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A Review of Successful Implementation of Six Sigma in Different Industries-Methodology, Tools & Techniques Used, Benefits and Critical Success Factors

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Abstract — *In this era of global competition industry/organization needs overall business excellence by implementing the breakthrough strategy like Six Sigma(DMAIC). This is an effective breakthrough improvement strategy which directly focuses on the bottom line of the organization. The main benefit of Six Sigma is this eliminates the non-value added activities of the process, by creating systematic environment to collect data, analyze the process and displaying data process which focuses on the both process and product. It is a project driven approach. The DMAIC model provides a framework to identify and eliminate source of variation in a process, improve and sustain performance. This paper aims to present the results of successful implementation of Six Sigma.*

Keywords- *DMAIC, Tools and Techniques, Critical success Factors, Methodology, Benefits.*

I. INTRODUCTION

a. Six Sigma- Definition

Mikel Harry, Doctorate from Arizona State University, introduced the path to reveal the evaluation of Six Sigma. The evaluation began in the late 1970's, when a Japanese firm tool over a Motorola factory that manufacturing TV sets. The factory was producing TV sets with 1/20th the number of defects they had produced under Motorola Management. Motorola Management decided to take quality issue seriously. In the early and mid 1980's, Bob Galvin with the chairman of Motorola and Motorola engineers decided to achieve the traditional quality levels. They developed new standards and created the methodology named Six Sigma. Six Sigma helps Motorola to achieve bottomline results in the organization.

The statistical meaning of sigma is standard deviation between the process mean and the nearest specific limit. That's why, reducing process variation is the core objective of the Six Sigma project, as process variation results in higher quality loss. Six sigma is the set of tools and techniques for the process improvement. Six sigma seeks to improve the quality of the output of a process by identifying and removing the causes of defects and minimizing variation in manufacturing and business process.

Each six sigma project carried out within an organization follows a defined sequence of steps and has specific value targets. The performance of the manufacturing process can be described by sigma rating which indicates the percentage of defect free products or the yield of the process.

b. Six Sigma- Concept

Six sigma projects follows two methodologies named DMAIC (Define, Measure, Analyze, Improve, Control) and DMADV (Define, Measure, Analyze, Design, Verify). DMAIC is used for projects which aim to improve the exiting business process. DMADV is used for new product and project development. Six sigma project needs to identify several key roles for its successful implementation which are listed in **Table 1**.

Name of the Role	Position in the Organization
Executive Leadership	CEO & other members of top management.
Champions	Mentors to Black Belt.
Master Black Belt	Assist Champions and guide Black Belt and Green Belt.
Black Belt	Apply six sigma methodologies to specific project.
Green Belt	Employees who take up six sigma implementation.

Table 1. Key roles of six sigma

The process spread is shown by normal distribution curve which is spread 3 sigma on either side from the mean. Even if the mean were to move right or left by 1.5 sigma at some point in future, there is still a good safety cushion as shown in **Fig. 1**. The sigma level can be measure with the help of DPMO (Defects Per Million Opportunities) which is measure of percentage of Total Defective Products per Unit(**Table 2**). The phase wise description and tools used are described in **Table 3** in detail:

