ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

Review Paper: Quality Improvement through Six Sigma DMAIC Methodology

Patel Rumana*, Darshak A. Desai

*ME Scholar, G. H. Patel College of Engineering & Technology, Vallabh Vidyanagar, Anand, Gujarat India

Professor & Head. Mechanical Engineering Department, G.H. Patel collage of Engineering and technology (GCET),Vallabh Vidyanagar, Anand, Gujarat, India

Abstract

This paper is an attempt to review and present how the DMAIC methodology has been studied and researched by various researchers.

Globalization, advanced technology, and increased sophisticated customer demands change the way of conducting business. Old business models no longer work in new economy. Defects rate of product plays an important role for the improvement of yield and financial conditions of any company. Business performance excellence is the competitive edge for commercial firms to survive in highly competitive markets. Among the many business improvement approaches available, the Six-Sigma approach has been recognized as one of the most effective methods. Organizations are increasingly adopting Six Sigma in a bid to improve the quality of their processes and products, and thus achieve competitive advantage. Six Sigma is a smarter way to manage business or department. It is a vision of quality that equates with only 3.4 defects for million opportunities for each product or service transactions, Strives for perfection. Ultimate objectives of the methodology to solve problems, improve the quality, profitability and customers satisfaction. Six Sigma is the tool through which we can improve the Quality and profitability by removing the cause of defects and variability in manufacturing and business processes. Six Sigma has been on an incredible run for over 14 years, producing significant savings to the bottom-line of many large and small organizations. Six sigma take the users away from 'intuition-based' decisions to 'fact-based' decisions. The objective of this paper is to present an overview of six sigma. The DMAIC Methodology (Define, Measure, Analyses, Innovation, Improve and Control) the problem solving steps used for six sigma projects are also reviewed in detail in this paper.

Keywords: Six Sigma, Quality improvement, DMAIC, CTQ, ANOVA, DOE..

Introduction

In the globalisation of markets and operations, focus on quality and productivity is of utmost importance[7]. Quality improvement in operations and production has been one of the most significant influences for organisation to be successful[7]. Meeting customer requirement at minimum possible cost and time is the main mantra of success for any sort of business[9].

The main objective of any business is to make profit. For increasing the profit, the selling price should increase and/or the manufacturing cost should come down. Since the price is decided by the competition in the market, hence the only the way to increase the profit is to cut down the manufacturing cost which can be achieved only through continuous improvement in the company's operation [18]. Six sigma is one such technique available to bring the breakthrough improvements almost in every sector through overall operational excellence [9]. The central idea of the Six Sigma approach is to design processes, or improve existing processes, to obtain very high process capability and hence defect rates that are close to zero [9]. Six sigma is a systematic, highly disciplined, customer-centric and profit-driven organization-wide strategic business improvement initiative that is based on a rigorous process focused and data-driven methodology [5], [12], [21], [24], [25], [26].

Six sigma is defined a customer oriented, structured, systematic, proactive and quantitative companywide approach for continuous improvement of manufacturing, services, engineering, suppliers and

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

other business process. It is a statistical measure of the performance of a process or a product [18]. Six Sigma is the methodology having statistical base focusing on removing causes of variations or defects in the product or core business processes. The improvement focus is on business outputs which are of critical importance to the customers [5], [19]. It drives customer satisfaction and bottom-line results by systematically reducing variation in processes and thereby promoting a competitive advantage. Six sigma is considered a strategic corporate initiative to boost profitability, increase market share and improve customer satisfaction through statistical tools and techniques that can lead to breakthrough quantum gains in quality [25], [29]. In simple words Six Sigma as a program aimed at the near elimination of defects from every products, process and transactions [3]. Six sigma blends management, financial and methodological elements to make improvement to process and products concurrently [25]. Six Sigma provides business leaders and executives with the strategy, methods, tools and techniques to change their organizations. There are four aspects of the Six Sigma strategy that are not emphasized in other business improvement methodologies and total quality management (TQM). First of all, Six Sigma places a clear focus on bottom-line savings. Second, Six Sigma has been very successful in integrating both human aspects (culture change, training, customer focus etc.) and process aspects (process stability, variation reduction, capability etc.) of continuous improvement. Third, Six Sigma methodology (DMAIC) links the tools and techniques in a sequential manner. Finally, Six Sigma creates a powerful infrastructure for training of champions, master black belts, black belts, green belts, and yellow belts [13].

