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Original Article

Application of Lean Six Sigma Tools for Performance Improvement in an Automobile Sector SME

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Abstract - *SME manufacturing units are basic contributors to Indian Automotive industries. These units are facing a tough time due to the economic slowdown, increasing electric vehicle market, variation in demand, higher variation in products/customers, automation requirements and worldwide political disturbances. Lean methods focus on the reduction of 7 types of important wastes. These methods were first used in Toyota Corporation Japan by Eiji Toyoda. Six Sigma is the operation improvement technique used to reduce the number of defects, faults and mistakes. The mixing of Six Sigma and Lean methods has given excellent results for many sectors in the world. These techniques are regularly used in process industries, pharma industries and the IT sector. Lean Six Sigma could bring positive change to SMEs but these units are reluctant to implement Lean Six Sigma. In the presented research work important Lean Six Sigma tools were derived by consulting industry experts, consultants and academicians. Company ABC (average 5 years turnover 8.2 crore rs) was selected for implementing Lean Six Sigma tools. Important tools like 5S, VSM, Ishikawa and standardization of operation were implemented. Considerable reductions in rejection rate and cost of production were achieved.*

Keywords - *Automotive industries, Lean Manufacturing, Rejection rate, Six sigma, SME.*

1. Introduction

1.1. Lean Manufacturing

The core principle of lean manufacturing is to eliminate any non-essential steps from a business' production process which do not add value for the customers. If any resource usage is found to be wasteful, it should be discontinued. This methodology differs significantly from traditional techniques such as batch processing and queuing systems [1].

In simple terms, "Lean" refers to the continuous improvement that aims to maximize customer value and minimize waste. Respect for people and ongoing progress are the two key elements that sum up this approach. Businesses need transition from traditional business models to Lean business models to achieve this.

Today's customers have unique expectations, and businesses are striving to meet them. Improving products and services to serve customers better is an ongoing challenge for industries and professionals. In order to achieve this, researchers and innovation specialists are constantly learning about customers' preferences, needs, and desires by studying their behavior. This helps them to offer greater value to consumers.

During the early 1990s, Lean manufacturing became increasingly popular among businesses, especially in the aerospace and automotive industries. At Toyota, equal importance was given to the company's organizational culture and ongoing development.

The collective effort of each individual contributes to creating a positive working environment. The ultimate goal of continuous improvement is to optimize the use of technological infrastructure and maximize its potential value. Table 1 represents the development stages of Lean manufacturing.

1.2. Six Sigma Basics

Businesses can increase their revenue by implementing the Six Sigma methodology to streamline their operations, improve the quality of their products or services, and eliminate any faults or defects. The term "Six Sigma" refers to reducing the variability in processes to ensure that less than 3.4% of the million components produced have defective parts.

This requires strict control over process variance. By applying Six Sigma, businesses can offer top-notch products and services while minimizing internal errors.

Table 1. Transition and hierarchy development of lean six sigma tools

Interchangeable machine Components.	E. Whitney	After 1850
Advanced machine tools start to develop.		From 1861 to 1876
Standards for drafting and drawing are established. A system of standardized tolerance is created.	H. Ford	From 1861 to1876
Time study research is created and presented. Work standardization procedures were established. standardized work was implemented	F. Taylor	From 1891 to 1911
Motion and Time studies Charts for process	F. Gilbreth	From 1891 to 1911
Machine assembly line Management philosophy developed by Ford Backward integration Flow machine manufacturing	H. Ford	From 1913 to 1925
SPC TQM	J. Juran E. Demming	From 1941 to 1947
JIT manufacturing Production system developed by TOYOTA Stockless manufacturing Work teams 5S Techniques Quality circles Employees empowerment VSM	E. Toyoda T.Ohno	From 1951 to1986

Table 2. Relation between lean and six sigma

Aspect	Lean	Six Sigma
Principle	Profit increment by waste reduction	Profit increment by variation reduction
Focus	Flow	Defect
Assumption	Reduction in waste leads to performance improvement	Variation reduction leads to performance improvement
Primary Effects	Reduction in cycle time and improvement in process efficiency	Reduction in Variation Customer satisfaction
Secondary Effects	Reduction in inventory Reduction in variation	Waste reduction Improvement in quality
Deficiencies	Statistical tools are not used	Long implementation period

1.3. Integrating Lean and Six Sigma

LSS is an effective combination of Lean and Six Sigma methodologies [2]. It has been successfully implemented in businesses that produce chemicals, medications, medical supplies, and information technology. While it is widely used in large automotive firms, there is also evidence that smaller auto auxiliary businesses have applied it [3].

Some major automakers have successfully implemented the Lean Six Sigma technique, resulting in significant outcomes [4].

1. The waste is being properly managed.
2. All items are provided without any defects.
3. A stronger emphasis on meeting the client's needs and delivering value to both the company and the client.