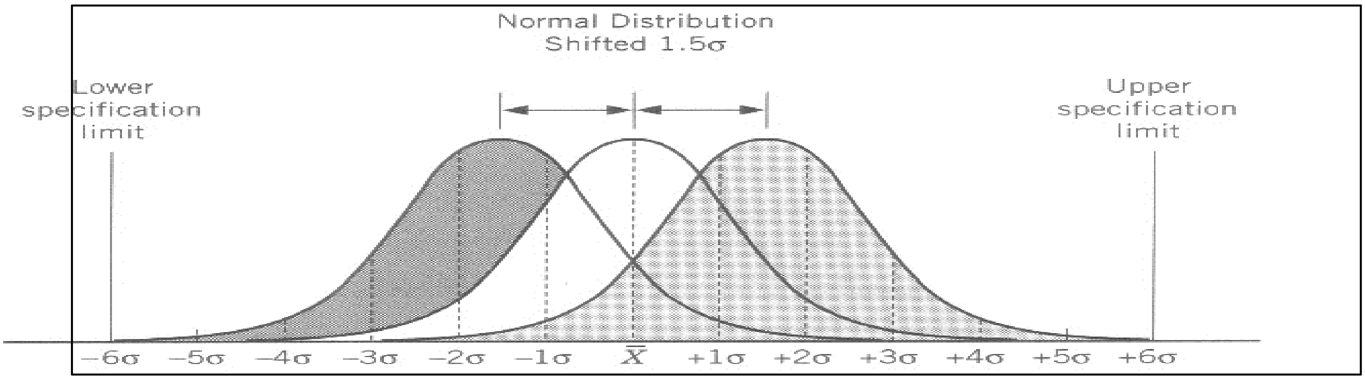

Figure 1. Process Spread with 1.5 Sigma Shift

Sr. No.	Sigma Level	DPMO	% Defective	% Yield
1	6	3.4	0.00034%	99.99966%
2	5	233	0.023%	99.977%
3	4	6210	0.62%	99.38%
4	3	66807	6.7%	93.3%
5	2	308538	31%	69%
6	1	691462	69%	31%

Table 2. Sigma Level

Phase	Description	Tools used
Define	Problem definition, Voice of Customer and their requirements, Project goals.	Benchmarking, Process Flow Mapping, Flow Charts, Project Charter, SIPOC, Review Existing Data.
Measure	Measure key aspects of current process and collect relevant data.	VSM, Cause and Effect Diagram, Defect Metrics, Statistical Analysis, Run Chart, Time Series Chart, Pareto Chart, Time Value Chart, Sampling.
Analyze	Investigate data and verify cause and effect relationships. Analyze all the factors affect the process, find out root cause.	Fishbone Diagram, FMEA, Root cause analysis, ANOVA, Scatter plots.
Improve	Based on analysis tool and techniques create new future state process.	Modeling, Tolerance control, Defect control, Design changes, Piloting, DOE, Best Practices, Mistake proofing.
Control	Implement control system to ensure that any deviations from the target are corrected before they results in defects.	SPC Charts, Performance metrics, Multiple Regression.

II. METHODOLOGY USED

The main objective of this paper is to explore the appropriate method to implement Six Sigma and its benefits to the organization. This paper provides the roadmap for initiation of six sigma project. These case studies are taken from well known journals and publications. These case studies are focused on the strategies which were used for the successful implementation in different environment. We have taken 11 case studies to discover the concept of six sigma. However most of the authors had not unveiled their research studies easily.

All the case studies are compared from different viewpoint and presented in following sequence:

1. Overview of case studies and publications.
2. Methodology used by case industries.
3. Benefits gained by industries.
4. Critical Success Factors.

III. OVERVIEW OF CASE STUDIES AND INDUSTRIES

In **Table 4**, different case studies are listed in a systematic manner, which indicates preferred name for different case studies(this will remain same in the whole paper), Title of case studies, Publication Details and Year of Publication, Name of Authors and Name of Product.

