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Productivity Improvement in Manufacturing Industry Through Lean Six Sigma Approach

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In Manufacturing Industry, there is more competition in the world. The ability to reduce production cycle times can be a decisive competitive advantage. A company's cycle time measures its efficiency and is a bellwether for profitability and competitiveness. The major problems are improved productivity, lead time, and defect rate. The Lean Six Sigma can be considered a guide for Problem Solving and Productivity Improvement. Lean Six Sigma has become a popular term in manufacturing companies. It is not easy to reduce manufacturing cycle times and focus on learning how to reduce cycle time or the expense of additional logistics investment without understanding the value. DMAIC cycle in Six Sigma into productivity improvement The goal of the Lean Six Sigma application is to improve the process of mechanical production machining, as well as improve from semi-automatic machines into automatic machines to improve productivity and reduce waste. Lean Six Sigma is a combination of two powerful Process improvement methods. The Productivity level is affected by the higher Cycle time of Production. Lean and Six Sigma practitioners are integrating the two strategies into a more powerful and effective hybrid, addressing many of the weaknesses and retaining most of the strengths of each approach. The main objectives are to reduce the non-value added time, reduce the lead time, reduce the total distance travelled, and reduce the defect rate. There are three commonly Referred Categories of Activities: Value – Added Activities (VA), Non – Value Added (Required Activities) [NA], Non – Value Added (Un Required Activities). NonValue Added Time and Value Added Time. Cycle Time and takt time are calculated. A case study is conducted in the manufacturing industry. As a result, the non-value-added time and distance travelled are reduced. Before LSS Methods, Value Added Time was 44.9 Seconds, and Non-Value Added Time was 482.96 seconds. The total Cycle Time is 527.86 Seconds. After LSS Methods, Value Added Time is 44.9 Seconds, and The Non – Value Added Time is Reduced by 337.01 Seconds.

Keywords: Lean, Six Sigma, Value Added Time, Non Value Added Time, LSS, Cycle Time, Lead Time, Manufacturing Industry, Defects Rate, DMAIC.

1. Introduction

The Goal of the Six Sigma methodology affected the Reduction of lead and cycle times in a manufacturing process. Lean and Six Sigma are two different approaches to continuous process improvement; their integration began and spread rapidly in the late 1990s. Six Sigma is the concept of improving the quality by reducing process variations, making continuous improvements, reducing defect rates and improving the processes [1]. Lean Six Sigma (LSS) is a structured, data-driven approach that integrates Lean Manufacturing and Six Sigma. LSS is a process improvement approach that analyses Quantitative data on process performance to identify, eliminate, and control problems and deficiencies related to Reduction Cycle Time, product quality, improve Productivity, and Manufacturing cost [2]. This process improvement methodology for enhancing quality levels was developed by Motorola in 1986 for its high volume manufacturing environment to increase its competitiveness against Japanese companies. Six Sigma is a well-structured knowledge management approach that focuses on reducing variation, measuring defects, and improving the quality of products, processes and Productivity [3]. Lean Six Sigma as a "hybrid methodology designed to accommodate global challenges and international constraints by capitalizing on two powerful process improvement methodologies: Six Sigma and Lean Thinking". Following the expansion and recognition of Lean and Six Sigma, Lean Six Sigma emerged were the first companies to start experimenting with the combination of the two process improvement methods was the first to realize the two methods are complimentary to one another (as the implementation of one method does not negatively impact the implementation of the other method) [4]. The Term 'Sigma' taken from the Greek alphabet, is used to designate the distribution or spread of the mean (average) of any parameter of product, process or procedure. In the manufacturing Processes, Sigma capability is a metric that indicates how the process is behaving [5]. The higher the sigma value, the better the capability of the Implementation of Six Sigma approach to quality improvement Process to produce defect-free work [6]. A Case Study is made in a manufacturing industry. The sequence of operations are made in Grinding, lathe, undercut, Induction hardening, surface grinding and cleaning machines. The non-value added time and total distance travelled, lead times are calculated from above processes and its values are high [7].

Objectives

The main objectives of this paper is:

- To reduce the non-value added time
- To reduce the lead time
- To reduce the total distance travelled.
- Reduction Defects Rate

2. Methodology

Lean Six sigma is a structured approach for Productivity Improvement, which involves the rigorous drive of the key principles in to the organizations strategy and should become the part of the philosophy. Six-Sigma DMAIC is a "simple performance improvement model" of an existing process to help firms achieve significant performance improvement by reducing the cost [8]. Six Sigma identifies causes of variation to develop improvement strategies. The selected Six-Sigma improvement framework used is DMAIC. DMAIC problem solving strategy relies on the following five phases: Define Measure, Analyse, Improve and Control.

This research study aims to apply the core principles of Six Sigma to minimize machine downtime, specifically utilizing the DMAIC (Define, Measure, Analyze, Improve, and Control) methodology. The primary focus is on enhancing productivity by reducing cycle time in the machine shop, ensuring a more efficient and streamlined manufacturing process. A Lean approach is integrated into this study to differentiate between various activities in the production process. Value-Added (VA) activities are those that directly transform inputs into the final product as per customer requirements, contributing directly to product quality and functionality [9]. In contrast, Non-Value-Added (NVA) activities do not contribute to product transformation and are considered unnecessary in the production cycle, often leading to inefficiencies and waste. Additionally, there are Necessary Non-Value-Added (NNVA) activities, which, although not adding direct value to the product from an industry perspective, are essential for delivering the final product under existing supply chain constraints. Unless a radical shift in the supply process is implemented, these activities remain integral to the manufacturing workflow. By employing the DMAIC methodology and Lean principles, this study seeks to identify inefficiencies, eliminate unnecessary steps, and optimize machine operations, ultimately leading to improved productivity and reduced cycle time in the machine shop.