1.4. Current Scenario of the Automobile Industry

- After China, the United States, Japan, and Germany, India is the world's fifth-largest producer of automobiles, including passenger cars, light commercial vehicles, minibuses, trucks, buses, and coaches.

- India has the fourth largest passenger and commercial vehicle market in the world, with 4.02 million units. This is after China (with 29.12 million units), the USA (17.58 million units), and Japan (5.24 million units). It is predicted that by 2026, India's market will rise to the third rank.
- India's passenger vehicle market had the second-highest growth rate globally in 2017-2018 at 7%, trailing only China.
- The automotive sector accounts for 45% of the manufacturing GVA and 7.1% of India's GDP.
- It is expected that by 2026, the automotive sector in India, including component manufacturing, will contribute more than 12% of the country's GDP and generate $250-280 billion in yearly sales, along with creating 65 million new jobs.
- India had only 32 cars per 1000 people in 2015, but with 66% of the population under 35, there is potential for growth.

1.5. Literature Review

Small and Medium-sized Enterprises (SMEs) are defined under the MSMED Act, 2006 as organizations with less than 500 employees and an investment in equipment and machinery ranging from five to ten crore Indian Rupees (INR). These businesses are crucial to the economies and economic development of many nations worldwide, accounting for 50% of global GDP and 60% of employment. The use of technology also assists Large-Scale Enterprises (LSEs) in achieving their objectives, and its importance in the global industrial sector leads to a significant output volume [5].

Small and Medium-sized Businesses (SMEs) encounter various challenges, such as excessive inventory, lengthy lead times, inadequate planning, and higher cycle times. They also deal with resource limitations, fixed manufacturing mechanisms, inefficient processes and procedures, lack of knowledge about modern machinery and technology, unfamiliarity with financial volatility and global market trends, and limited resources [6]. SMEs in both rural and urban areas of India are struggling to stay afloat due to poor product quality and high production costs. Adding to this challenge, much of their workforce is illiterate and works in unsafe conditions.

Furthermore, the lack of communication and knowledge-sharing among employees is negatively affecting their productivity [7]. To remain competitive, Small and Medium-sized Enterprises (SMEs) must adopt new strategies, instruments, and methods for continuous development, even in the absence of government funding, encouragement, and leadership [8].

Indian producers of automobiles and auto parts are looking for methods to leverage lean advantages to grow their businesses internationally in addition to domestically. As a result, OEMs have mandated that suppliers employ LSS tools in order to increase efficiency and save costs. By removing flaws, these solutions have shown to be incredibly effective in big businesses and Indian automakers around the world, making them more customer-focused.

The integration of LSS and sustainable manufacturing is largely practiced by developed nations, with little enthusiasm shown by developing or Asian countries [9]. Certain industries and processes require appropriate testing, modelling, and measurement methods to ensure their effectiveness and success. SMEs should adopt LSS and sustainability as they significantly contribute to the economy, jobs, and social progress [10, 11].

In a research conducted in the Netherlands, it was concluded that brainstorming, 5S, VSM and failure mode analysis are important tools for lean Six Sigma implementation in SMEs [12].

Research targeting various U.S. manufacturing firms reflected that 24% of large firms and 14% of small firms are interested in implementing improvement techniques [13].

Small scale industries have less financial resources and rigid management. This makes it difficult to implement new change methods [5].

Important research reflects that information technology, healthcare, infrastructure and process industries implement Lean Six Sigma integration [14].

DMAIC technique of Lean Six Sigma is popularly used for improvement in aerospace and engineering firms [15].

1.6. Research Gap and Problem Identification

Lean, Six Sigma and other methods are popular in developed countries like the U.S., Japan and other western countries. These methods are not widely used in India. It is derived that there are not many success stories about implementing LSS in automobile SMEs in India. Company management, practitioners, and field experts should join hands to improve the performance of automobile SMEs by integrating Lean and Six Sigma.

2. Materials and Method

2.1. Questionnaire Based Survey

Questionnaire based analysis is frequently utilized in Lean Six Sigma implementation [12, 13]. For the current research, a questionnaire was created to identify the important Lean/Six Sigma tool for automobile SMEs, as shown in Table 3. This questionnaire was forwarded to field experts, consultants and industry persons for feedback.

Table 3. Questionnaire: important lean six sigma tools for targeted SMEs

Description	Level of Agreement				
	1	2	3	4	5
FME Investigation					
Cause and Effect Analysis					
Kano Analysis					
Poka-Yoke					
Histograms					
Run Charts					
Process Flow Chart/ Mapping					
SPC Charts					
Scatter Diagrams					
Analysis of Variance					
PDCA					
Brainstorming					
Just in Time					
TPM					
Kaizen					
Cell Out					
Standardizing of Operations					
Quality Circles					
5S					
SMED					
Continuous Flow					
Kanban					
Quality Control SPC					
Value Stream Mapping					

2.2. Case Study Company Details

There are many success stories of the effective execution of Lean Six Sigma tools in SMEs. They can lead to a reduction in downtime, less inventory requirement, a rise in profit margin and reduced rejections [5]. Some developing economies are adopting these change methods, with an increasing number of SMEs added every year [13].

