

Six Sigma DMAIC Literature Review

Mr. Ganesh P. Jadhav, Mr. Sandeep B. Jadhav, Mr. Amol Bhagat

Abstract— Today manufacturing industries are highly impacted by the fast changing economic conditions. In this scenario manufacturing industries are facing global competition due to globalization. The major problems those are being faced by these industries are declining profit margin, customer demand for high quality product and product variety. There is a high pressure today on every manufacturing industry of reduced lead-time. ISO 9000, Total Quality Management, Kaizen, Just-in-time manufacturing, Enterprise Resource Planning, Business Process Reengineering, Lean management are some of the industrial engineering and quality management strategies developed to respond to the needs of global competition. A very recent and power philosophy in this area is six sigma. In manufacturing sector worldwide, six sigma is becoming very popular and its advantage is being taken for improving productivity and quality performance and also to make the process robust to quality variations. This paper presents a review of the six sigma case studies implemented in the Automobile Industries, small Scale Industries, Service Industries and also the Product Manufacturing Industries.

Keywords- Six Sigma, DMAIC, Quality

I. INTRODUCTION

SIX SIGMA is quality tool, used in many organizations, strive for near perfection. In other words Six Sigma is a data driven, disciplined approach and methodology. It is based on eliminating the defects in any process. It can be used in manufacturing product or service industries. The aim of Six sigma approach is to achieve and maintain the six standard deviations between mean and nearest specifications limit. In terms of statistical representation it can be said that six sigma describes quantitatively how a process is performing. a process must not produce more than 3.4 defects per million opportunities to achieve Six Sigma. Anything outside of customer specifications is called as a Six Sigma defect is. The total quantity of chances for a defect can be termed as a Six Sigma opportunity. We can use six sigma calculators to calculate process sigma.

The implementation of a measurement-based strategy that focuses on process improvement and variation reduction is the Fundamental objective of the Six Sigma methodology. This can be achieved by systematically using two of the Six Sigma

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sub-methodologies which are DMAIC and DMADV. The Six Sigma DMAIC processes (Define, Measure, Analyze, Improve, Control) is an improvement system for existing processes falling below specification and looking for incremental improvement. The Six Sigma DMADV process (Design, Measure, Analyze, Design, Verify.) is an improvement system used to develop new processes or products at Six Sigma quality levels. if a current process requires more than just incremental improvement then also DMADV can be employed. In 1989 Bill Smith defined Six Sigma as “Organized common Sense” [4]. Alan Larson (2003) stated that within Six Sigma System everyone is committed to meet customer’s expectations through the use of collaborative focus. “Six Sigma is a methodology for minimizing mistakes and maximizing value. Every mistake an organization or person makes ultimately has a cost-a lost customer, the need to do certain task again, a part that has to be replaced, time or material wasted, efficiency lost, or productivity squandered. In fact, waste and mistakes cost many organizations as much as 20 to 30 percent of their revenue! That’s a shocking number. Imagine throwing 20 to 30 percent of your money away in the garbage every time you cash a check. It may sound ludicrous, but that’s many organization do. Every organization and individuals have room to improve. Six Sigma methodology helps in this”. [3]

“Six Sigma” is a comprehensive and flexible system for achieving, sustaining and maximizing business success. Six Sigma is uniquely driven by close understanding of customer needs, disciplined use of facts, data, and statistical analysis, and diligent attention to managing, improving, and reinventing business processes. This is the definition that will provide the foundation for our efforts to unlock the potential of Six Sigma for your organization. The types of “business success” you may achieve are broad because the proven benefits of the Six Sigma “system” are diverse, including the following [2] Cost reduction

- Productivity improvement
- Market-share growth
- Customer retention
- Cycle-time reduction
- Defect reduction
- Culture change
- Product/service development

Six Sigma focuses on Six Sigma focuses on customer requirements, defect prevention, cycle time reduction, and cost savings. Thus, the benefits from Six Sigma go straight to the bottom line. Unlike mindless cost-cutting programs which also

reduce value and quality, Six Sigma identifies and eliminates costs which provide no value to customers, waste costs. For non-Six Sigma companies, these costs are often extremely high. Companies operating at three or four sigma typically spend between 25 and 40 percent of their revenues fixing problems. This is known as the cost of quality, or more accurately the cost of poor quality. Companies operating at Six Sigma typically spend less than 5 percent of their revenues fixing problems. COPQ values shown in Figure 28 are at the lower end of the range of results reported in various studies. The dollar cost of this gap can be huge. General Electric estimated that the gap between three or four sigma and Six Sigma was costing them between \$8 billion and \$12 billion per year. [1]