Research design and methodology

Generally, there are three methods of research design which are surveys, experiments and case study mostly used during the research. For this study we used “Case-Study” to collect the objective evidences and to conduct this case study. Personal visits were made to collect the required data and information with the purpose to get the true picture of the problem and not just to record what they say about themselves. According to the nature of the study, the DMAIC “(Define, Measure, Analyse, Improve and Control)” methodology of Six-Sigma is used. The DMAIC is a basic component of Six-Sigma methodology- a better way to improve work process by eliminating the defects rate in the final product. The DMAIC methodology has five phases Define, Measure, Analysis, Improvement, and Control. Six Sigma methodology was originally developed by Motorola in 1980s and it targeted a difficult goal of 3.4 defects per million. Six Sigma has been on an incredible run over 25 years, producing significant savings to the bottom line of many large and small organisations.

Research framework

Research gaps were identified and a draft of the research plan is prepared. The research framework explained in Fig. is used in the study on LSS implementation in Indian manufacturing industries. It consists of two methodologies for implementation in industries i.e., DMAIC for implementing LSS in the existing process and DFSS having DMADV for a new process. Tools and Techniques used in individual Research objective and the analysis software used for the study is explained. In the statistical analysis, hypothesis testing, ANOVA, standard deviation, and dedicated test Continuous Improvement in Manufacturing Industries through Lean Six Sigma (DMAIC Methodology) Status of Lean Six Sigma in Indian Industry Literature Review: Continuous Improvement through Lean Six Sigma Lean Six Sigma: (Overall benefit of Lean Six Sigma as per Manufacturing Industry perspective) Identification of critical success factors in Lean Six Sigma Implementation of Lean Six Sigma: A case study in Manufacturing industry Conclusions and Recommendations Phase - I Phase - II Phase - III Phase - IV Phase - V for analysis are used. Minitab and SPSS software is used in the analysis of statistical equation and other calculations in the study [10]. There are two widely used approaches DMAIC & DMADV in Lean Six sigma for process improvement deployment. DMAIC stands for Define, Measure, Analyse, Improve & Control and DMADV stands for Define, Measure, Analyse and Design & Verify. The DMAIC methodology (exhibit-2) should be used when a product or process is in existence in a company but is not meeting customer specification or is not performing adequately.

Six sigma 68-95-99.7 Rule

The statistical notion known as the 68-95-99.7 rule, often referred to as the Empirical Rule, is utilized in Six Sigma technique to comprehend the distribution of data. The normal distribution, often known as the bell curve, is a symmetrical probability distribution that captures the range of data in a population. It serves as the foundation for this rule. The 68-95-99.7 rule states that 68% of the data are within one standard deviation (sigma) of the mean, 95% are within two standard deviations of the mean, and 99.7% are within three standard deviations.

In a manufacturing business implementing Six Sigma to enhance product quality, statistical analysis plays a crucial role in measuring variations and ensuring consistency. Consider a scenario where the company manufactures a specific part and measures its length, which follows a normal distribution with a mean of 10 inches and a standard deviation of 1 inch. By applying the 68-95-99.7 rule (Empirical Rule), the company can make key observations about its production quality [11]. Approximately 68% of the parts have a length between 9 and 11 inches (within one standard deviation of the mean), while 95% of the parts fall within 8 to 12 inches (two standard deviations). Furthermore, 99.7% of the parts have lengths ranging from 7 to 13 inches (three standard deviations from the mean). This statistical approach helps the company set quality objectives and improvement targets by identifying the proportion of parts that meet desired specifications. Six Sigma aims to reduce defects and variations by ensuring that process performance remains within 6 standard deviations from the mean, achieving an exceptionally low defect rate of 3.4 parts per million (ppm). By applying this methodology, the company can enhance production efficiency, minimize errors, and maintain high-quality standards, ultimately leading to improved customer satisfaction and operational excellence.

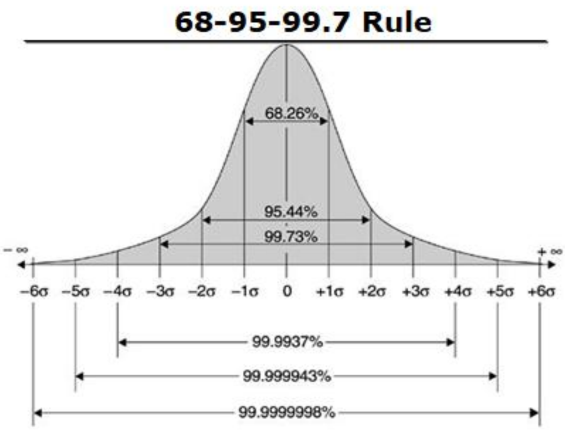


Fig .1: 68-95-99.7 ruleCycle and Lead Times

Cycle time and lead time are essential metrics for evaluating and optimizing production efficiency in the manufacturing industry. Cycle time refers to the total duration required to complete a single production cycle, starting from the initial stage and ending with the delivery of the final product. This encompasses various stages, including design, planning, material handling, manufacturing, quality control, and distribution. The efficiency of the production process and the overall capacity of the manufacturing system are directly influenced by cycle time [12]. Reducing cycle time enables a higher production rate within a given period, enhancing overall output and profitability for the company.

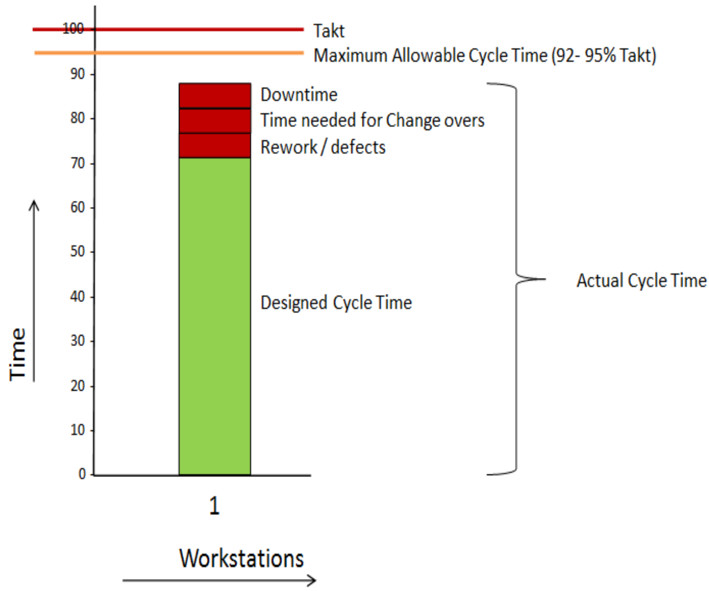


Fig.2: Cycle time analysis

Lead time describes the period of time between when a client places an order and when the goods is delivered in order to fulfil that purchase. The entire order processing process is covered, including order entry, production scheduling, material acquisition, production, quality control, and delivery. Since lead time has an immediate impact on the delivery timeline and dependability of the business, it is a crucial indicator for assessing customer service and satisfaction. Customers receive their goods more quickly with a shorter lead time, which can boost customer satisfaction and loyalty.

