total operating time is 78% , break time is 13% and the down time is about 9%.Here the downtime is reduced by the installation of the mobile maintenance.

6. CONCLUSION:

At present, the quality of the product is playing a vital role to satisfy customers needs, in which

it can be attained by providing a good maintenance strategy to maintain equipments and machines on the floor. When machines are more reliable to produce products of précised quality therefore that the customer will get satisfied automatically. For the maintenance of machines, maintenance department should adopt mobile maintenance or preventive maintenance strategy in small and medium size industries. Both maintenance are the part of the proposed TPM concept. This irrigation pump manufacturing SME has adopted mobile maintenance and got better improvement in the productivity by reducing downtime due to breakdowns. Availability, performance, quality rate have increased by providing this new maintenance concept. We have concluded that availability, performance, quality rate and OEE of the plant will increased by the implementation of the mobile maintenance concept and as shown in Table III. Table II shows that the OEE of all the machines was less than 50 percent before implementation of mobile maintenance and it increases up to the range of 60 to 65 per cent after implementation of the mobile maintenance concept. According to researchers, that was a drastic change in OEE of equipments in small and medium scale industry is due to the implementation of mobile maintenance.

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