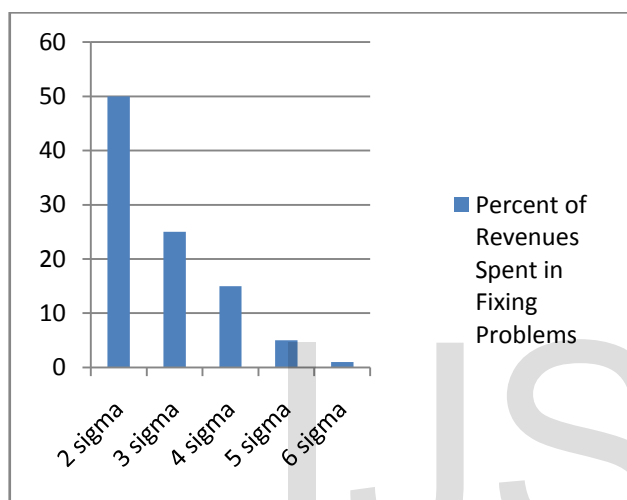


Fig. 1 Cost of Poor Quality versus Sigma Level [1]

TABLE I
UNITS FOR MAGNETIC PROPERTIES

Sigma Level	Defect Rate (PPM)	Yield In %	Cost Of Poor Quality (% Of Sales)	Competitive Level
6σ	3.4	99.99966	< 10%	World class
5σ	233	99.9767	10 to 15 %	
4σ	6210	99.379	15 to 20 %	Industry Average
3σ	66807	93.3193	20 to 30 %	
2σ	308537	69.1462	30 to 40 %	Non- Competitive

II. SIX SIGMA SCALES OF DEFECTS

Table I shows % yield for various sigma level.

III. SIX SIGMA IN MANUFACTURING INDUSTRIES

Kunal Ganguly (2012), [5] used DMAIC Six Sigma Approach for the improvement of the process for rolling Mill. He implemented Six Sigma DMAIC in a large aluminum

company to eliminate down time due to coil slippage during rolling at hot mill. The challenge for Company was to cater fast changing export demand for the flat rolled products with its existing resources. He had used the six sigma DMAIC methodology to determine the projects CTQ characteristics. He defined the possible causes, identified the various sources, established variable relationship and implemented control plans. Through his six sigma DMAIC project he could achieve measurable results like the cycle time was reduced, slippage problem was eliminated, trials with wider widths were successful.

Hsiang-Chin Hung and Ming-Hsien Sung (2011) [7] has used The DMAIC (define measure-analyze-improve-control) approach in food company in Taiwan. By this methodology he solved an underlying problem of reducing process variation . thus he could reduce high defect rate associated with it. The results obtained were the reduced defect rate of small custard buns by 70% from the baseline to its entitlement. He has also presented idea regarding the factors that are responsible for success of Six Sigma project in a food industry.

Prof. Dr. Vidosav MAJSTOROVIĆ, et. al (2010) [9] in his work has used DMAIC methodology in certain Serbian metal processing manufacturing company. What He achieved through his project was the reduction of process variability, thus reducing quantity of nonconformities product. It led to increase of Sigma Level for the observed manufacturing system/process and customer satisfaction.

S. Pimsakul, N. Somsuk, W. Junboon, and T. Laosirihongthong (2013) [13] applied Six Sigma DMAIC methodology to improve a production process of a laser computer Mouse. By operating under these resulting conditions, yield of the functional test procedure increases from 96.2 to 98.6 %.

Mohit Taneja, Arpan Manchanda (2013) [14] has used Six Sigma Approach to Improve Productivity in Manufacturing Industry. In his paper he begins with an overview of Six Sigma, followed by thorough literature review on Six Sigma DMAIC phases, application of Six Sigma in small medium scale industries and also in large manufacturing industries. He has also done literature survey on various Six Sigma quality tools used in the industries. These include Process capability analysis, Fishbone Diagram, Two-sample t-test.