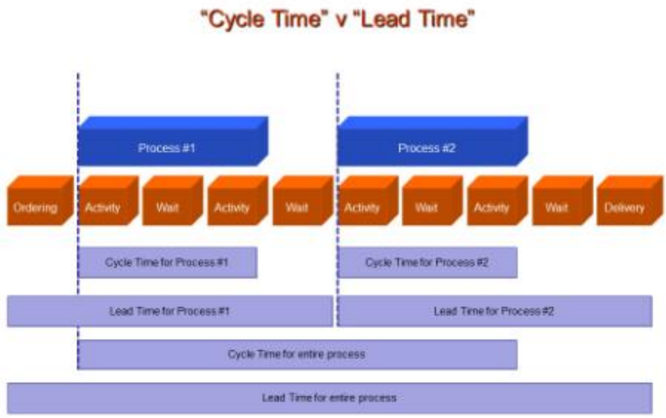
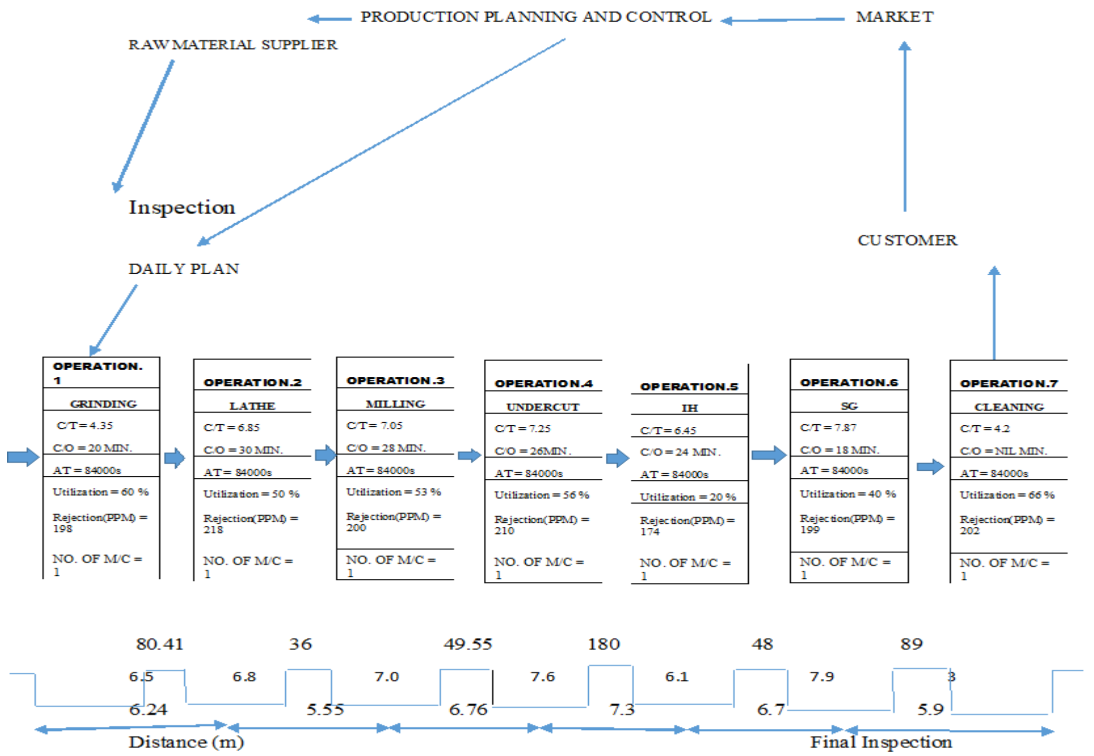


