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A Review of Six Sigma Implementation in Indian SMEs – Tools & Techniques Used and Benefits Drawn

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***Abstract*: -** *For achieving global competitiveness and operational excellence in current market condition, Industries are needed to produce the products which provide high quality at the lowest possible cost. Six Sigma has been widely used project-driven management approach to produce high-quality products with the lowest possible cost. From the review of previous publications it has been discovered that Indian SMEs have not adopted this approach up to its full extend. So the objective of this paper is to explore the impact of Six Sigma in Indian SMEs. This paper is mainly focussing on the DMAIC methodology of Six Sigma which has been successfully adopted by various SMEs. This paper discusses the various tools and techniques used in each phase of DMAIC approach, its impact on bottom line through benefits gained and critical success factors to show the roadmap for other SMEs to initiate Six Sigma in their industries.*

***Keywords*: -** *Six Sigma, SMEs, DMAIC methodology, Tools & techniques, Critical success factors*

I. INTRODUCTION

A. Six Sigma - Definition:

In the last two and half decades, Due to globalization and domestic business scenario Indian industries have faced many challenges to compete in the global market. They have initiated many strategies such as TQM, SQC, Lean Manufacturing, but these approaches did not provide breakthrough improvement given by Six Sigma [8]. Six Sigma is a business-driven, multi-faceted approach for reducing the defects and improving the process capability [41]. Six Sigma is a well-structured methodology that focuses on reducing variation, quantifying non-conformance and make products, process and services defect-free [17]. Six Sigma is a data-driven process improvement methodology used to make the process stable, outputs predictable and improve process capability. Six Sigma approach is a continuous improvement strategy that is mainly focused on customer satisfaction [27]. Six Sigma is a powerful business strategy that employs a disciplined approach to improve process capability using statistical and non-statistical tools and techniques [30]. Six Sigma is a process improvement and defect reduction methodology employed to increase company's profit and achieving operational excellence through use of statistical tools [34]. Six Sigma is a business strategy that uses data and facts to measure, identify the root cause and improving the performance of process or product through elimination of defects from the process [33].

Six Sigma is a quality improvement framework for controlling processes and getting results in terms of bottom line improvement through the use quantitative tools and techniques [40]. Six Sigma is a systematic methodology that uses statistical and non-statistical tools and techniques to maximize an organization's return on investment (ROI) through continuous quality improvement of processes by reducing defects and non-conformance [22]. Six Sigma is a data-driven methodology that helps organizations to increase their competitive capability and allows making the products defect free [28]. Six Sigma can also be referred as an integrated package of competitive strategy and technology with focus on improving customer satisfaction by reducing manufacturing and service costs [25]. Six Sigma is also defined as a methodology that analyze data for root cause and then try to implement control over it improve quality of the products and processes [5]. Six Sigma is a synergistic mixture of many statistical and non-statistical tools and techniques which employs quality and performance improvement of the processes and products [16]. Six Sigma is a proactive and quantitative continuous improvement approach which improves bottom line of the organizations through reduction of costs, waste and non-conformance [20]. Six Sigma is also referred as structured and systematic approach by its successful implementation leads to improved business performance and competitive advantages [15]. Six Sigma is defined as structured continuous improvement methodology which acts as a profit driver and improve economic dimension of quality [24].

B. Six Sigma - Concept

Six Sigma is an improvement methodology, developed by Motorola in the 1980s which were followed by many big industries across the world such as GE, Honeywell and Nissan [40]. Six Sigma was a way to express its quality goal of 3.4 DPMO where defect opportunity is a process failure that is critical to the customer. A normal distribution curve has a positive and negative spread of 4.5σ. But, in practice, it is observed that every process has a tendency to have inbuilt variance to the extent of 1.5σ. Due to this phenomenon the spread really is 4.5σ+1.5σ on both sides of the mean. That mean in order to deliver 100% acceptable quality output, the process output must be within 6σ spread on both sides of the mean as shown in Figure 1 [27].