Tushar N Desai and Dr. R L shrivastava (2008) [15], in their paper they have discussed the quality and productivity improvement in a manufacturing enterprise through a case study. The paper deals with an application of Six Sigma DMAIC methodology in an industry which provides a framework to identify, quantify and eliminate sources of variation in an operational process in question, to optimize the operation variables, improve and sustain performance viz. process yield with well-executed control plans. The process yield was improved as a result of implementing this methodology. It has effect of improved and better utilization of resources and decreased variations. It also helped in maintaining consistent quality of the process output.

E. V. Gijo, Johny Scaria and Jiju Antony (2011) [16]

discuss Six Sigma DMAIC methodology in context with a case study of Grinding Process. The aim of DMAIC approach was to solve the underlying problem of reducing process variation and improving the process yield. This paper briefly describes how a manufacturing process can be benefitted through a systematic use of above methodology to move towards world-class quality level. The application of the Six Sigma methodology resulted in reduction of defects in the fine grinding process from 16.6 to 1.19%. Also it has had a significant financial impact on the profitability of the company. This was due to saving on rework, reduction in scrap cost, man-hour reduction, and increased output. This project reported a saving of approximately US\$2.4 million per annum.

R. González Falcón , D. Velázquez Alonso , L.M. Gallego Fernández , Luis Pérez Lombard (2011) [22] have proposed the application of Six Sigma methodology for improving energy efficiency in a distillation unit of a naphtha reforming plant. The results show an expected savings around 150,000€/year. They found through their project that the Six Sigma methodology is highly useful to improve the energy efficiency of distillation units. The project is all about using five-phase DMAIC methodology to characterize and optimize distillation process of a naphtha reforming unit. Organizing data into useful information is accomplished in the measurement phase of the DMAIC process, which establishes the baseline against which all future improvements will be compared.

Jeroen deMast, Joran Lokkerbol (2011) [25] have analysed the Six Sigma DMAIC method from the perspective of problem solving. Their paper compares critically the DMAIC method with insights from scientific theories in the field of problem solving. The purpose of the analysis is to identify limitations of the method. They claimed that these identified limitations may be an inducement for attempts at improving the method. Also he asserted that some limitations may be inherent to DMAIC, as it is not plausible that a strong method can be applicable without restrictions in all circumstances. In those cases, the practical value of identified limitations is that they provide a basis for advising users when the DMAIC method is suited.

Ploytip Jirasukprasert et. al (2012) [26] have done a case study of defects reduction in a rubber gloves manufacturing process by applying Six Sigma principles and DMAIC problem solving methodology. The results obtained through this were reduction in defects per million opportunities (DPMO) from 195,095 to 83,750. This indicates 50% reduction in the defects rate and thus improvement in its Sigma level from 2.4 to 2.9. This work identifies the quality issues at a Thai rubber gloves manufacturing company.

Adan Valles et. al (2009) [27] have used Six Sigma DMAIC methodology in a semiconductor company dedicated to the manufacture of circuit cartridges for inkjet printers. They are tested electrically in the final stage of the process measuring electrical characteristics to accept or reject them. During data collection they found that Electrical failures were about 50% of all defects. Thus it was essential to reduce the

level of defects by establishing the main problems, causes and actions. They determined the key factors, identified the optimum levels or tolerances and improvement opportunities. The improvement was a reduction in the electrical failures of around 50%. The results showed that with proper application of this methodology, and support for the team and staff of the organization, a positive impact on the quality and other features critical to customer satisfaction can be achieved.

Lateef Ur Rehman, Ateekh-ur-Rehman (2012) [31] have used Six Sigma Approach For a Safety Management in a Manufacturing Company. There was a health and safety department at the manufacturing department in the focussed company and its objective was to set and improve accidents prevention system. The paper presents how the six-sigma technique will help to evaluate the safety and environmental hazards in performance of organizations. The objective of this study is to use six-sigma technique to identify and reduce the occurrences of accidents at the company in consideration.

