# Improving Automotive Sector using Lean Six Sigma

**Aaditya Kurte[1], Smital Nagap[2], Shivani Nalawade[3], Om Hule[4], Dr. Nitin Panaskar[5]**

*[1]Student, Dept. of Mechanical Engineering, Rajiv Gandhi Institute of Technology, Maharashtra, India*
*[2]Student, Dept. of Mechanical Engineering, Rajiv Gandhi Institute of Technology, Maharashtra, India*
*[3]Student, Dept. of Mechanical Engineering, Rajiv Gandhi Institute of Technology, Maharashtra, India*
*[4]Student, Dept. of Mechanical Engineering, Rajiv Gandhi Institute of Technology, Maharashtra, India*
*[5]Associate Professor, Dept. of Mechanical Engineering, Rajiv Gandhi Institute of Technology, Maharashtra, India*

---***---

**Abstract -** *The automotive industry has long been characterized by fierce competition, ever-evolving consumer expectations, and the need for continuous improvement. This project delves into the application of Lean Six Sigma methodologies to bring about a transformation in this sec-tor. The primary objectives include enhancing quality, reducing costs, and streamlining processes throughout the automotive manufacturing and supply chain. Through the DMAIC (Define, Measure, Analyze, Improve, Control) framework, this project identifies critical fac-tors affecting product quality, resource utilization, and overall operational efficiency. It integrates Lean principles to eliminate waste, enhance productivity, and minimize defects, while incorporating Six Sigma strategies to reduce process variations and enhance quality control. The utilization of various tools and techniques, including process mapping, statistical analysis, root cause analysis, and continuous monitoring, drives evidence-based decision-making. The expected outcomes of this project encompass substantial improvements in product quality, increased customer satisfaction, and significant cost reductions. Further-more, a cultural shift towards continuous improvement is anticipated, promoting a proactive approach to addressing issues and achieving long-term success in the automotive industry.*

***Key Words***: **DMAIC, Critical Path Method, Optimization**

## 1.INTRODUCTION

Six Sigma is a quality management approach with the primary goal of enhancing the quality of products and services through the identification and removal of defects. It is used in the automotive industry to improve the quality of vehicles and manufacturing processes, reduce costs, and increase efficiency. This is a data-centric strategy that employs statistical tools and methodologies to pinpoint and eradicate sources of variation, ultimately enhancing overall performance. Six Sigma can be applied to various aspects of the automotive industry, such as design, engineering, production, and service. Companies like Motorola started using six sigma techniques in the 1980s which was later popularized by Toyota and General Electric. The term Six Sigma refers to statistical measure of process performance where the goal Is to not have more than 3.4 defects per million opportunities. Six Sigma often uses various techniques such as DMAIC, SPC, DOE, FMEA.

### 1.1 Techniques in Six Sigma

**1. Brainstorming:** Brainstorming is an integral part of the problem-solving process and is frequently utilized in the "improve" phase of the DMAIC methodology. It serves as a crucial preliminary step before the application of any specific tools. Brainstorming entails the exchange of ideas and the generation of creative solutions through open and uninhibited group discussions. Typically, a facilitator, often a lead Black Belt or Green Belt, moderates these brainstorming sessions among participants.

**2. Root Cause Analysis/The 5 Whys:** This technique is employed to uncover the fundamental causes of the issues under consideration and is an essential component of the "analyze" phase in the DMAIC cycle. In the 5 Whys technique, the question "why" is repetitively asked, leading to a deeper understanding of the core issue. While "five" is a rule of thumb, the actual number of questions can vary to obtain a comprehensive insight.

**3. Voice of the Customer:** This process is designed to capture customer feedback, often termed the "voice of the customer," through internal or external means. The aim is to provide customers with the best products and services by continuously understanding their evolving needs through direct and indirect methods. The voice of the customer technique is primarily used in the "define" phase of the DMAIC method, helping to refine the problem definition.

**4. The 5S System:** Rooted in Japanese workplace principles, the 5S System focuses on eliminating waste and streamlining inefficient tools, equipment, or resources in the workplace. It consists of five steps: Seiri (Sort), Seiton (Set In Order), Seiso (Shine), Seiketsu (Standardize), and Shitsuke (Sustain).