Fig.3: Cycle vs Lead Time Process



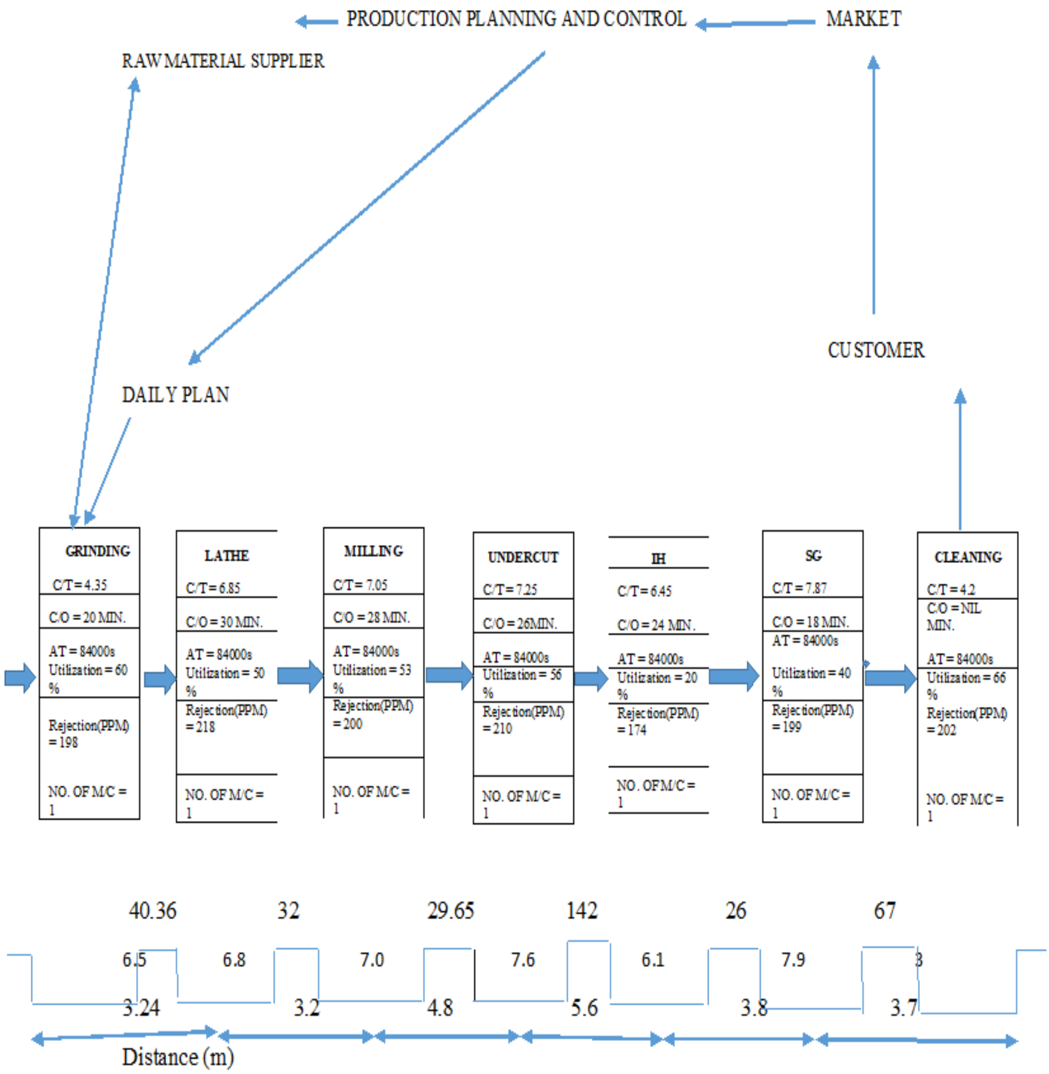
Lead Time = 7.8 hr

Total Non V/A = 482.96 Seconds

Total V/A = 44.9 Seconds

Total Distance = 38.45 m

Fig. 4: Cycle Time at Work Station (Machine Shop) Before LSS Method



Lead Time = 4.8 hr.

Total Non V/A = 337.01 Seconds

Total V/A = 44.9 Seconds

Total Distance = 24.34 m

Fig 5: Cycle Time at Work Station (Machine Shop) After LSS Method

Cycle time can be Defined as the period required for completing one Cycle of Operation or Completing a Job or task from start to Finish. Various Elements of Cycle time are set-up time, parts Movement time, Inspection time, and Rework time. By reducing cycle time to Produce a Product or to Finish a Job or Operation, Waste Can be Eliminated, and hence, profits can be higher due to Enhanced Productivity [13]. A Good Machine Tools System Concentrates on cycle time by eliminating the non–value–added Activities.

Expression for Calculating Cycle time;

$$\text{Cycle Time} = (\text{Set up time} + \text{Machining Time}) / \text{Number of Components Produced}$$

By Minimizing the Non – Value – Added Activity (e.g. Inspection, Set-up, Adjustments, and Tool Breakage etc.). To Fulfil the Above Problem Statement, the Following Objectives were considered;

- To Reduce Cycle Time in Machine Shop (Work Station).
- To Produce 40 Jobs per Shift.
- To Provide Min. Handling With in Working Area.
- To Increase Productivity with Modified Layout of Machine.
- To Reduce Rejection Rate Per Month.

For inspection of a lot Containing 10 Work Pieces, 35 – 40 Minutes are required. For Reducing the Cycle time by Avoiding Unwanted Movement of the Job. Production Capacity per shift can be increased from 28 to 36 jobs per shift. With excess machining of 8 jobs per Shift, Production Capacity of job can be increased from 2200 jobs per month to 2800 Jobs per Month.

Non Value Added (NVA) Time: Time study method has been adopted for determining cycle times for various operations on workstations.

Table.1: NVA Time Observation

S.NO.	OPERATIONS	NVA TIME (SEC.)	
1	Grinding to Lathe	80.41	40.36
2	Lathe Machine to Milling Machine	37	32
3	Milling Machine to Under cut	49.55	29.65
4	Under Cut to Induction Hardening	180	141
5	Induction Hardening to Surface Grinding	48	26
6	Surface Grinding to Cleaning	89	67
	Total	483.96 Sec. to 336.01 Sec.	

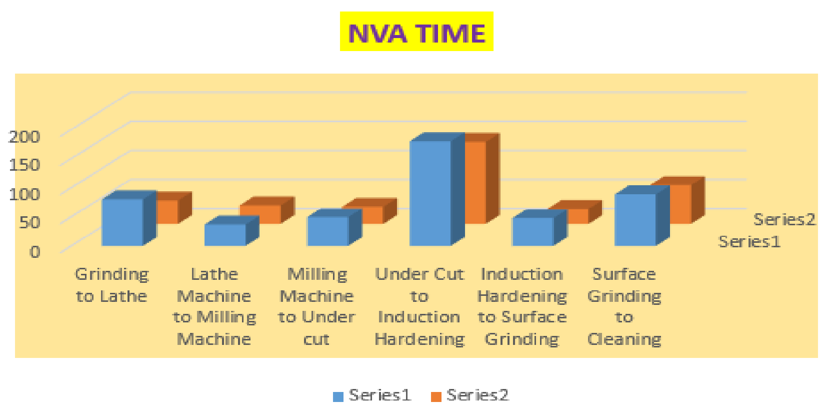


Fig.6: Non value added time before Vs. Non value added time after lean Six Sigma

Table.2: Total Distance Travelled (Met.) Observation

S.no.	OPERATION	Total Distance Travelled (Met.)	
1	Grinding to Lathe	6.24	3.24
2	Lathe Machine to Milling Machine	5.55	3.2
3	Milling Machine to Under cut	6.76	4.8
4	Under Cut to Induction Hardening	8.3	5.6
5	Induction Hardening to Surface Grinding	6.7	3.8
6	Surface Grinding to Cleaning	5.9	2.7
	Total	39.45 m	23.34 m