Six Sigma has been exploited by many world class organizations such as GE, Motorola, Honeywell, Bombardier, ABB and Sony to name but a few, and has resulted bottom-line savings in millions. Motorola launched Six Sigma in 1987 and the significant early benefits of the project resulted in Motorola winning the Malcolm Baldrige Award in 1988. IBM, Sony and Allied Signal followed Motorola in implementing Six Sigma in the early 1990s. Allied Signal successfully attained savings of US$2 billion during a five-year period. Soon, the impressive results induced General Electric (GE) to undertake a thorough implementation of the Six Sigma programme in 1995 and produced more than US$2billion in benefits. The impressive benefits of implementing Six Sigma programmes in Motorola, Allied Signal and GE resulted Six Sigma the most prominent trend in quality management, not only for the manufacturing and service industries, but also for non-profit organizations and government institutes [3], [4], [17],[18], [20], [29]. Six Sigma is a long-term commitment. It won‘t work well without full commitment from upper management [18].

Methodology of six sigma

Six Sigma has been defined as the statistical unit of measurement, a sigma that measures the capability of the process to achieve a defect free performance [18]. Six is the number of sigma measured in a process, when the variation around the target is such that only 3.4 outputs out of one million are defects under the assumption that the process average may drift over the long term by as much as 1.5 standard deviations[13], [18]. The term ―sigma‖ is used to designate the distribution or the spread about the mean of any process. Sigma measures the capability of the process to perform defect-free work. A defect is anything that results in customer dissatisfaction. For a business process, the sigma value is a metric that indicates how well that process is performing [18]. Higher sigma level indicates less likelihood of producing defects and hence better performance [18], [29], [30].

Six Sigma has two key methodologies:
DMAIC Methodology and DMADV Methodology, both inspired by Deming‘s Plan-Do-Check-Act Cycle [30].

- DMAIC
- DMADV

DMAIC:
The DMAIC means Define, Measure, Analyses, Improve and Control. These all works together to create the DMAIC process. This process is incredibly important in six sigma process because it is what helps bring a diverse team together. This is what helps them complete a process or model so that they can share their work and get the job done. It is used to improve an existing business process.[30], [18].
DMAIC consists of following steps:

- Define process improvement goals that are consistent with customer demands and the enterprise strategy.
- Measure key aspects of the current process and collect relevant data.
- Analyze the data to verify cause-and-effect relationships. Determine what the

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

relationships are, and attempt to ensure that all factors have been considered.
- Improve or optimize the process based upon data analysis using techniques like Design of Experiments.
- Control to ensure that any deviations from target are corrected before they result in defects. Set up pilot runs to establish process capability, move on to production, set up control mechanisms and continuously monitor the process [18], [29].

DMADV:
The DMADV means Define, Measure, Analyze, Design and Verify. Where DMAIC is used to improve the an existing business process. DMADV is used to create new product or process design.
DMADV consists of following steps:
- Define design goals that are consistent with customer demands and the enterprise strategy.
- Measure and identify CTQs (characteristics that are Critical To Quality), product capabilities, production process capability, and risks.
- Analyze to develop and design alternatives, create a high-level design and evaluate design capability to select the best design.
- Design details, optimize the design, and plan for design verification. This phase may require simulations.
- Verify the design, set up pilot runs, and implement the production process [18], [30].

In this paper we are going to discuss the DMAIC methodology in detail.

