A Review of Six Sigma Approach to Enhance Performance in Manufacturing Industries

Ravindra L. Karwande(✉), Santosh P. Bhosle, and Prashant M. Ambad

Department of Mechanical Engineering, Maharashtra Institute of Technology, Aurangabad, India
ravindrakarwande@yahoo.com

Abstract. From the last few decades, Six Sigma has played a vital role in global corporate as a top agenda in order to optimize cost and improve productivity, to generate maximum business benefit and competitive advantage by continually reducing defects in the organization. The paper summarizes a brief introduction to the Six Sigma methodologies in order to establish a basis of definition, methodology, advancement and scope for modernization of industry in terms of six sigma development. Article lightened the techniques of six sigma such as DMAIC, DFSS and Lean sigma with vast areas covered with advantages and benefits in the state of manufacturing and management organization to establish compact bonds of technology for further scope. Six Sigma techniques elaborated here, itself proves to be the best technique for present to future with the need of Artificial Intelligence and Information Technology: a new era of six sigma ahead for fast growing industries for more accurate and most efficient techniques for zero tolerance in order to achieve sustainable development goals worldwide.

Keywords: Six Sigma · Operational performance · DMAIC · TQM · DFSS · Lean Six Sigma

1 Introduction

The improvement of process performance and product quality is constantly prioritized in the age of globalization and rising market competition in order to achieve the organization's bottom-line objectives of profitability, sustainability, market share, and competitiveness. Products of poor-quality result in manufacturing mistakes, which raise manufacturing costs and lengthen the manufacturing process. Since zero tolerance is stressed, manufacturing businesses are looking for many more sustainable alternatives, such as process optimization, efficiency improvements, precession, and absolute product design and development times. Many strategies are now being used to address the aforementioned problems; however six sigma is the one that is most effective due to its simplicity, quality, profitability, and sustainability [1].

In terms of history, Bill Smith and Bob Galvin created the six sigma system of quality management in the 1980s in Motorola [2]. A statistical concept known as "sigma" refers to any standard deviation of the random variable from the mean value. Therefore, Six Sigma refers to having less than 3.4 defects per million opportunities, which is

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theoretically six times the standard deviation. Six Sigma is viewed as a philosophy or concept with a broad application that is crucial to transforming an organization and the globe [3]. The goal of Six Sigma, a formal and extremely disciplined approach, is to eliminate or reduce production errors or failures in order to increase customer satisfaction, lower costs, and financial success [4]. The Six Sigma methodology is a well-known industrial process improvement method that is systematic, organized, and uses a scientific approach to develop new products with the main goal of continuously improving procedures and achieving customer satisfaction [5].

Six Sigma becomes the newest management trend in leading organizations to transform and improve their financial performance by repackaging outdated quality management ideas, methods, and tools/techniques [6]. Although there are many difficulties and realities, including the need to comprehend business systems, productivity, and financial performance in addition to product quality, six sigma has benefited both technology-driven and project-driven organizations [6].

The goal of this paper is to review and analyze the development, advantages, and strategies of six sigma approaches in operational performance, as well as the diversity of six sigma approaches in cost, productivity, market share, customer satisfaction, cultural change, manufacturing industries, etc., with highs and lows of six sigma with advanced scope in today's manufacturing industries with wealth of tangible benefits [8]. Thus, Six Sigma falls within the category of process management programs. However, in some technological and organizational environments, a firm's ability to innovate and be responsive to new consumers may be hampered [9].

2 Six Sigma: Strategies, Tools

Six sigma is more comprehensive than earlier quality initiatives like Total Quality Management and Continuous Quality Improvement since it concentrated on financial results, more sophisticated tools for data analysis, customer concerns, and the application of project management techniques to improve operational performance, boost profitability, and enhance competitiveness resulting in a highly structured and disciplined methodology of never ending improvement in process management that produces the following correlation [7, 14]:

Six Sigma = TQM + Stronger Customer Focus + Additional Data Analysis Tools + Financial Results + Project Management.

3 Techniques in Six Sigma

Six Sigma techniques include some important process tools for process planning and quality assurance such as DMAIC, DFSS and Lean Six Sigma.

3.1 DMAIC

DMAIC cycle has a lot of similarities with Deming's "Plan-Do- Check-Act" (PDCA) cycle [10]. *DMAIC* basically stand for Define, Measure, Analyze, Improve and Control