Referred Name	Title	Journal, Year	Author/ Authors	Products
A	Six Sigma an Excellent Tool For Process Improvement- A Case Study	International Journal of Scientific & Engineering Research, 2011	Sushil Kumar, P. S. Satsangi, D. R. Prajapati	Housing cover
B	Right- First- Time Dyeing in Textile Using Six Sigma	International Journal of Scientific & Engineering Research , Aug- 2013	Dr. Anupama Pashar	Terry Towels
C	Improving Productivity and Profitability through Six Sigma: Experience of Small Scale Jobbing Industries.	Int. J. Productivity and Quality Management, 2008	Dr. D. A. Desai	Sleeve
D	Defect Control Analysis for Improving Quality & Productivity: An Innovative Six Sigma	Int. J. Quality and Innovation, 2011	M.shanmugaraja & M Nataraj, N. Gunasekaran	2-Stroke engine oil pump body
E	6 sigma project selection via LED	Int. J. Productivity and Quality Management, 2012	Muthuswamy Shanmugaraja, M. Nataraj, Nallasamy Gunasekaran	Vehicle delivery, Customer's satisfaction
F	6 sigma based approach to optimize the diffusion process of crystalline silicon solar cell mfg.	International Journal of Sustainable Energy, Oct-2013	A.Guru Prasad, S. Saravanan, E.V.Gijo, Sreenivasa, Murty Dasari, Raghu Tatachar, Prakash Suratkar	Cry stalling silicon solar cell
G	Process improvement through six sigma with beta correction: A case study of mfg company	Springer, 2013	E.V. Gijo, Johny Scaria	Plunger
H	A systematic methodology for the creation of 6	Elsevier, 2007	Chao-Ton Su,	Semiconductor

	sigma projects: A case study of semiconductor Foundry		Chia-Jen Chou	
I	Study of feasibility of six sigma implementation in a mfg industry: A case study	International Journal of Mechanical and Industrial Engineering, 2013	Mehdiuz Zaman, Sujit kumar Pattanayak, Arun Chandra Paul	Welding electrode
J	Applying 6 sigma methodology based on “DMAIC” tools to reduce production defects in textile mfg.	Recent Advances in Industrial and Manufacturing Technologies	Mohammaed T. Hayajneh, Omar Betaineh, Rami AI-Tawil	Medical and work wear garments
K	Application of six sigma methodology to reduce defects of a grinding process	Willey Online Library, 2011	E V.Gijo, Johny Scaria, Jiju Antony	Injection system pumps

IV. METHODOLOGY USED BY CASE INDUSTRIES

As mentioned earlier, there are two methodologies which are used in six sigma. DMAIC is used for performance improvement and DMADV is for product development. Most of the case industries adopted DMAIC methodology for the performance improvement of the existing process, shown in **Table 5**.

NAME	METHODOLOGY	OBJECTIVE
A	DMAIC	To improve quality by eliminating defects of foundry.
B	DMAIC	Increase the ability of yarn which reduces the defect of shade mismatch.
C	DMAIC	
D	DMAIC	Reduce rejection in PDC process.
E	DMAIC	Reduce delivery time from 48 hours to 24 hours and improve service quality.
F	DMAIC	To achieve operational excellence in POCl3- based equipment and improve Phosphorous Doping Process
G	DMAIC	Reduce process capability related problems and improve first pass yield.
H	DMAIC	Aims to develop systematic methodology to generate project on the basis of strategic policies.
I	DMAIC	Reduce rejection in welding electrode.
J	DMAIC	To establish well organized way to arrange the business strategic policies for possible projects.
K	DMAIC	To solve the underlying problem of reducing process variation and to improve the process yield.

Table. 5 Methodology Used and Objectives

V. BENEFITS GAINED BY INDUSTRIES

The main objective off any industry is to make profit by improving quality and productivity. These can be improved by reducing cycle time, rejection scrap by implementing six sigma. Various benefits gained by case industries are listed in **Table 6**.

NAME	BENEFITS
A	Improved quality levels by parameters at lower possible cost.
B	The process improved by 4% and saving INR 2.95 Million/month.
C	The rejection rate was brought down by 50% and net financial savings of 40%.
D	Sigma level increase from 2.51 to 3.03, improve product quality, rejection rate reduce to 4.8% to 17.22%.
E	This helps to identify the focal points of the organization and improve service to satisfy customers.
F	The diffusion improved significantly and constantly.

G	Saving due to reduction in repair, scrap and tool costs was estimated to be around US $87000.
H	A complete procedure from project generation to mapping is provided which can assist the top management in deciding critical projects.
I	Decrease the variation in diameter of electrode.
J	Reduction in overall defects from 7.7% to 2%.
K	Reduction in the defects of fine grinding from 16.6% to 1.19%.