A small and medium-sized enterprise, ABC that manufactures automobile components was selected to apply specific Lean Six Sigma (LSS) tools. ABC is a manufacturing facility located in Rajkot that was founded in 2014. The company is run by a proprietor who holds a diploma in mechanical engineering. Unfortunately, the business is facing challenges due to the recession and competition. However, the company is interested in implementing new techniques to improve its development process. Critical success factors play an important role in the success of any change method. Detailed research is carried out for important critical factors for the Indian scenario [14]. After several meetings with the company's management, it was decided to implement appropriate LSS tools for various processes.

2.2.1. Product Category ABC Company

- Automotive components (shafts, clutch/ brake parts, gearbox/differential parts etc.)
- Earthmoving components
- Valve and valve components
- The general engineering components

2.2.2. Turn Over

- Over the past five years, the average turnover has been 8.2 crore rupees every year.

2.3. LSS Team

LSS concepts are best learned as a team. A team representing all important functions and departments was formed. It was decided to meet twice a month. The main objective of the team was to learn and understand suitable LSS tools for quality and cost-effectiveness.

It can be difficult to find the time and personnel to implement change methods in small or medium-sized businesses. Therefore, a LSS coach with over 15 years of experience in implementing LSS was appointed. The coach reported to the general manager or owner of the business.

The functions of a Lean coach were:

- Selecting and assigning team members for the LSS implementation.
- Creating and carrying out training programs for workers and employees at various levels.
- Teaching LSS principles, tools, and importance.
- Directing the creation and implementation of the LSS operating system (standard works, Kaizen, 5S, supermarkets, etc.)
- Creating and maintaining a learning environment.
- Encouraging Lean transformation.
- Establishing a system of assessment, feedback, and correction for the application of LSS.

2.3.1. Team

- LSS coach
- Q.C.Manager
- Production in charge
- The assembly shop in charge

- Store and procurement manager
- Maintenance Engineer
- Head of Sales and Marketing Department

2.4. Implementation of Important LSS Tools in Company ABC

2.4.1. Implementation of 5S

A standard operating procedure was designed and implemented for 5S implementation, as shown in Figure 1.

Sort

- Determine which items are not in use and dispose of them. Parts which are not used regularly should be marked with a red mark.
- Take out of the work area any materials and items that are not in use, and store them somewhere else.
- Backup tools should be kept in a remote location with restricted access.
- Eliminate individual toolboxes for each technician. Only one toolbox for each workstation.

Straighten

- Everything has a place, and everything is placed accordingly
- Establish distinct locations for each item.
- Arrange the tools using foam cutouts or another method.
- The machine worker must be able to access the tools (they should be set up in front of them or on a tool balancer close to the work area).

Shine

- Neat workspace, equipment, and machinery
- Every operator has to clean up the workspace at the conclusion of their shift.

Standardize

- Create a protocol to uphold the initial three phases.

Sustain

- Create a weekly or monthly auditing system.
- Assign accountability to workers, operators and supervisors.

1(a) **1(b)** **1(c)** **1(d)**

Fig. 1 Implementation of 5S at ABC Company

2.4.2. Implementation of Value Stream Map (VSM)

Value stream maps can be effectively utilized for performance improvement in SMEs [15]. A VSM is a crucial tool that helps in identifying and eliminating waste produced during production. It is a visual representation of the process that shows the time, cost, inventory, and customer delivery time for both non-value-added and value-added operations. It illustrates the relationship between information, process, and material flow. The complete value stream map of a product includes all the steps involved in the process, starting from the moment an end-user generates an order until they receive the final product.

Value stream is important because;

- It illustrates the entire product flow through the factory.
- It provides visibility to processes so that they are easily comprehended.
- It displays the sources of process waste.
- It gives a picture so that everyone can see the goals with ease.
- It illustrates the proper flow of the work.
- It serves as a starting point for developing and putting into practice an improvement plan.

VSM for Brake Drum

A team consisting of a production supervisor, a quality control engineer, and an LSS consultant was established to create and evaluate present and future value stream maps for the brake drum.

Current state VSM

The production of brake drums consists of the following steps:

- Back face facing and boring
- Facing operation 1
- Facing operation 2
- Facing operation 3
- Grooving
- Boring of bearing seat
- Collar facing and turning
- Inspection.

The client places an annual order for brake drums. Each month, the customer needs 280 pcs of brake drums. The investment casting process yields the block that serves as the brake drum's basic material. Every three months, the company places an order for 840 pieces of raw material. Using this data, a current state value stream map was created; as seen in Figure 2, the cycle time for the produced part is 27.4 minutes, and the Lean time is 421.4 minutes.