DMAIC methodology

D:Define
This is the overall problem definition step. This is one of the most critical phases of DMAIC Methodology, if required, maximum time and efforts should be allocated to this phase. This phase identifies critical customer requirements and links them to business needs [3], [9]. The aim of Define phase is to define the project with all details including project title, objective, scope, team composition, expected benefits and schedule for the project in terms of the customer requirements and identify the process delivering these requirements [11]. This phase helps to envisage the scale and complexity of the problem. The first task was to develop a project charter to help team members clearly understand the scope and boundaries of the project, project objectives, project duration, resources, roles of team members, estimated financial gains from the project, etc. This creates a sense of ownership for the project; it also prevents the delivery of mixed messages between project managers and team members [26,[9]. The problem must be selected in such that it is directly linked to an organization's business metrics and bottom line. If the six sigma project is not in link with organizational goal then its not possible to get expected results from it [6], [10].

Following aspects were covered in this phase on the problems selected.
- Fixing problem statement to work upon.
- Critical to quality (CTQ) tree based on costumer's needs and requirements
- Drawing high-level process map to understand the process [9].

Problem statements:
This Problem statement should be SMART (Specific, Measurable, Achievable, Relevant and Time-Bound)[6], [3].
- CTQ tree:

For identifying requirements of the customers, the critical to quality tree being the most effective one, is useful. This will help to understand the critical quality requirements of the product. To improve the quality of the product, these CTQ need to be addressed [3], [5], [6], [9], [11], [12], [14], [19], [22], [24], [27].
- High-level process map:

This processes map shows how currently the process is operating. This helps in determining what in the process is not operating [3], [5], [9].

Tools and techniques used in define phase:
Project charter [12], [27].
SIPOC model [11], [12], [19], [21], [27].
Voice of Customer (VOC) [19], [22], [24], [27].
Process flow [23].

M: Measure
This is essentially a data-collection phase. Once the problem has been defined, it must be decided what additional measurements must be taken to quantify it [29]. This phase is concerned with selecting one or more product characteristics, mapping the respective process, making the necessary measurements, recording the results on process control cards, and establishing a baseline of the process capability or process performance [26]. This is basically a data collection phase wherein present situation data are collected and then current sigma level is calculated

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

for the process in question. Sigma level can be calculated by different methods, based on the type of data [9]. Wrong or incorrect data collection can sink the complete six sigma process [6], [10]. At this phase, the following two important aspects were addressed.

- Data collection

Accurate and sufficient measurement and data are needed. Data are the essence of the six sigma project [29].

- Calculation of present sigma level

Sigma level can be calculated by different methods, based on the type of data. For discrete data defects per million opportunity (DPMO) number is calculated and then sigma level is ascertained from the DPMO-sigma level table.

$$\text{DPMO} = \frac{(\text{Number of defects} \times 10^6)}{(\text{Number of Oppurtunities} \times \text{Number of units})}$$

where
Number of defects = number of rejections (i.e. at least one defect exists to impute the product as defective).
Number of opportunities = number of CTQs.
Number of units = number of units produced [3], [5], [7], [9], [11], [27].

But when the data is continuous, first the distribution is identified and then the sigma rating is computed accordingly [21], [27].
Tools and techniques used in measure phase:

Pareto chart [23].
Process flow chart [12], [24], [26].
Statistical Quality Control (SQC) tools [27].

A: Analyze

The measurement and data must be analyzed to see if they are consistent with the problem definition and also to see if they identify the root cause. A problem solution is then identified. Sometimes, based on the analysis, it is necessary to go back and restate the problem definition and start the process over [29]. The objective of Analyse phase in a Six Sigma project is to identify the root causes that are responsible for high variation in the selected CTQs [11]. The aim of the analyze phase in a Six Sigma project is to identify the potential causes for the process problem being studied and then select the root causes with the help of data and their analysis. Once a list of potential causes has been generated, the next step is to plan for validation of these causes based on the data collected from the process [7], [12], [24]. Lot of innovative thinking and discussions are required to identify the potential causes for a problem. A brainstorming session was planned and conducted by the team with the involvement of all the concerned personnel of the process, and a list of potential causes for variation in CTQ was generated. A cause-and-effect diagram was drawn based on these causes [11], [12].

Tools and techniques used in analysis phase:
Pareto Chart [3], [9], [26], [27].
Brainstorming [21], [27].
Root Cause Analysis [3], [5], [9], [11], [12], [19], [21], [22], [26], [27].
Five-Why Analyze Technique [9], [27].
Failure mode and effect analysis [2], [27].
Hypothesis Testing [20].