Table. 6 Benefits Gained by Industries

Sr. No	Challenges in Six Sigma
1	Selection of the project for Six Sigma Deployment.
2	Project Management and tracking skills of Six Sigma practitioners.
3	The 1.5 sigma shift resulting in a 3.4 DPMOs does not make sense in service processes.
4	The impact of leadership style.
5	Lack of standardization in belt training.
6	Availability of quality data is still a great challenge in Six Sigma projects.
7	The solutions driven by Six Sigma are expensive and only a small part of the solution is implemented at the end.
8	Owing to dynamic market demands, critical-to-quality characteristics should be critically examined at all times and refined as necessary.
9	Training programmes usually do not address forecasting and time series methods.

Table. 7 Challenges in Six Sigma.

VI. BENEFITS AND ADVANTAGES OF SIX SIGMA.

By successful implementation of Six Sigma an organization can achieve defect reduction, cycle time reduction, manufacturing cast reduction, market share growth, productivity improvement, product development and customer retention as benefits. The Six Sigma methodology also helps to:

- Increase the performance of the company by the improvement of the quality of its processes.
- Prepare business collaborators with advantage of efficiency by eliminating the defects.
- Get tools to reduce the costs.
- Provide methods tested to measure precisely and increase the return on investment.
- Allow undervaluing the financial risks.
- Accent puts to the measure of the defects.
- Imply all the personnel in real activities with the strategic objectives.
- Develop the statistical analysis of the data.
- Improve comprehension, control and performance of the key processes.

VII. CRITICAL SUCCESS FACTORS

Critical Success Factors are the main ingredients which are required for the successful implementation of six sigma. To achieve required good, the organization should focus on key elements. The top management's involvement and commitment are required for successful initiation and implementation of six sigma project. The top management should set some incentives plans based on success of the project to involve employees in the project. From the reviews of many papers it can be concluded that the most effective factors are: Top Management Commitment and Involvement, proper training and education, Linking projects to Financial benefits and business strategies, availability of recourses, Utilization of tools and techniques, proper selection of team members, availability of necessary data, proper documents, effective communication. The comparisons of all factors from the all case studies are listed in **Table 8**.

Sr. No	CRITICAL SUCCESS FACTORS	A	B	C	D	E	F	G	H	I	J	K
1	Top Management's Commitment and Involvement	√		√	√	√	√	√		√	√	√
2	Proper Training and Education			√			√		√	√	√	
3	Linking Projects to Financial and Business strategies		√	√	√	√			√	√	√	√
4	Availability of Resources	√	√		√		√	√	√			√
5	Utilization of Tools and Techniques	√	√	√	√	√	√	√		√	√	√
6	Proper Selection of Team Members	√	√		√	√		√		√		√
7	Availability of Necessary Data	√	√	√	√	√	√	√	√	√	√	√

8	Proper Documentations	√	√	√	√	√	√	√	√		√	
9	Effective Communication			√	√		√	√			√	
10	Customer Requirement and Satisfaction		√	√		√	√			√	√	√

Table. 8 Critical Success Factors

VII. CONCLUSION

The Six Sigma is a project driven approach. The six sigma is a system for an organization to address any type of problems in process. From the study of different case studies, it can be conclude that Six Sigma is a breakthrough improvement strategy which helps the organization to identify the defects and improve their performance drastically. Most of the organization preferred DMAIC methodology to improve performance. From the study, some tools and techniques were also revealed used in different stages of the project. It was also noted that DMAIC approach will bring paradigm shift in the organization by instilling high skill levels among their management personnel, managers, engineers and workers. It can be conclude that for the successful implementation of Six Sigma critical success factors like Top Management Commitment and Involvement, Proper Training and Education, Linking Projects to Financial and Business Strategies, Availability of Resources, Utilization of Tools and Techniques, Proper Selection of Team Members, Availability of Necessary Data, Proper Documentation, Effective Communication, Customer requirement and Satisfaction are must be present in the project. Six Sigma is a systematic framework to improve quality as well as productivity and operational excellence.

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