Future State VSM

It represents the picture of material flow, non-value-added time, value-added time and inventory after proposed improvements. The following modifications are made for the manufacture of a chosen part:

- A single inspection was carried out as the last operation in the current state map.
  - Prior to performing the initial collar facing, turning, grooving, and inspection operation, a series of stage inspections were conducted instead of this single inspection process. This helped to reduce the cost of rejection by enabling the identification of errors at an early stage during the production process.
  - Furthermore, it led to a 61.3-minute reduction in the overall lead time.
  - Five Sigma was applied at several work sites.
- To lower the inventory level, a change was made to order raw materials every two months rather than every three.
- A Jig fixture was introduced for drilling and facing the back face. Improvement measures resulted in a reduction of the overall lead time to 356.5 minutes and the cycle time to 20.5 minutes, as seen in Figure 3.

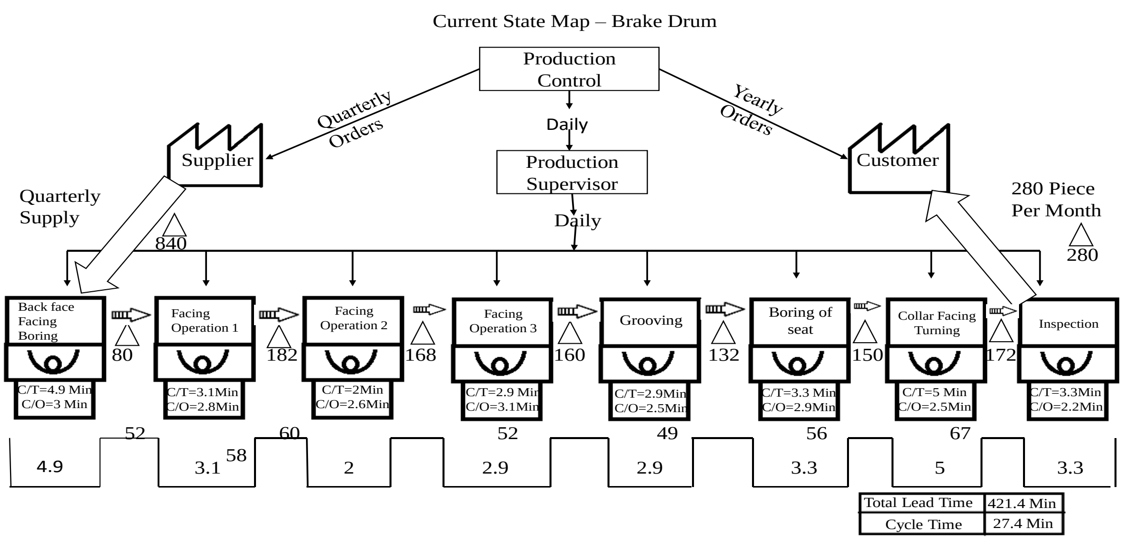

Fig. 2 Current state map for brake drum

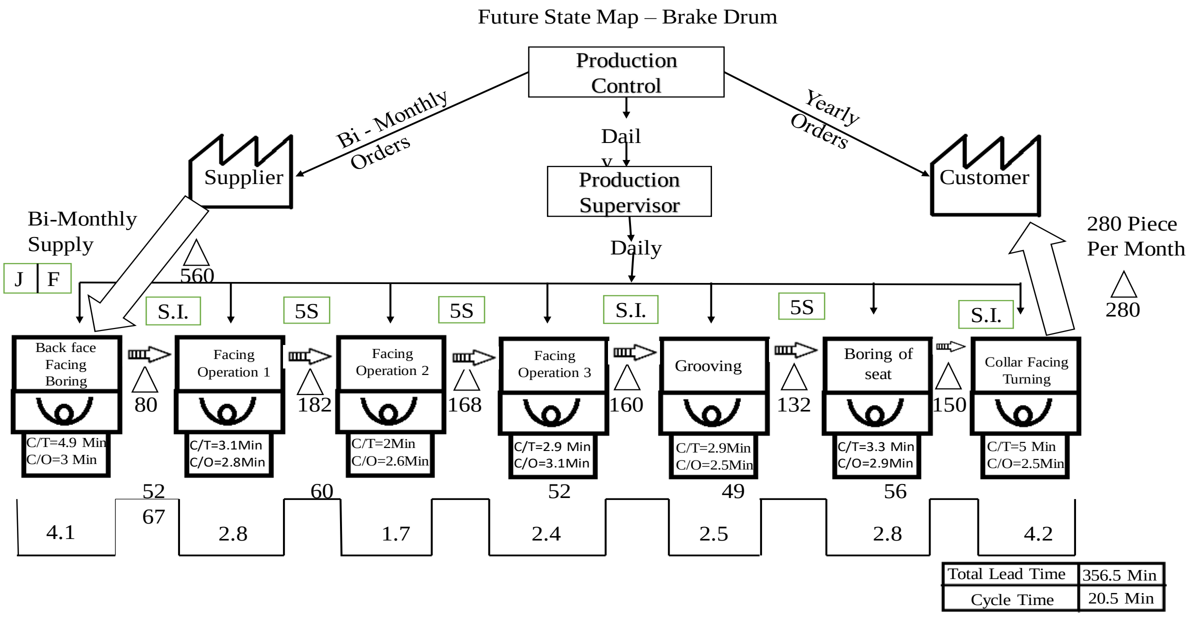

Fig. 3 Future state map for brake drum

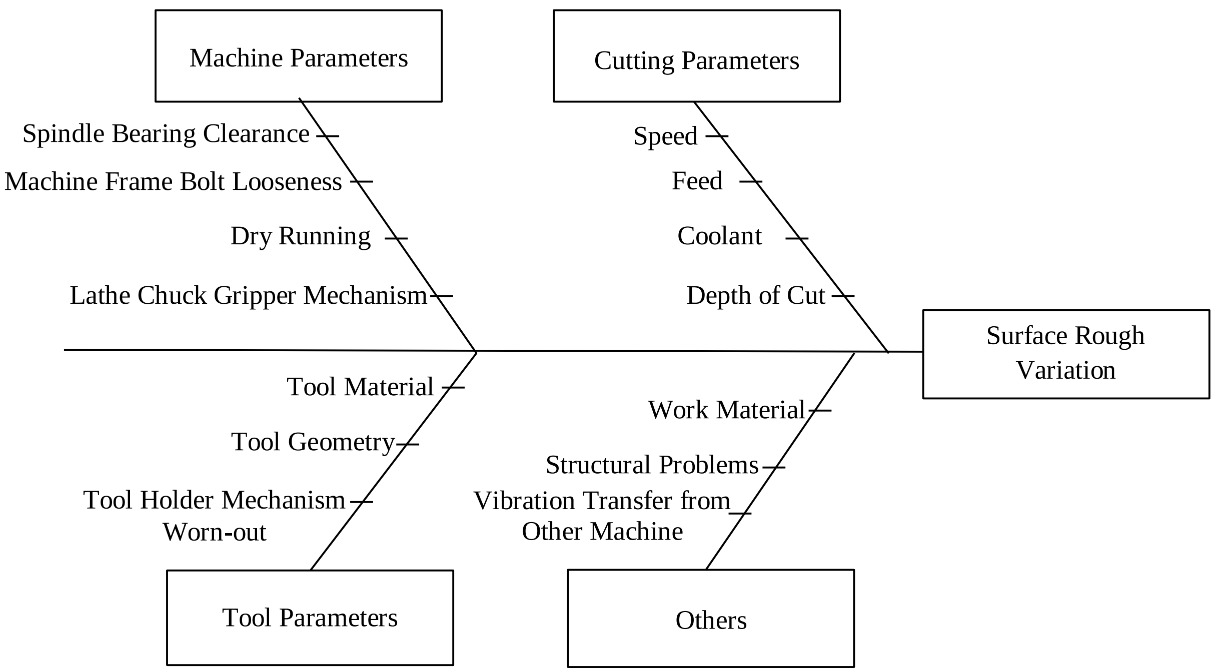

Fig. 4 Ishikawa diagram

2.4.3. Implementation of Ishikawa Diagram (Fish Bone Diagram)

Ishikawa diagrams are frequently used for early identification of causes of defects [16]. They are also known as fishbone diagrams. Kaoru Ishikawa initially introduced these graphics for the Kawasaki shipyards. They represent potential causes of defect. The defect is depicted as the head of a fish looking right, while the underlying reasons are illustrated as fish bones extending leftward. The origins of problems are identified by classifying the root causes into major groups. These diagrams enable us to view every underlying cause at once. It is a highly visual brainstorming tool that may recall further examples of root causes.

High Surface Roughness – Ishikawa Diagram

Parts made by a lathe machine had high surface roughness. An Ishikawa diagram was created to identify the root cause, as represented in Figure 4. The root causes were grouped into four categories i.e. machine parameters, cutting parameters, tool parameters and others. Three to four core causes exist for each group. One by one, the system's core causes were examined. The lathe spindle bearing was replaced because it was experiencing excessive clearance from wear.

2.4.4. Implementation of Standardization of Operation

Definition: "correcting, improving and redefining various procedures of an organization". As an important outcome of current research, standardization of operations is an important tool for the implementation of LSS in automobile SMEs. Standardization is an upgrade or alteration of operation intended to lower costs and reduce defects. To lower the cost of rejection, it is important to identify the source of the defect early in the production cycle. In this regard, every important operation and procedure was identified and examined for potential enhancements and changes. Staff members at all levels were invited to participate, and important departments were involved. Operational standardization was implemented to achieve significant anticipated outcomes, including cost savings, quality enhancement, customer happiness, inventory reduction, and flexibility. Standard procedures that successful LSS production units used were recommended for application.