I: Improve

During the improve phase of the project, solutions for the selected root causes are to be identified and implemented to observe the results. As per the decision of the team in the analyze phase [12]. After understanding the root cause of the problem and have quantitative data, we identify possible solutions. Tests may be required to understand any interaction between the input variables. Tolerances have to be examined to see if they truly represent need. Once we have tested the possible solutions, we implement the best of those solutions and verify that results we predicted are actually occurring [29], [30]. The improve phase spotlights on developing thoughts to get rid of root causes of variation, testing and standardizing those solutions [24], [5].

Tools and techniques used in Improvement phase:
Pareto diagram [5].
Taguchi's Design of experiment [7], [12], [14], [19], [27].
Brainstorming [21], [27].
ANOVA [7], [12], [14], [27].
Analysis of variance [7].

C: Control

The control phase is where the new system is in place and it is institutionalized by modifying various systems, polices, procedures, budgets, and instructions to make it work for the entire company. If you do not put into control the six sigma gaols, then the previous four stages were worthless [29], [30]. The basic objectives of this phase are to ensure that our processes stay in control after the improvement solution has been implemented and to

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

quickly detect out of control state and determine the associated causes so that actions can be taken to control the problem before non-conformances are produced. Success in this phase depends upon how we did in the previous phases. In control phase, tools are put in place to ensure that the key variables remain within acceptable ranges over time so that process improvement is maintained [3]. Depending up on type of the problem and operating system of the concern, the following control measures were recommended:

- Periodic review of the various measures suggested in Improve phase.
- Statistical Quality Control (SQC) charts [3], [5], [9], [11], [12], [21], [23], [24], [26], [27]. Thus maintaining targeted sigma level.

Conclusion

This paper was an attempt to review the six sigma methodology studied by various researchers. And it is in a way of learning six sigma concept and DMAIC in more detail.

Six Sigma has been widely publicized in recent years as a powerful methodology to combat quality-related problems and to achieve customer satisfaction. It has been considered as a strategic approach to improve business profitability and to achieve operational excellence through effective application of both statistical and non-statistical tools/techniques. The application of Six Sigma is growing almost every day moving from the manufacturing industry to service, transactional, administrative, R&D, sales and marketing, healthcare, and software-development industries.

Six Sigma is a measure of process performance and a process operating at 6-Sigma quality has a defect rate of 3.4 parts-per-million opportunities. In many instances a Six Sigma process is regarded as world class. The average performance of most processes today is in the range of 3–4 Sigma. The Six Sigma measure of process capability assumes that the process mean may shift over the long term by as much as 1.5 Sigma, despite our best efforts to control it. In the Six Sigma process, 3.4 defects per million opportunities (DPMO) is obtained by assuming the specification limits are six standard deviations away from the process target value and that the process may shift by as much as 1.5 Sigma. The 3.4 DPMO value is the area under the normal curve beyond 6-1:5= 4:5 Sigma. Similarly the 66807 DPMO for the 3-Sigma process is the area under the normal curve beyond 3-1:5= 1:5 Sigma.

The define phase involves identifying a project's critical-to-quality (CTQ) characteristics driven by the voice of the customer (VOC), followed by developing a team charter and finally defining a high-level process map. A good decision for project generation not only provides profits but also increases customer satisfaction. However, there still lacks a well-structured approach to assist a company in creating the feasible projects.

In the measurement phase, the team identifies the key internal processes that influence CTQ characteristics and measures the defects currently generated relative to those processes.

The analyse phase consists mainly of three steps: establishing process capability with the help of capability indices, defining performance objectives by the team benchmarking, and identifying the sources of variation.

The improvement phase optimize the process based upon data analysis.

In control phase improvements are maintained beyond the completion of the project. It is well known that real improvement will only come from the shop floor. The application of Six Sigma requires top-management involvement and provision of appropriate resources and training . Senior managers within the organization must be taught the principles of Six Sigma to enable the restructuring of the business

organization and to change their attitude towards this more disciplined approach.