### 1.2 Advantages of Six Sigma

**1.Improved Quality:** Six Sigma methodologies focus on reducing defects and errors, leading to higher product and service quality.

**2. Data-Driven Decision-Making:** It relies on data analysis to make informed decisions, enhancing accuracy and problem-solving.
**3.Increased Customer Satisfaction:** Better quality products and services result in increased customer satisfaction and loyalty.
**4.Process Efficiency:** Six Sigma identifies and eliminates inefficiencies, streamlining processes and reducing waste.

## 2. Need for After Sales Development

•Maintenace and after sales development is one of the most important aspect of automobile industry. The quality of after sales service can have a drastic effect on the popularity of the company and the development of customer relations.
•The focus on quality of after sales service must be of priority for customer satisfactions, which is essential for the profits of an automobile industry.
•The automobile after sales service generally consists of periodic maintenance of vehicles, minor repairs, major repairs, washing, cleaning and parts replacements.
•To improve the after sales services, effective improvements must be done to the layout of the service centre and improving the process which takes the most amount of time.

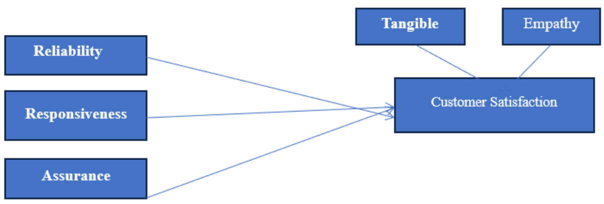


**Fig -1**: Factors for customer satisfaction

## 3. Problem Statement

This Research study will study and analyze the use of six sigma in the automotive industry to achieve the following factors in manufacturing:
• Improved Efficiency
• Reduced cost
• Improved quality
• Better product design
• Improved employee engagement
In this research study, the primary objective is to conduct an in-depth examination and evaluation of the application of Six Sigma principles within the automotive industry. The study aims to investigate how Six Sigma contributes to achieving the following key objectives in the manufacturing process.

## 3. Methodology

The DMAIC framework is a structured problem-solving and process improvement methodology used in Six Sigma. It stands for Define, Measure, Analyze, Improve, and Control. Each phase represents a set of activities and steps to guide a project from problem identification to sustained process improvement. Here's an explanation of each phase

### 3.1 DMAIC

**Define:**
**Problem Statement**: Clearly define the problem or opportunity for improvement. This should be stated in a way that is specific, measurable, achievable, relevant, and time-bound (SMART).
•**Project Charter:** Create a project charter that outlines the scope, objectives, team members, stakeholders, and high-level timelines for the project.
•**Voice of the Customer (VOC):** Collect and analyze customer feedback and expectations to understand their requirements and priorities.
Measure:
**Data Collection:** Identify the critical process parameters and collect data on them. Ensure the data is accurate and reliable.
•**Process Mapping:** Create process maps to visualize the current process and identify areas for measurement.
•**Baseline Performance**: Establish the baseline performance of the process, often referred to as the "as-is" state.
**Analyze:**
•**Data Analysis:** Analyze the collected data to identify patterns, trends, and variations in the process. Statistical tools and techniques are often used in this phase.
•**Root Cause Analysis:** Determine the root causes of defects or problems by using tools like the Ishikawa diagram (Fishbone diagram) and the 5 Whys technique.
•**Hypothesis Testing:** Formulate and test hypotheses to confirm the relationships between variables and issues in the process.
**Improve:**
•Generate Solutions: Develop and evaluate potential solutions to address the identified root causes. Brainstorm and prioritize improvement ideas.
•Pilot Testing: Implement the selected solutions on a small scale to test their effectiveness without disrupting the entire process.
•Optimize Processes: Refine the solutions and make necessary adjustments to improve the process. Consider factors like efficiency, cost, and customer satisfaction.
**Control:**
•Standardization: Develop and implement standard operating procedures (SOPs) and controls to maintain the improved process performance.

