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A Review: Six Sigma Implementation Practice in Manufacturing Industries

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ABSTRACT
Higher Productivity achievement is very crucial factor for the field of production. With the High productivity various other factors must be taken in to consideration in manufacturing industries such as global competitors, diversity in product range, lead time and customer demand in terms of quality and quantity. A new benchmark called Six Sigma has been invented for dealing with all these needs. Six sigma is a quality initiative which reduces variations in a process and helps to lower the cost of product as well as process. The objective of this paper is to review and examine the advancement and encounters of six sigma practices in Global manufacturing Industries and identify the key tools for each step in successful Six Sigma project execution. The paper also integrates the lessons learned from successful six sigma projects and their prospective applications in various manufacturing Industries. In today scenario, many global manufacturing industries operate their processes at the two to four sigma quality levels.

Keywords – Six Sigma, DMAIC, review, Tools and Techniques.

I. INTRODUCTION

The history of quality is as old as civilization. Various quality management strategies have been applied for many years and those strategies are continuously involved in the quality improvement for the customer's satisfaction [1]. There are several different definitions of the Quality Concept and many different opinions of what should be encompassed in the concept of product quality. "The quality of a product is its ability to satisfy and preferably exceed the needs and expectations of the customers".[2]

In the more recent history of the quality development, the quality improvement program Six Sigma has been successful. Six Sigma was created at Motorola in the 1980s. Owing to Six Sigma, Motorola managed to reduce their poor-quality costs and decrease variation in many processes. As a result, Motorola became the first recipient of America's Malcolm Baldrige National Quality Award in 1988.[3] Six Sigma is one of the last additions in the field of quality improvement methods and (or) business process improvements methods. Although it has been implemented for many years mainly in large manufacturing companies, like Motorola, GE and Honeywell etc.[4]

Six Sigma leads mainly to reduction of poor quality cost. The DPMO concept is not just a slogan but a much grounded way to measure how successfully Six Sigma objectives are implemented.[6]

II. SIX SIGMA DEFINITION

The term Six Sigma comes from statistics as the Greek letter s (sigma) symbolizes the standard deviation, namely the dispersion of the data from the mean average. Number six expresses the accepted level of quality that is six times the standard deviation. Most people consider Six Sigma as a purely statistical methodology. In methodology's practice the term Six Sigma level, means 3.4 defects per million opportunities or success rate of 99.999660 percentages. Six Sigma's purpose is to reduce the variance-variability in processes, so to provide to the clients-consumers of the organization, products or services which are more reliable and with fewer errors. Moreover, some companies implement or try to adopt Seven Sigma level, which means even fewer defects and more satisfied customers.[4]

The six sigma method includes measured and reported financial results, uses additional, more advanced data analysis tools, focuses on customer concerns, and uses project management tools and methodology.

Six Sigma = TQM (CQI) + Stronger Customer Focus + Additional Data Analysis Tools+ Financial Results+ Project Management.[5]

2.1 DMAIC Process

The tools of Six Sigma are most often applied within a simple performance improvement model known as Define-Measure-Analyze-Improve-Control, or DMAIC. DMAIC is summarized in Figure 1. DMAIC

is used when a project's goal can be accomplished by improving an existing product, process, or service.

Steps	Key processes
Define	Define the requirements and expectation of the customers. Define the project boundaries. Define the process by mapping the business flow.
Measure	Measure the process to satisfy customer's need. Develop a data collection plan. Collect and compare data to determine issues and shortfalls.
Analyze	Analyze the causes of defect and sources of variation. Determine the variation in the process. Prioritize opportunities for future improvement.
Improve	Improve the process to eliminate variation. Develop creative alternatives and implement enhanced plan.
Control	Control process variations to meet customer requirements. Develop a strategy to monitor and control the improved process. Implement the improvements of systems and structures.

Table 1 Key steps of Six sigma DMAIC process[7]

2.2 DFSS Process

As shown in figure 1. Design for Six Sigma (DFSS) is a systematic methodology utilizing tools, training and measurements to enable the organization to design products and processes that meet customer expectations and can be produced at Six Sigma quality levels. DFSS is potentially far more effective than DMAIC as its application is in the early stage of new product/process development.[8]

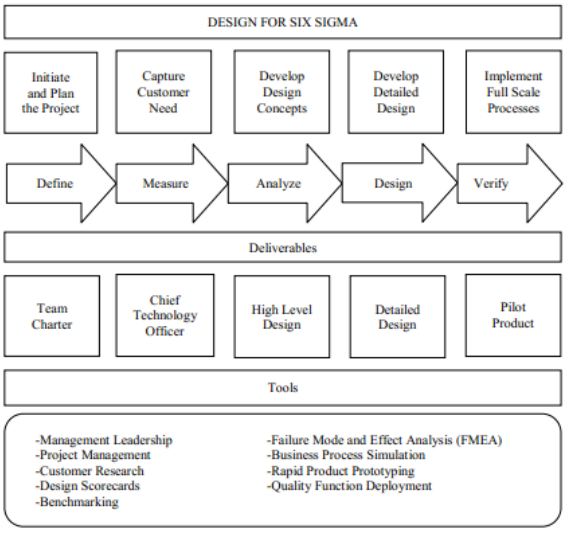

Fig 1 Five Step DFSS process[9]

III. RESEARCH METHODOLOGY

The main purpose of this study is to present the benefits and to discover the various trends of six sigma. The research strategy was made by selecting the research paper in which successful implementation of six sigma was presented and documented. The considered cases are taken up from the well-known journals and publications. Due to lack of Information only 9 cases are considered.