It is essential that each employee of the company understands the status quo of their work environment as well as all the decisions the company make. Employees should understand the concept for each process improvement and more important, become involved in the company's initiatives. Leadership has been proven to be an extremely important factor for Six Sigma implementation. it was observed that all hurdles in executing the study were cleared by strong leadership at middle management. Thus, it was identified that improvement initiatives require strong leadership support not only at the higher level but also in the middle level of the organization. The main enabler for Six Sigma implementation is the top management commitment.

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

The Six Sigma Approach is customer-driven. The approach aims at continuous improvement in all the process within the organisation. This works on the belief that quality is free, in that the more we work towards zero-defect production, the more return on investment we will have. The advantages of six sigma approaches are reduction in defects/rejections, cycle time, work in progress etc. and increase in product Quality &Reliability, customer satisfaction, productivity etc. leading ultimately to excellent business results. The core principles of statistical thinking and the role of management in statistical thinking for improving business performance will continue to grow in importance in the forthcoming years.

References

1. T.R. Vijayaram, S. Sulaiman, A.M.S. Hamouda, , M.H.M. Ahmad 'Foundry quality control aspects and prospects to reduce scrap rework and rejection in metal casting manufacturing industries', Journal of Materials Processing Technology 178 (2006) 39–43
2. Chao-Ton Su , Chia-Jen Chou, 'A systematic methodology for the creation of Six Sigma projects: A case study of semiconductor foundry',mExpert Systems with Applications 34 (2008) 2693–2703
3. Darshak Desai, 'Increasing Bottom-Line Through Six Sigma Quality Improvement Drive: Case of Small Scale Foundry Industry', Udhyog Pragati Vol. 36, No. 2, April-June, 2012
4. M. Shanmugaraja, M. Nataraj and N. Gunasekaran, 'Empirical Study for Six Sigma Success: Mapping Organizational Hierarchy with Barriers', International Journal of Applied Engineering Research ISSN 0973-4562 Volume 5 Number 10 (2010) pp. 1821–1826
5. Darshak A. Desai, 'Improving productivity and profitability through Six Sigma: experience of a small-scale jobbingmIndustry', Int. J. Productivity and Quality Management, Vol. 3, No. 3, (2008)
6. E. V. GIJO & TUMMALA S. RAO, 'Six Sigma Implementation – Hurdles and More Hurdles' Total Quality ManagementmVol. 16, No. 6, 721–725, August (2005)
7. M. Shanmugaraja and M. Nataraj, 'Defect control analysis for improving quality and productivity: an innovative Six Sigma case study' Int. J. Quality and Innovation, Vol. 1, No. 3, (2011)
8. Muthuswamy Shanmugaraja* andmMuthuswamy Nataraj 'Literature snapshot on Six Sigma project selection for future research', Int. J. Services and Operations Management, Vol. 11, No. 3, (2012)
9. Darshak A. Desai, 'Quality and productivity improvement through Six Sigma in foundry industry', Int. J. Productivity and Quality Management, Vol. 9, No. 2, (2012)
10. *E.V. Gijo*, '11 Ways to Sink Your Six Sigma Project', Six sigma forum magazine, November (2011), 27-28
11. E. V. Gijo & Johny Scaria, 'Process improvement through Six Sigma with Beta correction: a case study of manufacturing company', Int. Journal of Advance Manufacturing Technology (2014) 71:717-730 DOI 10.1007/s00170-013-5483-y
12. E.V. Gijo, Shreeranga Bhat, N.A. Jnanesh, 'Application of Six Sigma methodology in a small-scale foundry industry', International Journal of Lean Six Sigma Vol. 5 No. 2, (2014) pp. 193-211
13. Darshak A. Desai, Mulchand B. Patel, 'Impact of Six Sigma in a developing economy: analysis on benefits drawn by Indian industries' Journal of industrial engineering and management (2009) – 2(3): 517-538 - ISSN: 2013-0953
14. Andrew Thomas and Richard Barton, 'Developing an SME based six sigma strategy', Journal of Manufacturing Technology Management Vol. 17 No. 4, (2006) pp. 417-434
15. Taho Yang and Chiung-Hsi Hsieh, 'Six-Sigma project selection using national quality award criteria and fuzzy multiple criteria decision making method' 978-1-4244-2108-4/08/$25.00 © (2008) IEEE
16. Darshak A. Desai, 'Cost of quality in small- and medium-sized enterprises: case of an Indian engineering company', Production Planning & Control, Vol. 19, No. 1, January (2008), 25–34
17. Darshak A. Desai, Jiju Antony, M.B. Patel, 'An assessment of the critical success factors for Six Sigma implementation in Indian industries' International Journal of Productivity and Performance Management Vol. 61 No. 4, 2012 pp. 426-444