Md. Enamul Kabir, S. M. Mahbubul Islam Boby, Mostafa Lutfi, (2013) [33] have studied and evaluated the processes of the case organization, to find out current sigma level and finally to improve existing sigma level through productivity improvement. This has been done by using six-sigma DMAIC cycle. By using DMAIC methodology it has been possible to improve productivity by reducing defect rate. This research work has been carried out in a fan manufacturing company to show how to improve its productivity and quality by using Six-sigma. This paper related to work is not only applied to fan manufacturing company but also in any other types of organizations. By implementing Six-sigma a perfect synchronization among cost, quality, production time and control time will be observed. By applying 5s it is possible to reduce repetitive task by saving time which have shown on data analysis. Consequently, there is less possibility for producing defective fan which is the main target of six-sigma. On the other hand by applying line balancing, productivity increases from 240 to 312 per day by reducing defect. Finally it is said that, it is possible to improve productivity by using six-sigma which is the main purpose of this study. In the future, it is likely that more changes will emerge; making Six Sigma an even more beneficial application for organizations of all types and sizes.

IV. SIX SIGMA IN AUTOMOBILE INDUSTRIES

Dr. Rajeshkumar U. Sambhe (2012)[8], in his paper has focused on mid-sized auto ancillary unit consisting of 350-400 employee and employed Six Sigma methodologies to elevate towards the dream of Six Sigma quality level. The methodology is executed on one of product assembly for trimming down defects level which are critical to customers and its implementation has had a significant financial hit on the bottom-line of the enterprise. In define phase he developed project charter and then defined Opportunity statement and goal statement.

J Antony, M Kumar, and M K Tiwari (2005) [11] has dealt with the application of Six Sigma based methodology in

eliminating an engine-overheating problem in an automotive company. The aim was to reduce process variation and the associated high defect rate. This paper briefly presents how a foundry can use a systematic and disciplined approach to move towards the goal of Six Sigma quality level. The results obtained are reduction in the jamming problem encountered in the cylinder head and increased the process capability from 0.49 to 1.28. The financial impact was saving over \$US110 000 per annum.

Rajeshkumar U. Sambhe and Dr. Rajendra S. Dalu (2011) [19] have evaluated Six Sigma implementation in medium scale Indian automotive enterprises. In this paper they have discussed critical success factors for successful Six Sigma implementation in medium scale automotive industries in India. The survey was conducted using the questionnaire method. Their concluding remarks are there is very little research carried out in automotive sector and the study finds that only a 25.64% of medium scale automobile sector has implemented Six Sigma. They also stated that Medium Scale Automotive Enterprises are having good foundation of ISO 9000 .they also claimed that many enterprises have started adopting other good quality management strategies like Kaizen and TPM. They concludes that there is little implementation of advanced quality management system like Six Sigma in MSAI's which can hamper gain from World market. They also firmly said that the expensive consultation charges can be saved through in-house training.

Prof.S.N.Teli, Dr. U.M.Bhushi, Mr.V.G.Surange, (2012) [21] have given the Six Sigma implementation frame work. They also stated that Six Sigma can be equally applicable to small and medium-sized enterprises and service organizations too. In Indian small medium enterprises there is a huge research gap yet to be explored.

S. Suresh, A. L. Moe and A. B. Abu (2015) [28] have used Six Sigma DMAIC methodology for Defects Reduction in Manufacturing of Automobile Piston Ring. Using the Six Sigma method, the rejection percentage is reduced by 13.2% from the existing 38.1% of rejection. Further improvement in the rejection is expected in the long run after the continuous implementation of all the solutions.

S.N.Teli, Dr.V.S.Majali, Dr.U.M.Bhushi, Sanjay Patil (2012) [29] have discussed in their paper the Six Sigma tool to Reduce the Cost of Quality for Automobile Industry. Initially the Six Sigma DMAIC methodology is discussed in brief along with its applications and, advantages. Also the Six Sigma tools are discussed in brief. A case study is presented about Reduction in Exhaust Pipes & Silencer Failures. Also it was claimed that making use of Six Sigma concept helps keep the quality of the product controlled in a pleasing way to avoid unnecessary downsizing of one's overall profits. In cases where business quality costs starts to limit incoming profits, the best way to save everything is employing the Six Sigma methodology to the entire operation. This can increase the quality of the business output as well as the morale of the employees as well.