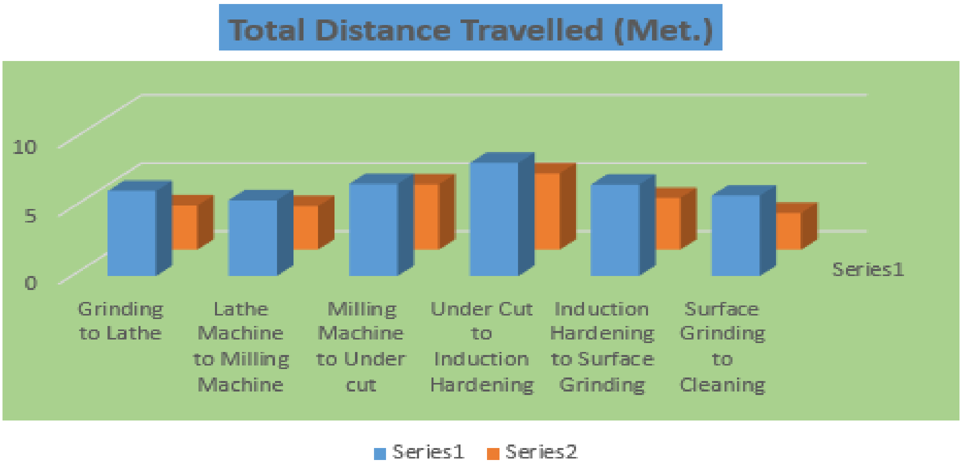


Fig.7: Total distance travelled before and after lean Six Sigma

Lead Time Reduction

Lead Time is reduced from 6.1 hr. to 2.1 hr. After the application of Lean Six Sigma Principle.

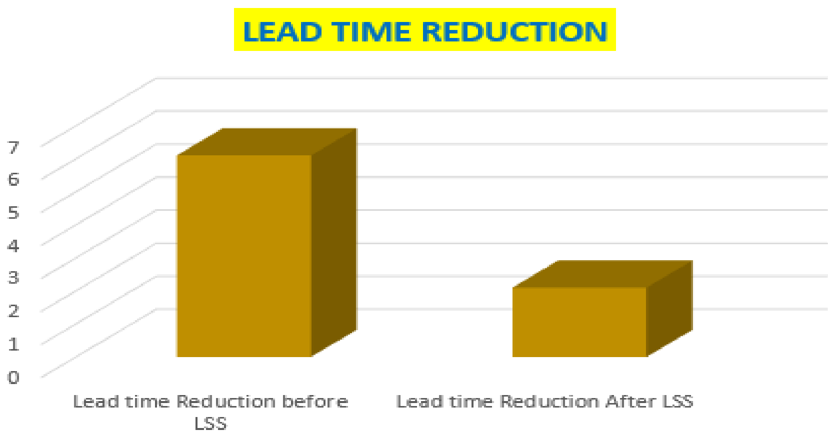


Fig.8: Lead time Reduction before and after Lean Six Sigma

Time Study

Comparison of Existing and New Methods in Fig. , Total Value Added Time is 44.9 Seconds and Non – Value Added Time is 482.96 Seconds. Total Value Added Time is 44.9 Seconds and Non – Value Added Time is 337.01 Seconds.

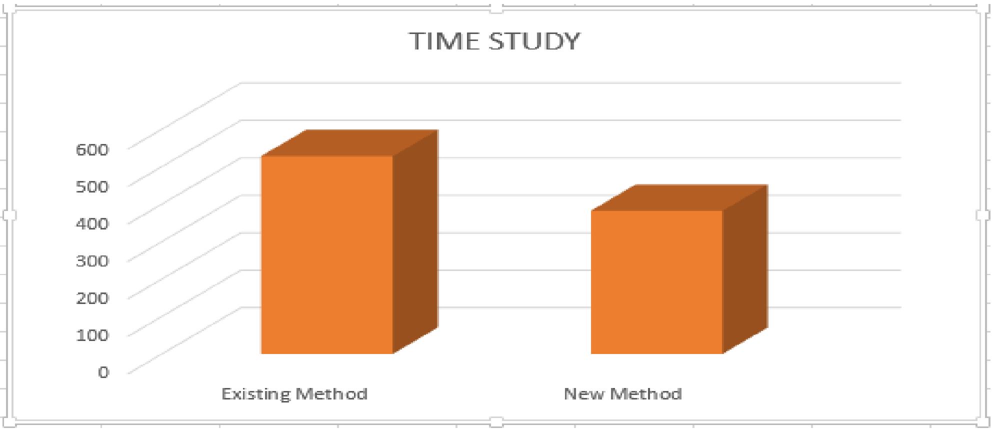


Fig.9: Comparison of Existing and New Method

There are five stages called DMAIC Method (Define, Measure, Analyse, Improve, and Control). Process Activity Mapping (PAM) Process activity mapping can be used as a tool to determine the proportion of detailed activity, which are grouped into value added (VA), necessary non value added (NVA) and non-value added (NVA) [14]. Process activity mapping is used to identify the waste or non-value added activity that occurs on each production process.

Inspection Time

Comparison of Existing and Newly Methods for Inspection Time is in Fig. In contrast to the Existing Method, Use of Newly Method to Complete the Inspection of 2180 Components per day [15]. The Inspection Time for the old Method is 10 Minutes and The New Method is 4 Minutes, which is a Greater Reduction of Time and cost.