•Statistical Process Control (SPC): Use SPC charts and tools to monitor and control process variation and identify issues early.
•Continuous Monitoring: Continuously monitor key performance indicators (KPIs) and process metrics to ensure that the improvements are sustained over time.
•Documentation and Training: Document the changes made, and provide training to the team to ensure that everyone understands and follows the new procedures.
The DMAIC framework is a data-driven approach to problem-solving and process improvement. It is designed to lead to sustainable improvements in quality, efficiency, and customer satisfaction. Throughout each phase, the emphasis is on data collection and analysis, enabling organizations to make informed decisions and validate the effectiveness of process.

### 3.2 Service Flow Chart

Service plan diagram for a service center, also known as a service plan or service plan, is a well-known step-by-step process for providing customer service goods. It describes the various stages of the delivery process, including the interaction between customers and service providers and the associated support or resources.

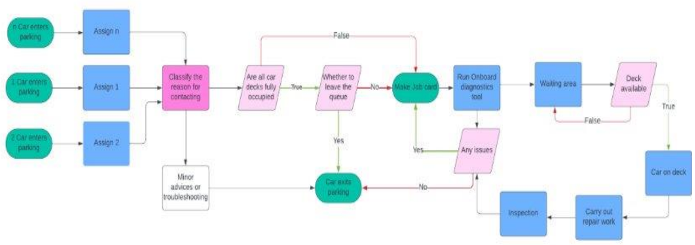


**Fig -2**: Service Flow Chart

### 3.3 Critical Path Method

Critical Path method (CPM) is a project management technique used to identify the most important tasks and ensure that tasks are completed on time. Although it is often associated with construction and real estate, it can be adapted to a variety of industries, including automotive services. Here's how to use CPM to make Service centres more efficient: then deliver the car to the customer. This may include inspections, diagnostics, orders, repairs, quality control and customer communications.

| Activity | Description | Duration | Dependencies |
|---|---|---|---|
| A | General inspection | 1.0 | - |
| B | Engine Oil Check | 0.2 | - |
| C | Engine oil top-up | 0.5 | B,A |
| D | Air filter inspection | 0.1 | - |
| E | Air filter cleaning and replacement | 0.5 | D,A |
| F | Spark Plug Inspection | 0.1 | A |
| G | Spark plug Adjustment | 0.5 | F,A |
| H | Fuel filter cleaning | 0.8 | A |
| I | Fuel filter replacement | 0.2 | H |
| J | Valve Check | 0.8 | A |
| K | Valve Adjustment | 1.5 | J |
| L | Brake Check | 0.1 | A |
| M | Brake pads replacement | 1.0 | L |
| N | Clutch Check | 1.5 | A |
| O | Clutch replacement and Adjustment | 1.5-18.0 | N |
| P | AC Service | 6.0-12.0 | A |
| Q | Battery Inspection | 1.5 | A |
| R | Tire inspection & Pressure Check | 1.0 | A |
| S | Wheel Alignment | 6.0 | R |
| T | Steering Alignment | 3.0 | A |
| U | Chassis and Bodywork | 6.0 | A |
| V | Emission | 0.5 | A |