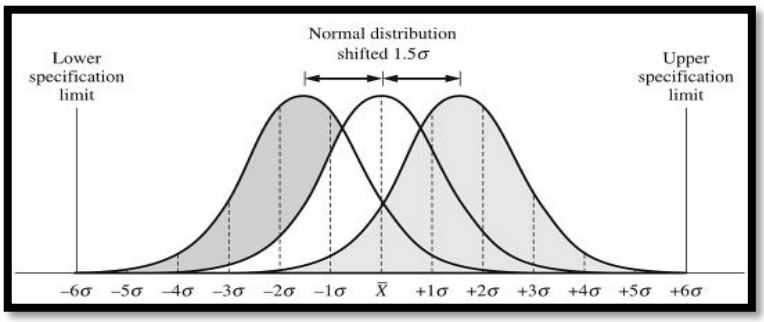

Figure 1: Process Spread on both sides of the mean [27]

Table 1: Performance Measure

Sigma Level	Percent Output	DPMO
1σ	30.23	697700
2σ	69.13	308700
3σ	93.32	66810
4σ	99.3790	6210
5σ	99.97670	233
6σ	99.999660	3.4

Six Sigma mainly consists of two methodologies that are DMAIC used for process improvement and DFSS used for design improvement. DMAIC is applied to existing processes and DFSS is applied to new process or product development. From the many literatures it is explored that DMAIC is mostly used as compared to DFSS. From review of many different literatures, DMAIC methodology with different processes in each phase is shown in table 2. If these processes are applied systematically in each phase, company will able to achieve drastic improvement in their business performance.

C. SMEs – an Overview

According to IDC report (2008), Department of Scientific & Industrial Research (DSIR), small and medium enterprises can be defined as "*Small enterprises are those companies who have an investment between in plant and machinery of up to INR 5 Crores. Medium enterprises are the ones who have an investment between INR 5 Crores to INR 10 Crores in plant and machinery. Companies having a turnover of up to INR 50 Crores were considered as small company and companies with turnover in the range of INR 50 to 250 Crores were considered as medium companies*" [13]. According to D. A. Desai (2006 & 2008) Six Sigma in Indian industries are not used up to its full extend especially in SMEs. He also provides roadmap for the SMEs to carry out Six Sigma projects in small scale industries by case studies showing financial impact by reducing rejection rate [8][10]. According to E.V. Gijo & T.S. Rao (2005) despite of many benefits from Six Sigma implementation still some issues are their which creating obstacles for the Six Sigma implementation, These obstacles are insufficient knowledge of tools and techniques, Improper project selection, Lack of resources, Lack of coordination between functions, Concentration on trivial many rather than the vital few, Short closure of projects, Non-availability of data, Impatience to get results and improper selection of team member for the project [16]. According to Vikas Kumar and Rajiv Khanduja (2013) one of the most favourable benefits of Six Sigma as an improvement drive is the ability to introduce a concept of customer satisfaction which is the aim of any size and type of firm. In global market large organization are highly dependent on SMEs for getting quality products and services. This force from large organization has left no alternative for SMEs except to introduce Six Sigma business strategy [41]. There are myths that Six Sigma is suitable for large organizations only but, Six Sigma is equally suitable for SMEs too [8].

Table 2: Phase wise processes

Phases	Key Processes

Define	• Identification of suitable projects based on business objectives • Define the scope and goals of the improvement project in terms of customer requirement • Development of project charter and critical to quality issues
Measure	• Selecting product characteristics and measurement system analysis • Mapping the respective processes and data collection • Recording the results with process capabilities and exploring the performance gap
Analyse	• Detailed analysis to find out various root causes • Validation of the root causes • Prioritizing of most affecting root causes
Improve	• Brainstorming possible alternative improvements for implementation • Implementation of the selected improvements • Verification of key process variables for improved conditions
Control	• Control process variations to meet customer requirement • Develop a strategy to monitor and control the improved process • Verify the project objectives

II. RESEARCH METHODOLOGY

The aim of this study is to explore the benefits which Six Sigma provides to the SMEs for improvement of their processes and compete globally with application into their respective environment. This is an attempt to show roadmap to Indian SMEs for initiation of Six Sigma projects. The strategy employed is to collect the different literature and case studies where Six Sigma approach is successfully implemented in Indian environment. All the case studies which are selected in this paper are from established publications to show the real research and give impactful path to Indian SMEs. Most of the case studies are from Indian environment so obstacles of different environment in different countries will not be evident. These case studies are taken from the established journals and publications. However most of the research studies are not disclosed easily by the authors, we have taken 17 case studies from Indian SMEs to explore the concept.