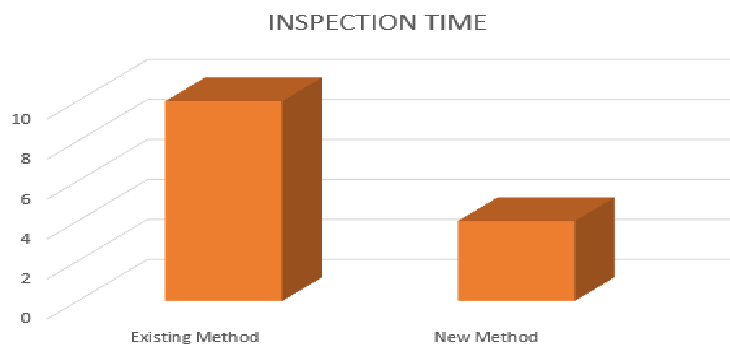


Fig.10: Comparison of Existing and New Methods for Inspection Time

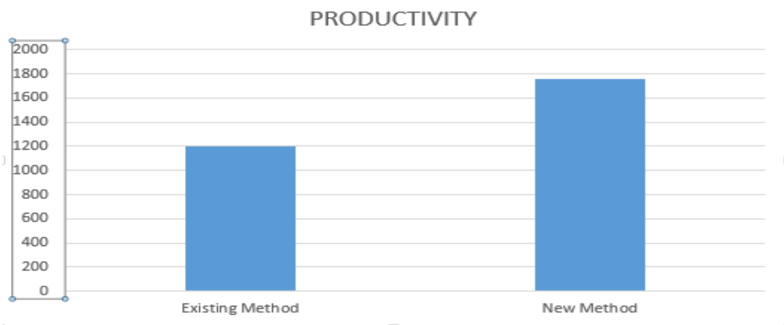


Fig.11: Comparison of Existing and New Methods for Productivity

Rejection Rate

Comparison of Existing and New Methods for Rejection Rate is in Fig. The Rate of Rejection before and After the Usage of the Newly Lean Six Sigma Method is:

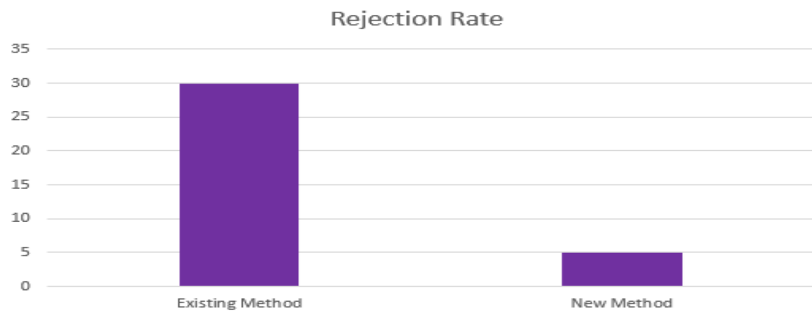


Fig.12: Comparison of Existing and New Methods for Rejection Rate

A Plot of unit-wise number of components that needed Rework. There are mainly two shops/sections that is a lathe machine shop and a drilling and tapping machine section that contributed to reworking in the considered organization's processes. The Six Sigma Metric System states a process to be in six sigma there can be a 3.4 DPMO. Only i.e., a process with 99.99 % Defects Free.

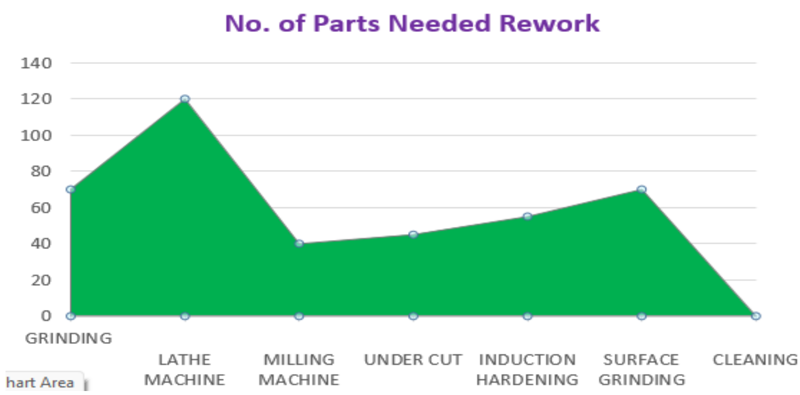


Fig.13: No. of Parts needed rework

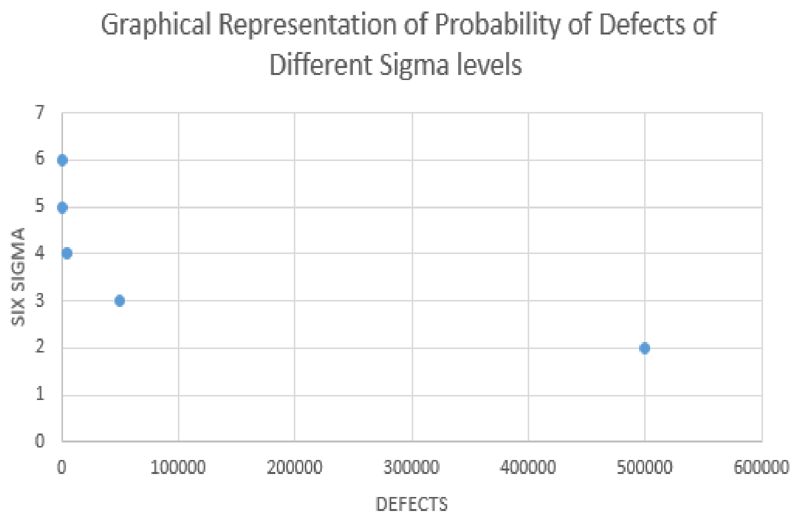


Fig. 14: Graphical representation of probability of defects of different sigma levels

Table.3: Sigma performance and yield Process

Six Sigma Performance Level	Defects per Million Opportunities	Process Yield (%)	Defect (%)	Estimated Cost Or Poor Quality
1.0 σ	697,700	30.23	69.1	> 40 %
2.0 σ	308,537	69.20	30.9	30 – 40 %
3.0 σ	66,807	93.32	6.7	20 – 30 %
4.0 σ	6,210	99.38	0.62	15 – 20 %
5.0 σ	233	99.98	0.023	10 – 15 %
6.0 σ	3.4	99.99	0.00034	< 10 %