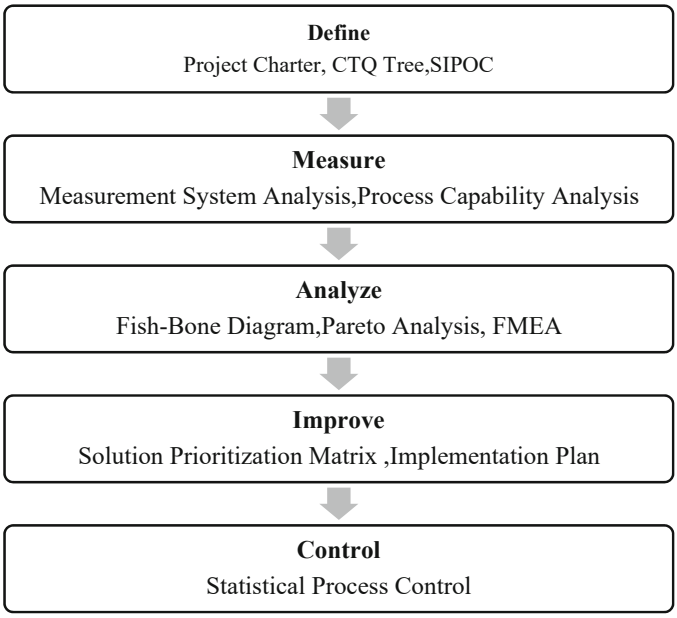

Fig. 1. DMAIC Flow Chart [8, 9, 12]

(See Fig. 1). It is an organized and innovative roadmap inside the six sigma framework for resolving business issues, and accurate and successful project execution based on genuine and scientific facts as opposed to on experience and expertise [11].

Maximizing resource usage, reducing redundancy, waste, and rework are just a few of the difficulties that this technique helps to solve more effectively [12]. It is used to address issues with the current procedures and products incorporating concepts from Taguchi's off-line quality control, statistical quality control, comprehensive quality management, and other quality engineering insights. It expanded on insights from the field of quality engineering [15, 16, 18, 19].

Foundry operations that use DMAIC technologies include the sand-casting process with response to surface methodology, optimization of the radial forging operation variables, supply chain management, estimation of wastage and to shorten the cycle time of production in a biopharmaceutical operation, shock absorber manufacturing, etc. This makes DMAIC a key tool that was successful in identifying the issue, improving the procedure, and a solution [20, 30].

3.2 DFSS Process

A systematic methodology called Design for Six Sigma (DFSS) uses tools, training and measurements to help a company design products and processes.

The DFSS technique out performs DMAIC in the early stages of New Product Development (NPD), Utilizing the Identify, Design, Optimize and Validate (IDOV) strategy improves the design process [13]. The DFSS technology can be used in both conventional and traditional production processes to improve both goods and manufacturing

Fig. 2. DFSS technique process parameter [26, 27]

processes while taking into account the complexity of current operations. This method is essential for enhancing the features of six sigma technology. The DFSS considers systematic and economical methods for developing new products and processes in order to minimize product defect and process variation, qualitative as well as quantitative analysis of assembly, product and part design etc. [25, 38]. DFSS is nothing more than the design and redesign of both goods and services with the primary goal of incorporating quality into both by determining customer needs, translating these into quality characteristics, implementing these through particular aspects of the product/service design, and appropriately verifying the final design (Fig. 2).

Several DFSS frameworks exist, including the Identify, Define, Develop, Optimize, and Verify framework (IDDOV) and Define, Measure, Analyze, Design, and Verify (DMADV) [26, 27].

Innovative theory of creative problem-solving (TRIZ), a technique integrated into product development processes in DFSS for generating a new product, is one of the frameworks that are extensively employed in a variety of industries. As a result, DFSS has been demonstrated to be the ideal technique, particularly for designing new products in today's advanced manufacturing processes [28].

3.3 Lean Six Sigma Techniques

Six Sigma was used to adopt numerous cost-cutting strategies, of which Lean Six Sigma is the systematic application of the integrated approach throughout the organization [29].

Process mapping, value stream mapping, cause-and-effect matrices, and failure mode and impact analyses are just a few of the numerous integrated tools that make up Lean Six Sigma. In order to get the greatest results, the six sigma and lean six sigma approaches have been integrated by utilizing their respective advantages in various contexts.

Numerous elements, such as leadership and strategic direction, quality-driven organizational culture, ongoing training, teamwork, customer satisfaction, and technological system, influence the implementation of LSS [30].

Benefits of lean Six Sigma:

- retain and attract customers
- reduce manufacturing costs
- increase process flexibility
- Increase capacity.
- Increasein work flow and information flow.
- Improve process documentation.

Lean six sigma plays a crucial strategic role in reducing waste and non-value-added operations throughout the organization and producing potent solutions to persistent issues.

Application of Lean Six Sigma

- Cutting down on machine downtime.
- A uniform housekeeping system should be established, and employee confidence should rise.
- Enhancing OPE and OEE; encouraging a sense of pride in one's work among employees.
- Addressing client complaints.
- Decrease in inventories.
- Cutting down on machine setup time.
- Cutting down on workplace accidents [31].

4 Six Sigma: Practical Approach

4.1 Six Sigma as an Integrated Process Management Methodology

In terms of scope, methodology, and approach, Six Sigma has a flexible approach for enhancing organizational processes that work to alleviate continuous improvement in order to achieve reduced variation, lower costs, and high-quality final products. Thus, employing lean six sigma techniques like Kaizen, Value Stream Mapping, Pareto charts, Single-Minute Exchange of Die (SMED), and 5S, Six Sigma has become possibly the most effective and viable technique for process quality improvement [11, 18].