**Table -1**: Critical Path Method

## 4. RESULTS

| Activity $(i,j)$ (1) | Duration $(t_{ij})$ (2) | Earliest time Start $(E_i)$ (3) | $(E_j)$ (4) | $(L_i)$ (5) | Latest time Finish $(L_j)$ (6) | Earliest time Finish $(E_i + t_{ij})$ (7) = (3) + (2) | Latest time Start $(L_j - t_{ij})$ (8) = (6) - (2) | Total Float $(L_j - t_{ij}) - E_i$ (9) = (8) - (3) | Free Float $(E_j - E_i) - t_{ij}$ (10) = ((4) - (3)) - (2) | Independent Float $(E_j - L_i) - t_{ij}$ (11) = ((4) - (5)) - (2) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2-3 | 0.2 | 1 | 1.2 | 1 | 20 | 1.2 | 19.8 | 18.8 | 0 | 0 |
| 2-4 | 0.1 | 1 | 1.1 | 1 | 20 | 1.1 | 19.9 | 18.9 | 0 | 0 |
| 2-5 | 0.1 | 1 | 1.1 | 1 | 20 | 1.1 | 19.9 | 18.9 | 0 | 0 |
| 2-6 | 0.8 | 1 | 1.8 | 1 | 20.3 | 1.8 | 19.5 | 18.5 | 0 | 0 |
| 2-7 | 0.8 | 1 | 1.8 | 1 | 19 | 1.8 | 18.2 | 17.2 | 0 | 0 |
| 2-8 | 0.1 | 1 | 1.1 | 1 | 20.4 | 1.1 | 20.3 | 19.3 | 0 | 0 |
| 2-10 | 12 | 1 | 13 | 1 | 20.5 | 13 | 8.5 | 7.5 | 0 | 0 |
| 2-11 | 1.5 | 1 | 2.5 | 1 | 20.5 | 2.5 | 19 | 18 | 0 | 0 |
| 2-12 | 1 | 1 | 2 | 1 | 14.5 | 2 | 13.5 | 12.5 | 0 | 0 |
| 2-13 | 3 | 1 | 4 | 1 | 20.5 | 4 | 17.5 | 16.5 | 0 | 0 |
| 2-14 | 6 | 1 | 7 | 1 | 20.5 | 7 | 14.5 | 13.5 | 0 | 0 |
| 2-15 | 0.5 | 1 | 20.5 | 1 | 20.5 | 1.5 | 20 | 19 | 19 | 19 |
| 3-15 | 0.5 | 1.2 | 20.5 | 20 | 20.5 | 1.7 | 20 | 18.8 | 18.8 | 0 |
| 4-15 | 0.5 | 1.1 | 20.5 | 20 | 20.5 | 1.6 | 20 | 18.9 | 18.9 | 0 |
| 5-15 | 0.5 | 1.1 | 20.5 | 20 | 20.5 | 1.6 | 20 | 18.9 | 18.9 | 0 |
| 6-15 | 0.2 | 1.8 | 20.5 | 20.3 | 20.5 | 2 | 20.3 | 18.5 | 18.5 | 0 |
| 7-15 | 1.5 | 1.8 | 20.5 | 19 | 20.5 | 3.3 | 19 | 17.2 | 17.2 | 0 |
| 8-15 | 0.1 | 1.1 | 20.5 | 20.4 | 20.5 | 1.2 | 20.4 | 19.3 | 19.3 | 0 |
| 10-15 | 0 | 13 | 20.5 | 20.5 | 20.5 | 13 | 20.5 | 7.5 | 7.5 | 0 |
| 11-15 | 0 | 2.5 | 20.5 | 20.5 | 20.5 | 2.5 | 20.5 | 18 | 18 | 0 |
| 12-15 | 6 | 2 | 20.5 | 14.5 | 20.5 | 8 | 14.5 | 12.5 | 12.5 | 0 |
| 13-15 | 0 | 4 | 20.5 | 20.5 | 20.5 | 4 | 20.5 | 16.5 | 16.5 | 0 |
| 14-15 | 0 | 7 | 20.5 | 20.5 | 20.5 | 7 | 20.5 | 13.5 | 13.5 | 0 |

The Forward Pass method in Critical Path Method (CPM) is a technique used to calculate the earliest possible start (ES) and finish (EF) times for each activity in a project schedule. CPM is a step-by-step project management technique for process planning that defines critical and non-critical tasks with the goal of preventing time-frame problems and process bottlenecks. The Forward Pass is a crucial part of this process, helping to identify the minimum project duration and the earliest dates by which each activity can be completed.

E1=0

E2=$E1$+$t$1,2 [$t$1,2=$A$=1]=0+1=1

$E$3=$Max${$Ei$+$ti$,3}[$i$=1,2]

=$Max${$E$1+$t$1,3;$E$2+$t$2,3}

=$Max${0+0.2;1+0}

=$Max${0.2;1}

=1

E4=$Max${$Ei$+$ti$,4}[$i$=1,2]