These all case studies are then compared from different perspective and presented into following sequence:

- Overview of case studies and publications
- Methodology adopted by case industries
- Phase wise use of Tools and Techniques
- Benefits gained by case industries
- Critical success factors in case studies

III. OVERVIEW OF CASE STUDIES AND PUBLICATIONS

For the clear view, Different case studies are arranged in a systematic manner as shown in table 3. It indicates preferred name for different case studies (Same will be used in the rest of the paper), Title of case studies, Detail of publications with year of publication, Name of the authors and name of the product. To track the current trend in Indian industries, all case studies are taken from a set time frame of 21st Century.

IV. METHODOLOGY ADOPTED BY CASE INDUSTRIES

As discussed earlier in Six Sigma concept that there are mainly two methodologies for the Six Sigma, but most of the cases industries are initiating their projects with DMAIC approach to improve performance of their existing processes rather than going for DFSS approach to design their new processes or products. Table 4 showing the methodology and goal which have been adopted by different considered case industries. It is clear from the table 4 that all the case industries have initiated with DMAIC methodology.

V. PHASE WISE USE OF TOOLS AND TECHNIQUES

According to ISO 13053-1 standard, there is an existence of so many tools and techniques which are normally used in different phases of DMAIC approach [40]. These tools and techniques can be management or statistical base. These all tools are not suitable for Indian SMEs. Table 5 showing the various tools and techniques used by different case industries in Indian environment. General tools and technique which are used in different phases are shown below

Define Phase: Project Charter, Pareto Diagram, Flow Chart, CTQ Tree, Process Map, and Supplier-Input-Process-Output-Customer (SIPOC) Diagram.

Measure Phase: Pareto Diagram, Data Collection form, Control Charts, Gauge R & R, and Detailed Process Map. Process capability analysis

Analyse Phase: Histogram, Run Chart, Control Charts, Scatter Chart, Cause and Effect Diagram, Analysis of Variance (ANOVA), Design of Experiment (DOE), Failure Mode and Effect Analysis (FMEA), Regression Analysis, Hypothesis Testing, Multivariate Chart, Interrelations Diagram.

Improve Phase: Brainstorming, Affinity Diagram, Multi Voting, Suitability Matrix, DOE.

Control Phase: Related Activity Chart, Standard Operating Procedure (SOP), Control Charts

VI. BENEFITS GAINED BY CASE INDUSTRIES

The main aim of any industry is to make profit and compete into ever changing global customer-centric market. This can be achieved by improving the performance of the business in terms of increase in quality and productivity. Quality and productivity can be improved by reduction in rejection, rework, cycle time, idle time and scrap by application of Six Sigma. The case industries which we have taken for study have also gained so many benefits by reducing rejection, rework or cycle time. Various benefits gained by different case industries are shown in table 6. From the table 6 it is clear that many SMEs have gained breakthrough improvement in their business by reduction of rejection or rework with application of DMAIC methodology of Six Sigma.

Table 3: Overview of Case Industries and Publications

Referred Name	Title	Journal, Year	Author/Authors	Products
A	Application of Six Sigma methodology in a small-scale foundry industry	International Journal of Lean Six Sigma, 2014	E.V. Gijo, Shreeranga Bhat, N.A. Jnanesh	Leaf spring
B	Quality and productivity improvement using Six Sigma and Taguchi methods	International Journal of Business Excellence, 2011	M. Shanmugaraja, M. Nataraj, N. Gunasekaran	Oil pump body
C	Increasing Bottom-Line Through Six Sigma Quality Improvement Drive: Case of Small Scale Foundry Industry	Udyog Pragati, 2012	Darshak A. Desai	Cooler Plate, Hammer and Nose-ring Segment
D	Improving productivity and profitability through Six Sigma: experience of a small-scale jobbing industry	International Journal of Productivity and Quality Management, 2008	Darshak A. Desai	Sleeve
E	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, 2013	Sunil Dambhare, Siddhant Aphale, Kiran Kakade, Tejas Thote, Uddhava Jawalkar	V-12 Cylinder Engine
F	Study of Feasibility of Six Sigma Implementation in a Manufacturing Industry: A Case Study	International Journal of Mechanical and Industrial Engineering, 2013	Mehdiuz Zaman, Sijit Kumar Pattanayak, Arun Chandra Paul	Welding electrodes
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 Arturo Garza-Reyes, Horacio Soriano-Meier, Luis Rocha-Lona	Rubber gloves