The study of all the cases is then compared and is presented in the following sequence 1) General overview of publication and the case industry. 2) General methodology of Six Sigma implementation and the methodology adopted by the cases industries 3) Tools and Techniques used in various phase by them 4) Benefits reaped by each of case industries.

IV. GENERAL OVERVIEW OF CASE INDUSTRIES

The table II below gives the publication name (i.e. research paper title), the product of the case industry and country it belongs. The referred name on the left most column indicates the name by which the publication has been referred in the rest of the review paper. The table also gives information about the journal, authors' name and year of publication of the selected cases. The publish cases Considered from a set time frame (i.e. 21stcentury).

Referred name	Title	Journal ,Year	Author/Authors	Product (Country)
A	Improving the Quality of Asbestos Roofing at PT BBI Using Six Sigma Methodology	International Congress on Interdisciplinary Business and Social Science,2012	Jonny and Jessika Christyanti	asbestos roofing (Indonesia)
B	Process improvement in farm equipment sector (FES): a case on Six Sigma	International Journal of Lean Six Sigma,2014	Anupama Prashar.	Farm Equipment (India)

	adoption			
C	Study of feasibility of six sigma implementation in a Manufacturing industry : a case study	International Journal of Mechanical and Industrial Engineering,2013	Mehdiuz zaman,sujit kumar pattanayak and arun chandra paul	Welding Electrode (India)
D	Right- First- Time dyeing in Textile using Six Sigma methods	International Journal of Scientific & Enginee ring Research,2013	Dr. Anupama Prashar	fabric dyeing process (India)
E	Reducing electronic component Losses in lean electronics Assembly with Six Sigma Approach	International Journal of Lean Six Sigma,2012	Tan Ping Yi, Chin Jeng Feng, Joshua Prakash and Loh Wei Ping	Electronic components (Malaysia)
F	Improvement process for rolling mill Through the DMAIC six sigma approach	International Journal for Quality research,2012	Kunal Ganguly	Rolling mill (India)
G	A Case Study of Defects Reduction in a Rubber Gloves Manufacturing Process by Applying Six Sigma Principles and DMAIC Problem Solving Methodology	International Conference on Industrial Engineering and Operations Management , 2012	Ploytip Jirasukprasert , Jose Art uro Garza-Reyes ,Horacio Soriano-Meier , Luis Rocha – Lona	Rubber Gloves (UK)
H	Implementation of Six Sigma in a Manufacturing Process: A Case Study	International Journal of Industrial Engineering,2009	Adan Valles, Jaime Sanchez, Salvador Noriega and Berenice Gómez Nuñez	Semiconducto r (Mexico)
I	Engine Assembly Process Quality Improvement Using Six Sigma	World Congress on Engineering, 2008	Dr. R.L. Shrivastava, Khwaja Izhar Ahmad and Tushar N. Desai	Vehicle Engine,(India)

Table II an Overview of Case Industry

These two methods/approaches are general approach but the author [1] has listed many methods which are a modified version of the above mentioned method. P-DMAIC (Project DMAIC), E-DMAIC (Enterprise DMAIC) and DMAICR (DMAIC report) are some DMAIC modified versions whereas DMADV (Define Measure Analyze Design Verify), DCOV (Define Characterize Optimize Verify) are some of DFSS modified versions. DMAIC is generally used for process improvements and DFSS for new development of product and service. [10] The case industries here have used DMAIC as the general methodology. Table III shows the list of method and process used by case industry.

Name	Method Adopted	Process
A	DMAIC	Side Flat Rejection
B	DMAIC	To reduce field failures of its tractor assembly.
C	DMAIC	Reducing the rejection in Welding Electrode.
D	DMAIC	To improve the RTF % in fabric dyeing process.
E	DMAIC	Reducing electronic component losses in lean electronics assembly.

F	DMAIC	Improving the process of Rolling mill.
G	DMAIC	Reduction of defects in a rubber gloves.
H	DMAIC	Reduction in defects in manufacturing of circuits.
I	DMAIC	Reduce the number of Vehicle engine rejection.