V. SIX SIGMA IN SMALL SCALE INDUSTRIES

Joshua Chan Ren Jie, Shahrul Kamaruddin and Ishak Abd Azid, (2014) [6] has proposed a DMAIC as a Lean Six Sigma (LSS) framework in his paper in Small Medium Enterprise (SME). He has focussed on the SME's problem of facing the pressure from its competitors; mainly large companies as they could provide products of greater value with lower cost as compared to SMEs. The DMAIC framework has been developed and verified in a label printing company by author. This SME label printing company produces various types of labels such as computer labels, offset & silkscreen stickers and bar code labels. The productivity of the label printing section shows an increase by 584 impressions/hour, which is an increase of 21.93% of the current production output.

Rajeshkumar U. Sambhe (2012) [10] discussed about the Journey of Six Sigma in Indian SMEs through a thorough Literature review. He mentioned that Six Sigma is a process improvement and defect reduction methodology employed to increase company's outturn and actualize the organizational excellence over appropriate exercising of statistical tools. As Six Sigma is a customer driven methodology, so it is necessary to prioritize the projects which provides utmost satisfaction to buyers through fulfilment of their demands and achieves more gain for the enterprise. As per him Financial and human resources are the two major constraints in Six Sigma implementation in small and medium scale enterprises. The top management commitment is most critical success factor in Six Sigma methodology implementation since it shows highest rank from most of former researches. The selection of the right project is over and above a challenge but customer satisfaction and financial benefits

U. D. Gulhane, C.A.Nalawade, K.P.Sohani , V.S.Shirodkar (2012) [24] has proposed implementation of Six Sigma model to medium scale tool industry. He has chosen a file manufacturing company for the purpose. Here, he initiated his DMAIC project with an objective decreasing the current rejection rate of 35000 defects per million opportunities of 6" Regular Taper File to minimum possible rejection rate quantified as less than 10000 defects per million.

VI. SIX SIGMA IN SERVICE INDUSTRIES

Darshak A. Desai (2006) [12] has used Six Sigma DMAIC methodology to Improve customer delivery commitments in an Indian small scale industry. It was found that on account of improved delivery the firm reported around 25% increase in their turnover by satisfying existing customers and developing new business.

K.G. Durga Prasad, K.Venkata Subbaiah, G.Padmavathi (2012) [18] have discussed the case study where the Six Sigma Methodology in an Engineering Educational Institution. They have mentioned that this approach has helped to establish a novel approach with a view to improve quality in an engineering educational institution. In this paper the students who are admitted to an engineering educational institution are considered as raw materials and

they are processed with an aim to convert in to final products called engineering graduates to meet the customer (industry) expectations. The purpose of this paper is to enhance quality in education. The authors firmly claimed that the Six Sigma approach proposed in the paper assures quality in education, desired placements in reputed companies, opportunity of higher studies, developing prospective entrepreneurs and higher percentage of pass outs. To implement Six Sigma methodology in engineering education, the first and the foremost requirement is the quality consciousness mind in the management of the institutions and the unconditional commitment and constant effort by every participant in the education system are essentially required.

S. Arun Vijay (2014) [23] has the objective of his research to reduce the cycle time of the patients discharge process using Six Sigma DMAIC Model in a multidisciplinary hospital setting in India. He has conducted study through the five phases of the Six Sigma DMAIC Model using different Quality tools and techniques. This study suggested various improvement strategies to reduce the cycle time of Patients discharge process and after its implementation; there is a 61% reduction in the cycle time of the Patients discharge process. Also, a control plan check sheet has been developed to sustain the Improvements obtained. This Study would be an eye opener for the Health Care Managers to reduce and optimize the cycle time of Patients discharge process in Hospitals using Six Sigma DMAIC Model. This study validated the application of Six Sigma DMAIC methods to reduce and optimize the patients discharge process with specific focus on a Medical and Surgical Department. Even though the average discharge time reduced from 234 minutes to 143 minutes demonstrating 61% decrease.