4.2 Cost Reduction

To boost operational performance process expenses should take into account cost reduction and quality control approaches [32]. The DMAIC approach, a continuous improvement methodology was adopted by Six Sigma to reduce potential variability from processes and products [17].

In order to achieve operational excellence in a manufacturing application such as the assembly process, vehicle crash-worthiness, design optimization in high productivity, reduction of material in material coatings, and good quality, it is crucial to apply the Six Sigma tools of DMAIC and lean six sigma. These tools significantly improve the

ability to determine wastage and to reduce the cycle time of the production process cycle efficiency (PCE), waste minimization and process performance improvement. Lean Sigma approach implementation led to savings of around $140,000 annually, $660,000 annually, and over $243,000 annually [11, 21, 31, 33].

DMAIC phases, according to some researchers, reduced the defect rate from 31% (baseline) to 4% [22].

4.3 Other Practical Application in Industry

a. **In project management:** The critical to quality characteristics (CTQs), which went from 40% to 61%, were improved by the usage of project management of Six Sigma tools and Lean Production for the enhancement of total equipment effectiveness. This decreased variability [30]. With the help of DMAIC and the lean paradigm, Six Sigma is able to reduce process time and costs, increase quality, and optimize process management [20].

b. **In manufacturing process**

- By applying Six-Sigma approaches to the sand-casting process, a greater number of potential failure reasons are found and prevented, increasing efficiency and performance levels. [20, 34].
- The metal casting industry's green sand casting process, which uses DMAIC to systematically identify and solve the key problems, was successful in identifying the issue, streamlining the procedure, and controlling the flaws. [23].
- Failure mechanism and effect analysis in non-value added activities and owing to product defects, unsuitable processing, and waiting were types of manufacturing waste that were regularly occurring in the iron ore industry. This was done in order to improve the manufacturing process capability. Six sigma plays a crucial role in this iron ores industry sector by reducing errors, failure modes, manufacturing waste, etc. [3, 22].
- The Six Sigma approach has a considerable reduction in residual stress and an improvement in production quality to optimize the radial forging operation variables [24].

c. **Lean Six Sigma in energy sector:** Six sigma using lean methodology has great application in improving daily management, improvement suggestion from, a new customer case per reason for calling, to developed a Control Plan and a Monitoring Plan document, control the process in order to avoid deviating from the established targets, as demonstrated by researchers in a service activity for the energy sector [35].

d. **DMAIC in production process:**

- Six sigma employing DMAIC has been shown to be the most effective way in the manufacturing industries, with benefits including avoiding fines for breaching agreements, lower production costs, more productivity, and ultimately a reduction in the quantity of work in progress as per the company's terms. Due to superior organization, lack of overtime, the ability to accept more orders throughout the calendar season, and other factors related to production planning and control, it also increased customer satisfaction [2].

- Six Sigma guidelines for process mining using the DMAIC model have been created to aid firms in selecting the most effective process mining method systematically. Process mining has been shown by researchers to be an effective method for carrying out process analysis and improving frameworks in mining processing [36].

e. **Six Sigma in tire manufacturing:**

The literature suggests that the lean sigma strategy was created in the tier industry because tyres from the automobile industry make up the majority of the waste in developing nations. The analysis of end-of-life management aspects, tyre reworking system design, value analysis for scrap tyres in the cement industry, and profitability of car and truck tyres are all significant areas where six sigma methodologies are crucial. Thus, lean six sigma contributes to the proposal of approaches for process parameter improvement in the tyre and vehicle industries [37].

5 Future of Six Sigma

Six sigma important initiatives to improved operational performance, overall management not only incurred vast application quoted in article and many others. The boundaries of six sigma technology, such as mechatronics, are becoming more and more attractive. Many researchers and practitioners are attempting to integrate six sigma with other innovative management practices already in use, such as artificial intelligence and IT sector. They are also integrating and contrasting the six sigma principles and characteristics with total quality management, human resource functions, ISO 9000, ISO 9001, and the capability maturity model, among other things.

Six Sigma lacks a theoretical foundation and a basis for research, implementation difficulties, a lack of competent coaching, etc. aside from "best practice" studies. Therefore, extensive research is needed to practically integrate Six Sigma in manufacturing industries and production management. Beyond this, collaboration with advanced manufacturing research methodologies like AI and IT is also necessary.

6 Conclusion

Six sigma is a mild stone in today's growing and fully implemented organization with the caliber of removing defects, reduction in process cost, large variety of practical application, flexibility, and huge scope of implementation of today's advanced technique. It delivers world-class quality standards of product and service in terms of measurement of quality, improvement in efficiency, and excellencies in process implementation.

Thus, Six sigma techniques itself proves to be best for present to future with need of Artificial intelligence information technology for fast growing industries for more accurate zero tolerance in order to achieve sustainable development goals worldwide.

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