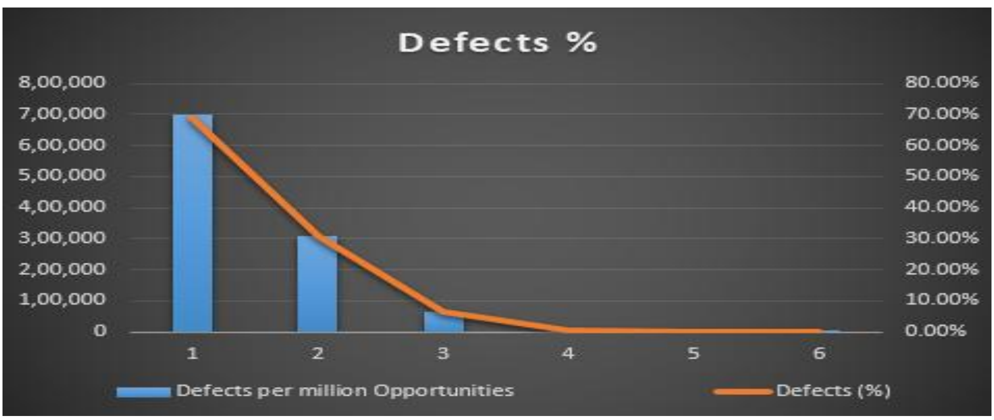


Fig.15: Pareto chart for Process Yield

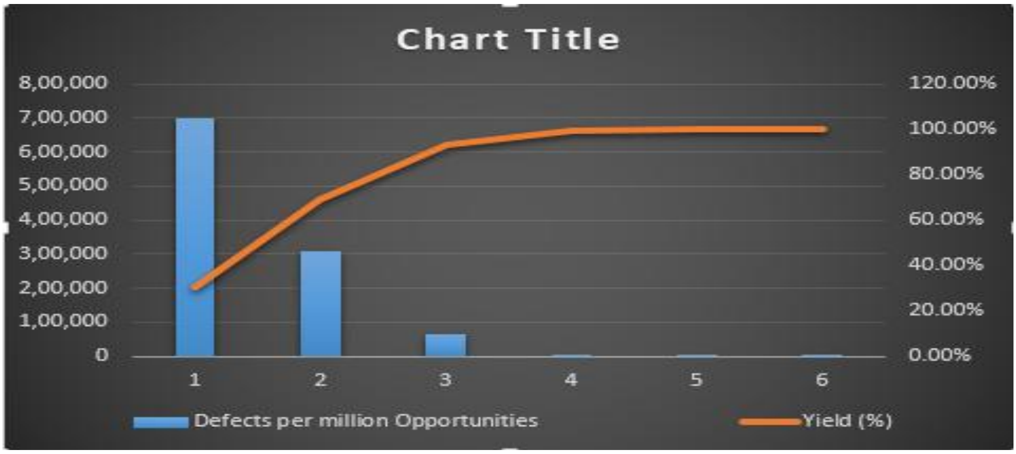


Fig.16: Pareto chart for Defects Rate

3. Results

The sequence of operations are noted, Grinding, Lathe, undercut, induction hardening, surface grinding, and cleaning machines. The process is occurred in sequence and cycle time is noted for every processes, tool changeover time, utilization, Rejection, no. of Machines.

Before LSS Method

The Operation 1 has Grinding, Where the Operation time is 6.5 sec. and the Setting time is 80.41 Sec. The Operation 2 has Lathe Machine, Where the Operation time is 6.8 Sec. and the Setting time is 36 Sec. The Operation 3 has Milling Machine, Where the Operation time is 7.0 Sec. and the Setting time is 49.55 Sec... The Operation 4 has Under Cut, Where the Operation time is 7.6 Sec. and the Setting time is 180 Sec. The Operation 5 has Induction Hardening , Where the Operation time is 6.1 Sec. and the Setting time is 48 Sec. The Operation 6 has Surface Grinding, Where the Operation time is 7.9 Sec. and the Setting time is 89 Sec. The Operation 7 has Cleaning , Where the Operation time is 3 Sec. . Total Value Added Time is 44.9 Seconds and Non – Value Added Time is 482.96 Seconds. Total Cycle Time is 527.86 Seconds, Distance travelled (38.45 m), and lead time (6.1 hr.).

After LSS Method

The Operation.1 has Grinding, Where the Operation time is 6.5 sec. and the Setting time is 40.36 Sec. The Operation 2 has Lathe Machine, Where the Operation time is 6.8 Sec. and the Setting time is 32 Sec. The Operation 3 has Milling Machine, Where the Operation time is 7.0 Sec. and the Setting time is 29.65 Sec. The Operation 4 has Under Cut, Where the Operation time is 7.6 Sec. and the Setting time is 142 Sec. The Operation 5 has Induction Hardening, where the Operation time is 6.1 Sec. and the Setting time is 26 Sec. The Operation 6 has Surface Grinding, Where the Operation time is 7.9 Sec. and the Setting time is 67 Sec. The Operation 7 has Cleaning, Where the Operation time is 3 Sec.

Total Value Added Time is 44.9 Seconds and Non – Value Added Time is Reduced 337.01 Seconds. Total Cycle Time is Reduced 381.91 Seconds, Distance travelled is Reduced (24.34

m), Lead time is Reduced (2.1 hr.).

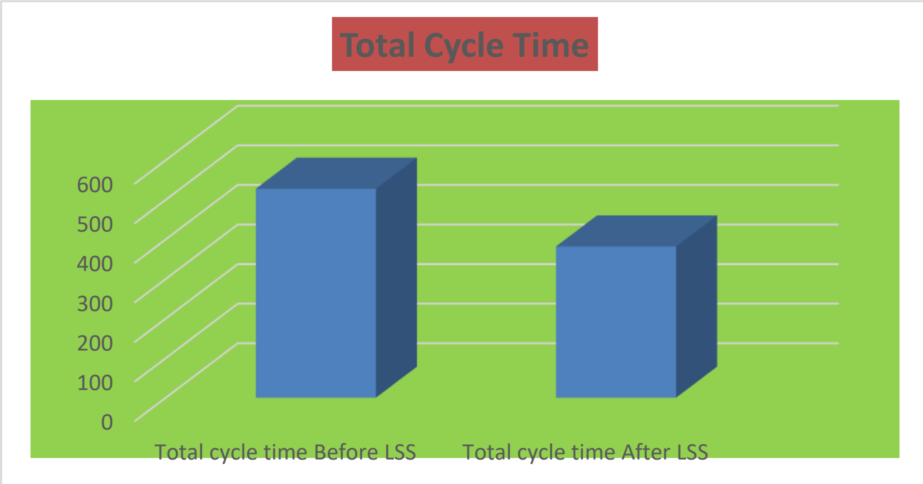


Fig.17: Total Cycle Time Before & After LSS Tool

Measure the Current State

As per data, the team has identified the following data to be collected for measuring the current state of the manufacturing process:

- Cycle time
- Lead time
- Defect rates

They then analyse this data and determine that the average cycle time for the manufacturing process is 10 hours, the average lead time is 5 days, and the defect rate is 2%. They also calculate the process capability index (Cpk) to be 1.2, which indicates that the process is capable but needs improvement. The team then identifies the root cause of the high defect rate to be the lack of training for the production team. They determine that by providing additional training and support, the defect rate can be reduced.

Table.4: Initial status of case considered

Metric	Value
Cycle Time	10 hrs
Lead Time	5 days
Defect Rate	2%

Table.5: Final Results

Metric	Before Lean Six Sigma	After Lean Six Sigma
Cycle Time (Seconds)	527.86	381.91
Lead Time (hours)	6.1	2.1

Using lean Six Sigma tools, setup time reduction the lead time is reduced from 6.1 hr. to 2.10 hr. The total Non-value added time is reduced from 527.86 sec to 381.91 sec. Total distance travelled by the work piece is reduced from 38.45 m to 24.34 m. The Total Value Added Time is 44.9 Seconds and The Non – Value Added Time is 337.01 Seconds .Total Cycle Time is 381.91 Seconds. Improvement 145.95 Seconds. An Attempt has been made to improve the productivity by increasing production which is achieved by reducing cycle time of Component. Production Capacity per shift can be increased from 27 to 35 component per Shift. Production Capacity increased from 1500 jobs Per Month to 2400 Jobs per Month.

Research Outcomes

Sigma level is a procedure to know the existing condition of a production shop. The calculation of sigma level is based on the number of Defects per Million opportunities (DPMO). DPMO, three distinct pieces of information are required:

a) The number of units produced.

b) The number of defects opportunities per unit.

c) The number of defects.

$$\text{DMPO} = \frac{(\text{No.of Defects} * 100000)}{[(\text{No.of Defects opportunities per unit}) * \text{No of units}]}$$

Six Sigma is several things:

- A statistical basis of measurement: 3.4 defects per million opportunities
- A philosophy and a goal as perfect as practically possible
- A methodology
- A symbol of quality

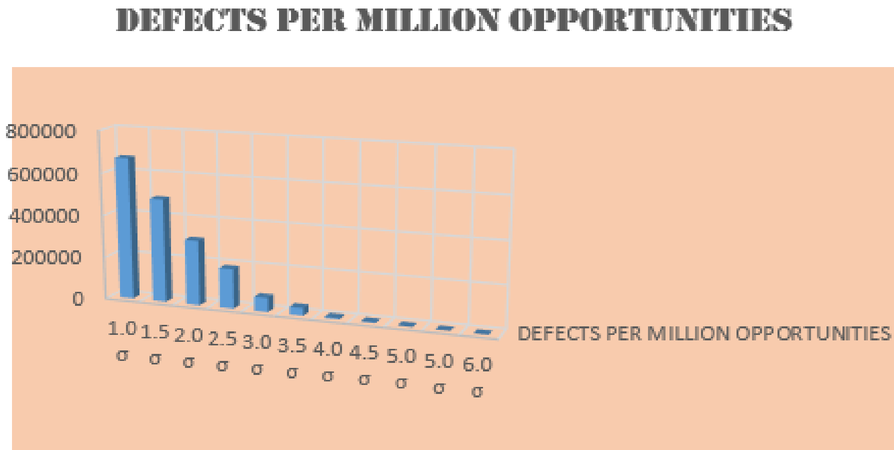


Fig.18: Graphical Represent Defects per Million Sigma levels Opportunities

Table.6: Defects Per Million Opportunities

SIGMA PERFORMANCE LEVEL	DEFECTS PER MILLION OPPORTUNITIES
1.0 σ	670000
1.5 σ	489268.5
2.0 σ	308537
2.5 σ	187672
3.0 σ	66807
3.5 σ	36508.5
4.0 σ	6210
4.5 σ	3221.5
5.0 σ	233
5.0 σ	118.2
6.0 σ	3.4

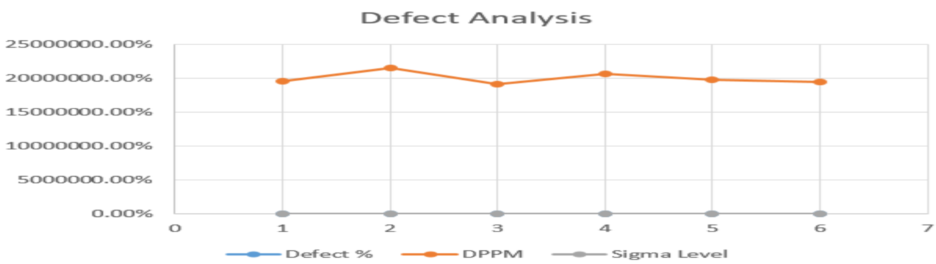


Fig.19: Defects Analysis

4. Conclusion

A Comprehensive understanding of Lean Six Sigma's impact on Productivity improvement, defect reduction, and Reduction Cycle time and lead time in manufacturing industrial. This approach is based on the systematic elimination of waste and continuous improvement of productivity. Improve the productivity by increase production rate which is achieved by reducing cycle time of job. Output of workstation is increased up to 21 jobs per shift. With reduction of cycle time by 2.44 minutes per job, production capacity per shift can be increased from 10 to 13 jobs per shift. With improved machining of 4 jobs per shift, production capacity can be increased from 1000 jobs per month to 1400 jobs per Month.

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