VII. SIX SIGMA REVIEW

Darshak A. Desai, Mulchand B. Patel (2009) [17] have analysed the impact of Six Sigma on developing economy like India. The study provides an insight into what kind of benefits Indian industries are gaining from Six Sigma as a whole. The study further highlights similarity and differences of benefit gained by different scales and sectors of Indian industries through Six Sigma. This exhaustive analysis of the benefits drawn by Indian industries through Six Sigma can assist other industries in India as well as those in other developing countries, who have yet not experimented with Six Sigma, to become more focused regarding their expectations from this improvement drive. As a whole, this study provided a comprehensive picture regarding benefits being drawn by Indian industries through Six Sigma improvement drive till date. They claimed that the study provided an insight into what kind of benefits Indian industries are gaining from Six Sigma. This can help other industries, who have yet not experimented with Six Sigma, to become more focused regarding their expectations from this improvement drive. Based on the analysis of this study, individual industry based on their size and type of operations can expect some specific benefits from Six Sigma implementation. The Six Sigma programme can be initiated with some specific benefits in

view based on industry operations.

Rakesh Kumar Tekade, Narendra Kumar Jain (2008) [20] have discussed Six Sigma as A Growing Quality Management Strategy with the aim of developing a general awareness with motivating approach justifying need to adopt Six Sigma. The work also argues additional benefits of Six Sigma over prior existing quality management approaches and addresses the concerns towards its implementation. Authors have discussed some of the important points such as Underlying Theory and Definitions of Six Sigma, its Historical Prospects, Fundamental Components of Six Sigma like process, defects, variation calculation of sigma level, Six Sigma staff. In this paper they have given a brief overview of DMAIC methodology through a literature review.

Nilesh V Fursule Dr Satish V Bansode Swati N Fursule (2012) [30] have discussed the benefits and limitations of Six Sigma methodology through a thorough literature survey. The main obstacles in Six Sigma implementation as per them are organizations own management and employees, active supplier participation, active customer's participation. They asserted that Six Sigma is a long term organizational commitment. It won't work well without full commitment from upper management. Six Sigma changes the way a company thinks by teaching fact based decision making to all levels. The programme changes the DNA of a company by changing the way the leaders think and by improving the management pipeline by developing the management skill and communication skill in people.

T. N. Goh (2002) [32] has done a strategic assessment of Six Sigma in his paper , some strategic perspectives on the subject are presented, highlighting the potential and possible limitations of Six Sigma applications particularly in a knowledge-based environment. He has discussed some inherent limitations of Six Sigma with the help of literature review. Figure shows Six Sigma DMAIC Methodology.

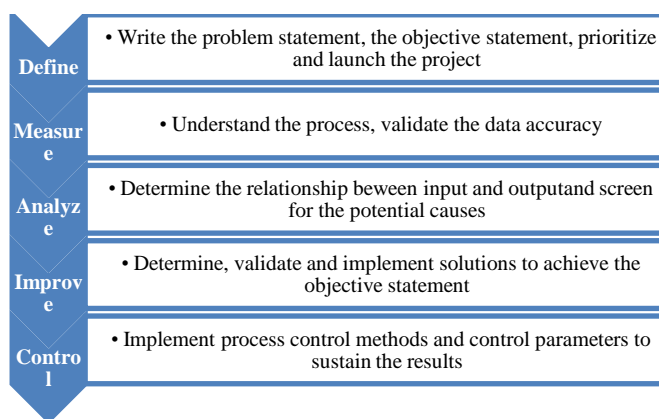


Fig. 2 Six Sigma DMAIC Methodology [3]

VIII. CONCLUSION

Six Sigma DMAIC methodology has been used in the manufacturing industries like automotive part manufacturing, metal processing, gloves manufacturing, file manufacturing, laser mouse manufacturing, semiconductor manufacturing, grinding operations, rolling mills. In one of the papers the Six

Sigma is used for safety level improvement. Six Sigma DMAIC methodology also has been used in the service industries like hospital and educational institute. The Six Sigma DMAIC methodology also found its application in delivery commitment fulfilment project. There is also thorough literature review done by many authors on the Six Sigma DMAIC methodology. From the literature review conducted it was found that there is not sufficient work carried out using Six Sigma in a steel industry especially in continuous casting processes. Thus there is a scope to use Six Sigma DMAIC tools for a quality improvement in a steel industry undertaking continuous casting processes. By using these DMAIC tools defects can be reduced in the steel industry. Also by reducing the quantity of defects the energy can be saved which were spent producing defective products, as a secondary outcome.

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