=$Max${$E$1+$t$1,4;$E$2+$t$2,4}

=$Max${0+0.1;1+0}

=$Max${0.1;1}

=1

$E$5=$E$2+$t$2,5 [$t$2,5=$F$=0.1]=1+0.1=1.1

E6=$E$2+$t$2,6 [$t$2,6=$H$=0.8]=1+0.8=1.8

E7=$E$2+$t$2,7 [$t$2,7=$J$=0.8]=1+0.8=1.8

E8=$E$2+$t$2,8 [$t$2,8=$L$=0.1]=1+0.1=1.1

E9=E2+t2,9 [t2,9=N=1.5]=1+1.5=2.5

E10=E2+t2,10 [t2,10=P=12]=1+12=13

E11=E2+t2,11 [t2,11=Q=1.5]=1+1.5=2.5

E12=E2+t2,12 [t2,12=R=1]=1+1=2

E13=E2+t2,13 [t2,13=T=3]=1+3=4

E14=E2+t2,14 [t2,14=U=6]=1+6=7

E15=Max{Ei+ti,15}[i=2,3,4,5,6,7,8,9,10,11,12,13,14]

=Max{E2+t2,15;E3+t3,15;E4+t4,15;E5+t5,15;E6+t6,15;E7+t7,15;E8+t8,15;E9+t9,15;E10+t10,15;E11+t11,15;E12+t12,15;E13+t13,15;E14+t14,15}

=Max{1+0.5;1+0.5;1+0.5;1.1+0.5;1.8+0.2;1.8+1.5;1.1+0.1; 2.5+18;13+0;2.5+0;2+6;4+0;7+0}

=Max{1.5;1.5;1.5;1.6;2;3.3;1.2;20.5;13;2.5;8;4;7}

=20.5

## 5. CONCLUSIONS

This type of technique can provide a framework to small and medium scale automotive manufacturing plants. By using the DMAIC technique in the case study, production of the TATA Nexon can achieve 93% defect free. The use of Six Sigma is very important in different companies because it is used to improve performance that focuses on reducing the number of defects in products, processes and services and this is the case for this case study will improve the manufacturing defects. Six Sigma remains a very effective method adopted by many companies to improve their quality and productivity. This type of framework can help automotive companies to reduce waste and improve their quality control department to im-prove their profits. A project aimed at improving the automotive sector using Lean Six Sig-ma methodologies has demonstrated significant benefits and transformative outcomes. Lean Six Sigma, a combination of Lean principles focused on waste reduction and Six Sigma techniques for process improvement, has been a game-changer in this industry. Through the systematic application of Lean Six Sigma, the automotive sector has seen substantial enhancements in various aspects Lean principles have streamlined processes, reduced unnecessary steps and minimized waste. This has led to quicker production cycles, reduced lead times, and cost savings. Manufacturers can produce more vehicles with the same or fewer resources. The implementation of the Critical Path Method (CPM) significantly optimized the process timeline, resulting in a substantial reduction in duration. The critical path of the project is : 1-2-9-15 and critical activities are A,N,O Initially, the process required 522 minutes for completion. After the application of CPM, a strategic scheduling and project management technique that focuses on task sequencing and critical path identification, the total process time was effectively reduced to 205 minutes. This represents a decrease of approximately 60.7%, showcasing the efficacy of CPM in enhancing operational efficiency and minimizing time expenditure in complex processes. The implementation of the Critical Path Method (CPM) significantly optimized the process timeline, resulting in a substantial reduction in duration.

The authors can acknowledge any person/authorities in this section. This is not mandatory.

## REFERENCES

Automotive Component Manufacturers Association of India (ACMA) (2017). Presentation on "Auto and Auto Components Sector Profile".

Automotive Component Manufacturers Association of India (ACMA) (2021). Annual report 2020-21.

Noori, B., & Latifi, M. (2018). Development of Six Sigma methodology to improve grinding processes: a change management approach. International journal of lean six sigma.

Isa, M. F. M., & Usmen, M. (2015). Improving university facilities services using Lean Six Sigma: a case study. Journal of Facilities Management.

Kabir, M. E., Boby, S. M. M. I., & Lutfi, M. (2013). Productivity improvement by using Six-Sigma. International Journal of Engineering and Technology, 3(12), 1056- 1084.

Gupta, N. (2013). An overview on six sigma: quality improvement program. International Journal of Technical Research and Applications, 1(1), 29-39.