Table III methodology and process under implementation

V. TOOLS AND TECHNIQUES USED BY CASE INDUSTRIES

Over the years, companies have included numerous tools into the Six Sigma approach to make them more effective and to eliminate possible gaps after its application. Such toolsets include statistical and analytical tools both from industrial engineering and operations research fields.[11] In this instance, these tools enrich the practical and industrial approach with a stronger theoretical basis to achieve a better equipment and resources utilization.[12]

There are many tools and techniques for Six Sigma implementation used in various phases of DMAIC methodology. In addition many of the tools/techniques used in the implementation of Six Sigma were referred and categorized by phase of define-measure-analyze-improve-control (DMAIC) which they are used. There was another classification according to proposals from ISO 13051-1 standard for the utilization of every tool or technique. The use of tools and techniques for cause exploring, data analysis and decision making, considered to be essential. These tools are not all statistical but there are also analytical or managerial, like brainstorming, process mapping, and etc.[4]

Here the some other useful tools and Techniques are listed. The use of all this tools and techniques by the case industries in various phases are presented in table V. This is to study which are the most commonly used and prominent tools and techniques among the exporting industries. From the table V we can list down the general tools and techniques used in different phase which is listed in Table IV. List involves the tools that are mostly used by the different case industries.

Phase	General tools and techniques
Define	Brainstorming, Pareto diagram, Pie, bar chart, SIPOC diagram and Critical to Quality matrix.
Measure	Pareto diagram, Control charts, Gauge R & R, Process map and Statistical process control.
Analyze	Pareto diagram, Histogram, Hypothesis testing, Analysis of variance, Brainstorming, Cause & Effect diagram, Process map, FMEA.
Improve	Pie, bar chart, analysis of variance, Design of experiments and brainstorming.
Control	Control charts, Flow Chart and descriptive statistics.

Table IV Phase and general tools and techniques

VI. BENEFITS REAPED BY CASE INDUSTRIES

SS implements methods of measuring performance, after its application, so to represent the success of its implementation. Financial benefits and sigma level are such as a measure of expressing the SS achievement.

For the past 3 decades Six Sigma has been implemented by many industries and most of them have reaped fruitful benefits. The benefits achieved mark a difference in their earlier and current status. These benefits do make a difference in their bottom-line. The benefits achieved in the case industries have been presented in the table VI.

Tools and Techniques	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Pareto Chart	D	A	A,I,C	A	A		M	A	A
Cause and Effect Diagram	A	A		A	A	M	A	A	M,A
SIPOC/COPIS	D	D	D	D		D			D
Process map		M	D	M	M				D
Control Chart	D,M,C	C	C		C	C			C
Control plan		C		C					
Project charter	D	D		D			D		
Measurement System Analysis		M		M					
Process capability			M						

Critical to Quality (CTQ)		D		D		M		D	
5 Why				A					
FMEA matrix	A	I				M			
Hypothesis testing		A		A		A			
Key Quality Characteristic			D						
Brainstorming			I		I		A	A	I
Voice Of Customer (VOC)						D	D		
Box Plot							I	D,A,I	
Design of Experiment(DOE)						I	I		
Analysis of Variance (ANOVA)	I					A	I	A	
Regression Analysis			A						
Residual Plot								A	
Why Why Analysis									A
Residual Plot								A	
test Of Equality of Variance								I,C	
Gauge R & R								M	
Normality Test								M	
Pie, Bar chart					D				
Dot Plot			I						
Capability Analysis		M							
Fishbone Diagram			A						
Counter Measure matrix				I					
Process indicator									M
Improvement Plan		I							
Probability Plot			M						
Flow Chart							A		
Action Plan	A								
Standard procedure	C								

Table V TOOLS AND TECHNIQUES USED BY THE CASE INDUSTRIE

Name	Benefits
A	Improved sigma level to 5.02 sigma and DPMO level at 180.
B	Cost savings of INR 4.366 million /annum.
C	Reduce the Defect Per Million Outputs (DPMO) from 28356.96 to 1666.67.
D	cost saving of INR 2.951 million per month
E	Average weekly saving of $1280
F	The cycle time was reduced from 47 days to 20 days.
G	reduction in defects per million opportunities (DPMO) from 195,095 to 83,750
H	reduction in the electrical failures of around 50%
I	Cost of poor quality (COPQ) has been reduced from $ 30, 000 to $ 9, 000 per annum

Table VI BENEFITS REAPED BY THE CASE INDUSTRIES

VII. CONCLUSION

From the study done on the manufacturing industries in 21st century we conclude that Six Sigma is indeed a business strategy that can provide a breakthrough improvement in the competitive era. The key strategy for successful implementation of Six Sigma is that the industry applying it should follow a correct methodology and use of tools and techniques is done in such a manner that it gives effective solution to respective problem. Thus a use of proper combination of tools and techniques can lead to great benefits. This study will help manufacturing units to motivate and apply Six Sigma at their organization and reap high benefits. The current status suggests there is future scope of getting better and become a world-class level organization by reaching Sigma level above 5.

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