First Piece Approval Report

After examining Q.C. data, it was decided to implement first-piece approval reports for all significant machines, parts, and processes. Studies have revealed that there is a greater likelihood of defects following certain activities, such as changing machine settings, tool change, and new batch of casting, changing operators, and fixing a breakdown. As a result, it was decided to examine the first four pieces manufactured after these events. All machines and parts have had their first piece approval reports created and completed. Table 4 represents the sample first piece approval report.

3. Result and Discussion

3.1. Important Six Sigma and Lean

Essential Lean and Six Sigma tools were derived using feedback from respondents. In Figure 5, the percentage of participants who have indicated that a given tool had an importance level of 4 or 5 are plotted on the Y-axis (percentage occurrence) represented by the height of the bar chart. The particular tool is mentioned on the X-axis.

Significant lean tools are Kaizen, VSM, 5s, standardization of operation, TPM, Quality control SPC and Quality circle. 5s, Kaizen and standardization of operations have an occurrence percentage of 84%, 80% and 78%, respectively.

3.2. Rejection Rate and Cost of Rejection Analysis

Appropriate LSS tools were applied at firm ABC, and the results of such implementation were examined. The total pieces produced, total rejection, percentage of rejection, and cost of rejection (per piece) for the 14 different parts produced in the company prior to LSS adoption are shown in Table 5. Table 6 represents the data after the implementation of LSS tools, as discussed in the materials and method section.

Table 4. Sample first piece approval report for brake drum-BD09

FIRST PIECES APPROVAL REPORT								
Name Of Component: Brake Drum-BD09								Drawing No. : SC924
Material: FG - 260 CI								Date
Shift: First / Second				Set Up: 1st				Machine Name and No.
Sr	**Parameters**	**Specification and Tolerance**	**Measuring Instruments**	**Set Up: 1st**				**Remarks**
				1 Piece	**2**	**3**	**4**	
1	Visual Inspection	Free from cracks, blow holes, and other casting defects	Visual					
2	O.D	250. ± 0.1	Vernier Caliper					
3	Bore	107.00 to 107.20	Snap Gauge					
4	Brake Size	225.00 to 225.00	Snap Gauge					
5	Total Height	86.7 ± 0.5	Height Gauge					
6	Depth	60.0 ± 0.1	Height Gauge					
7	Depth	76.0 ± 0.1	Height Gauge					
FIRST SAMPLE		Approved :						Not Approved
Note: First piece set up approval when new setting, M/c rectification after breakdown, tool change, casting batch change, Operator Change.								
Operator Name and Sign :								Supervisor Sign:

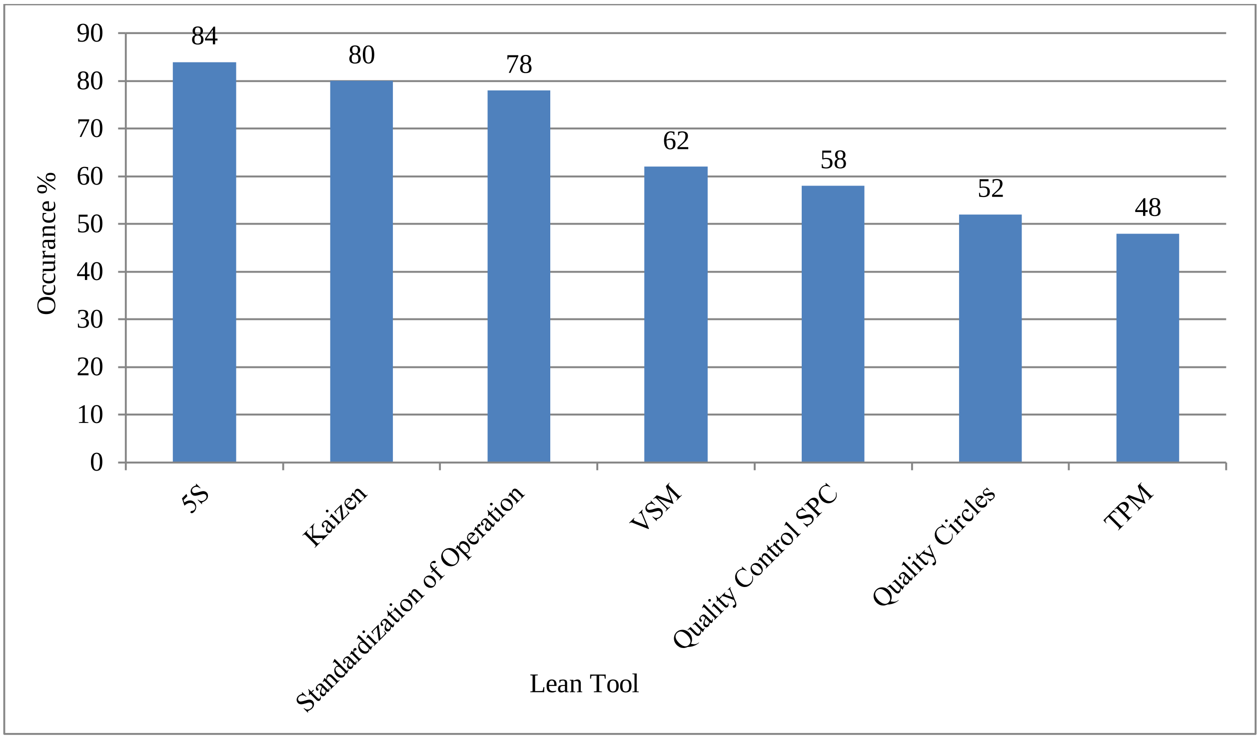

Fig. 5 Suitable lean tools

Table 5. Monthly rejection analysis Jan 2021, 10-2-21

Monthly rejection analysis Jan 2021, 10-2-21					
Sr. No	**Part No.**	**Total Production (Piece)**	**Total Rejection (Piece)**	**Rejection Percentage**	**Cost of Rejection per Piece (in Rs)**
1	T1826	1228	12	0.97	666
2	T1949	326	4	1.22	585
3	T2653	2688	31	1.15	853
4	T2356	937	15	1.6	553
5	T2626	4570	42	0.91	1176
6	T1224	620	11	1.77	2164
7	T1823	96	2	2.08	625
8	T1827	738	12	1.62	167
9	T1336	236	3	1.27	328
10	T1924	3260	35	1.07	1330
11	T2036	832	10	1.2	680
12	T2826	720	10	1.38	2820
13	T2729	40	0	0	822
14	T2830	282	6	2.12	2790
Total		16573	193	1.16	

Table 6. Monthly rejection analysis Jan 2022, 18-2-22

Monthly Rejection Analysis Jan 2022, 18-2-22					
Sr. No.	**Part No.**	**Total Production**	**Total Rejection**	**Rejection Percentage**	**Cost of Rejection per Piece (in Rs)**
1	T1826	1426	10	0.8	666
2	T1949	280	3	1.1	585
3	T2653	2530	19	0.8	853
4	T2356	870	10	1.15	553
5	T2626	4296	24	0.6	1176
6	T1224	537	7	1.3	2164
7	T1823	182	3	1.64	625
8	T1827	636	7	1.1	167
9	T1336	252	2	0.8	328
10	T1924	3341	22	0.7	1330
11	T2036	836	7	0.83	680
12	T2826	742	7	0.9	2820
13	T2729	62	1	2.5	822
14	T2830	326	4	1.2	2790
Total		16316	126	0.76	

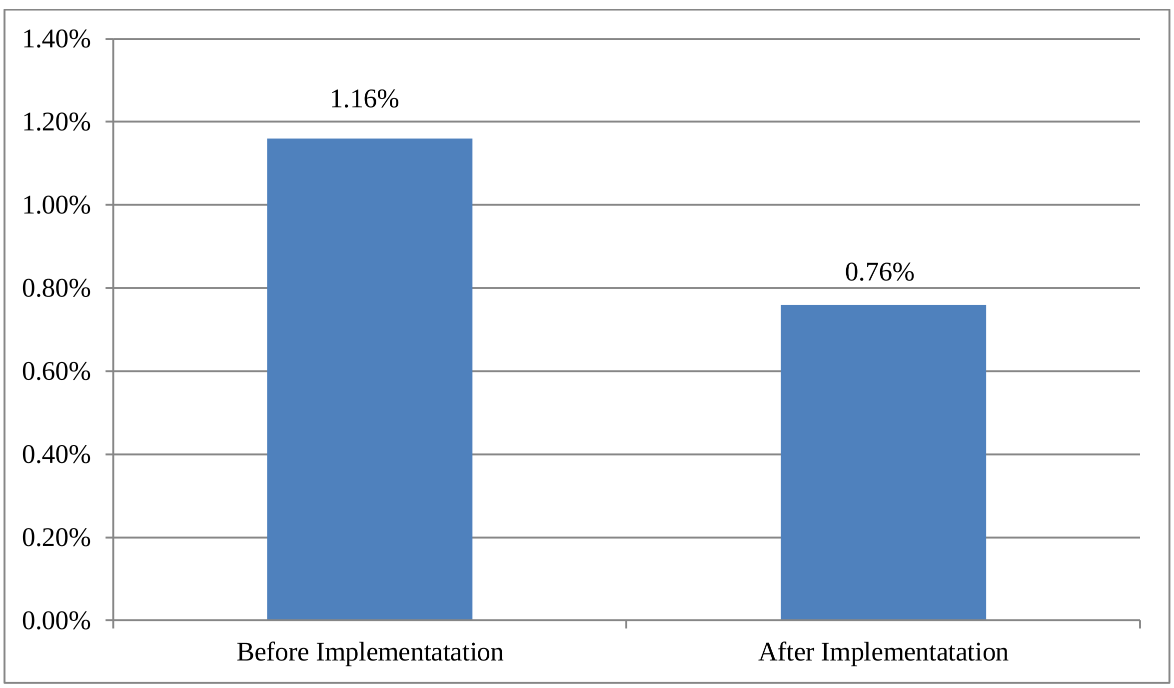

Fig. 6 Status of rejection rate before and after implementation of lean six sigma at ABC