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

18. Neha Gupta, 'An overview on six sigma: Quality improvement program', International Journal of Technical Research and Applications e-ISSN: 2320-8163, Volume 1, Issue 1 (March-April 2013), PP. 29-39
19. Kunal Ganguly, 'Improvement process for rolling mill through the DMAIC Six Sigma approach' International Journal for Quality research, Vol. 6, No. 3, (2012)
20. Sunil Dambhare, Siddhant Aphale, Kiran Kakade, Tejas Thote, Uddhava Jawalkar, 'Reduction in Rework of an Engine Step Bore Depth Variation using DMAIC and Six Sigma approach : A case study of Engine Manufacturing Industry', International Journal of Advanced Scientific and Technical Research Issue 3 volume 2, March-April (2013) ISSN 2249-9954
21. Mehdiuz zaman, Sujit Kumar Pattanayak & Arun Chandra Paul, 'Study of feasibility of six sigma implementation in a manufacturing industrial: A case study' International Journal of Mechanical and Industrial Engineering (IJMIE) ISSN No. 2231-6477, Vol-3, Iss-1, (2013)
22. Veena Badiger1, R V Praveena Gowda, ' reduction in customer complaints due to inlet port leak in engine cylinder head of a light commercial vehicle sub assembly by lean six sigma tools' International journal of management research and business strategy Vol. 2, No. 3, (July 2013)
23. A. Kumaravadivel1, U. Natarajan, 'Empirical study on employee job satisfaction upon implementing six sigma DMAIC methodology in Indian foundry – A case study' International Journal of Engineering, Science and TechnologyVol. 3, No. 4, (2011), pp. 164-184
24. Mohammed T. Hayajneh, Omar Bataineh, Ramial-Tawil, 'Applying Six Sigma Methodology Based On "DMAIC" Tools to Reduce Production Defects in Textile Manufacturing', Recent Advances in Industrial and Manufacturing Technologies ISBN: 978-1-61804-186-9
25. Jiju Antony, Darshak A. Desai, 'Assessing the status of six sigma implementation in the Indian industry Results from an exploratory empirical study' Management Research News Vol. 32 No. 5, (2009)pp. 413-42
26. J Antony1*, M Kumar2, and M K Tiwari Proc., 'An application of Six Sigma methodology to reduce the engine-overheating problem in an automotive company', IMechE Vol. 219 Part B: J. Engineering Manufacture (2005)
27. Omkarprasad Vaidya and Sushil Kumar, 'Achieving better results using Six Sigma approach', Vol. 34, No. 2, April-June, Udhyog Pragati (2010)
28. R. M. Nachiappan, N. Anantharaman and N. Muthukumar, 'Evaluation of lean Six sigma in a Continous product line manufacturing system', Vol. 34, No. 2, April-June, Udhyog Pragati (2010)
29. Warren Brussee, 'All about six sigma', TATA McGraw-Hill publishing company limited.
30. Craig W. Baird, 'The six sigma manual for small and medium businesses', Yes Dee publishing Pvt Ltd.
31. Angelo R. Uy, Marvin V. Picardal, Patrocinio Enriquez, Arnold C. Alaraz, 'Package Crack Resolution through Low Stress Dambar Punch Design: A Six Sigma DMAIC Approach', 34th International Electronic Manufacturing Technology Conference, (2010)