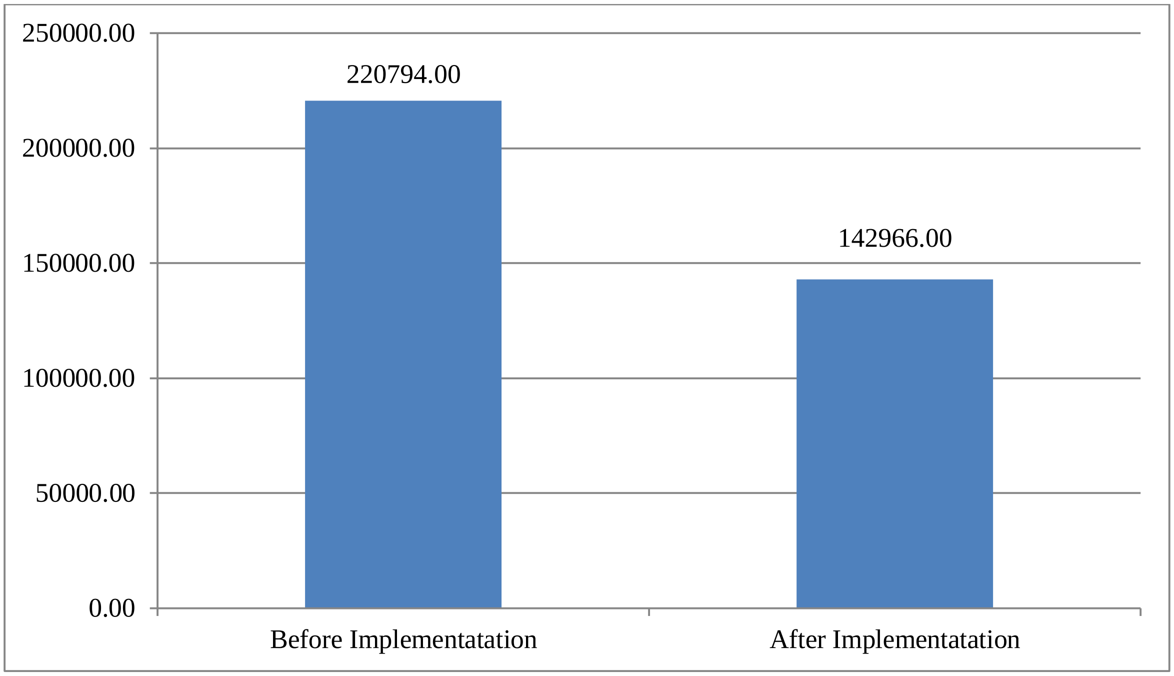

Fig. 7 Status of cost of rejection before and after implementation of lean six sigma at ABC

It is derived that the rejection rate reduced from 1.16% to 0.76% after the implementation of specific LSS tools as shown in Figure 6. As represented in Figure 7, the cost of rejection decreased significantly, by 35.24%, from 220794 to 142966 rupees per month. In Tables 5 and 6, the last column represents the cost of rejection for each piece. It is assumed that during the implementation stage, the cost of rejection per piece does not change.

3.3. Novelty of Research Work

A novel idea involving distant LSS practitioners, Company management/Employees and Consultants was implemented to address the key issues. Potential improvement areas were identified based on customer feedback and the weightage of the issue. The junior and middle-level employees were trained for the implementation of Lean Six Sigma.

The project detail was forwarded to various distant LSS practitioners (who were not directly involved in the project). Suggestions from practitioners were implemented for the questionnaire design and implementation phase. Integration and teamwork of three levels of personals resulted in considerable improvement compared to other state-of-the-art techniques.

3.4. Limitations and Suggestions for Improvement

- Employ reward system was not implemented because of financial limitations.
- The project was carried out in a comparatively newer plant, and the same methodology may not work in old plants.
- Methodology and tools were implemented for automobile sector SMEs. They may not work for other sectors.
- Suitable tools are to be investigated for SMEs of textile, FMCG and other sectors.
- Experts should be involved from different sectors/countries.
- Critical success factors should be investigated.
- Culture change requires a longer time for implementation.

4. Conclusion

- Appropriate Lean Six Sigma tools are derived using a conventional questionnaire.
- Certain small and medium-sized automotive industries can successfully apply 5S, VSM, Ishikawa, and standardization of processes.
- Uses of LSS methods have been shown to enhance both quality and cost aspects significantly.
- Managers can design strategies for improved outcomes by referring to the results of presented research. Three main issues facing managers are a lack of expertise, inadequate training, and cultural shifts.
- Faculty members and students studying engineering and management can benefit from using current research as a case study.

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