H	Reduction of rework the Six Sigma way: case study of an Indian small scale industry	International Journal of Six Sigma and Competitive Advantage, 2012	Prasenjeet C. Gholap, Tushar N. Desai	Track shoe
I	Application of Six-Sigma Methodology in SSI: A Case Study	International Journal of Current Engineering and Technology, 2013	Vikas Kumar, Rajiv Khanduja	Pump head
J	Empirical study on employee job satisfaction upon implementing six sigma DMAIC methodology in Indian foundry - A case study	International Journal of Engineering, Science and Technology, 2011	A. Kumaravadivel, U. Natarajan	Flywheel
K	Quality and productivity improvement through six sigma in foundry industry	International Journal of Productivity and Quality Management, 2012	Darshak A. Desai	Flange
L	Six Sigma practice for quality improvement - A case study of Indian auto ancillary unit	Journal of Mechanical and Civil Engineering, 2012	Dr. Rajeshkumar U. Sambhe	Lighting stalk assembly
M	Improving customer delivery commitments the Six Sigma way: case study of an Indian small scale industry	International Journal of Six Sigma and Competitive Advantage, 2006	Darshak A. Desai	Sanitary SS valves and fittings
N	Ambience of Six Sigma in Indian foundries - an empirical investigation	International Journal of Six Sigma Competitive Advantage, 2012	Bikram Jit Singh, Dinesh Khanduja	FM-132 alloy pistons
O	Relevance of Six Sigma Line of Attack in SMEs: A Case Study of a Die Casting Manufacturing Unit	Journal of Engineering and Technology, 2011	Prabhakar Kaushik	Engine mounting bracket
P	Six Sigma process improvements in automotive parts production	Journal of Achievements in Materials and Manufacturing Engineering, 2006	M. Sokovic, D. Pavletic, E. Krulcic	Aluminium castings
Q	Process improvement in farm equipment sector (FES): a case on Six Sigma adoption	International Journal of Lean Six Sigma, 2014	Anupama Prashar	Relief valve

Table 4: Methodology adopted by Case Industries

Name	Methodology	GOAL
A	DMAIC	Reducing rejection in the hardening process of leaf spring leaf spring manufacturing
B	DMAIC	Reducing defect level in aluminium die casting
C	DMAIC	Reducing rejection in casted products in foundry
D	DMAIC	Reducing rejection rate in sleeve on CNC operation
E	DMAIC	Reduction in rework of an engine step bore depth
F	DMAIC	Reducing rejection in a welding electrode
G	DMAIC	Reduction of defects in a rubber gloves
H	DMAIC	Reduction of rework in track shoe
I	DMAIC	Reducing rejection in pump head of hydraulic jack
J	DMAIC	Reducing defects in sand casting process for flywheel and improving job satisfaction

K	DMAIC	Improving rejection rate and cycle time of the flange casting
L	DMAIC	Reductions in rework and field failure
M	DMAIC	Improvement in the success rate of delivery commitments
N	DMAIC	Reducing rejection in pistons manufactured from FM-132 alloy
O	DMAIC	Reducing rejection rate of the engine mounting bracket
P	DMAIC	Identification and Reduction of expenses in the debarring process for aluminium die castings
Q	DMAIC	Reduction in field failure problems of Relief valve up to 95%

Table 5: Phase Wise Use of Tools and Techniques (where, D=Define, M=Measure, A=Analyse, I=Improve and C=Control)

Tools and Techniques	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**	**Q**
Pareto diagram			A	A		A,I, C	M	D		A	A	M,A, I	A	M		M	A
Histogram								M,I									
Run chart		M, C															
Pies, bar charts			A				I	I				M		D			
Project charter	D						D	D				D	D	D			D
Multivoting			A	A							A		A				
Hypothesis tests					A												A
ANOVA	I	I				A	I							A		A	
Check sheet																	C
Normality test																A	
Regression analysis					A	A											
Multi-Vary analysis																A	
Correlation analysis																A	
DoE	I	I					I		I					I	I		
Brainstorming	A	D	A			I	A	D		M				D		I	A
Tree diagram					A												
Cause-effect diagram	A	A	A	A		A	A	A	A		A	A	A	M	A	M	A
Two sample T-test									A					A	A		
Boxplot					I		I					A		A		A	
Cause-effect matrix										M		A					
Control chart			C	C	C	C		C	C	I	C	C		C	C		C
Flow chart	D						A			D							
GANTT chart														D			

Process map				D,A				D	D		A	D,A	A,I			M	M
Process capability analysis	M					M,I			A,I	M,C					A,I	I	M
SIPOC diagram	D					D		D	D		D	D	D	D	D		D
CTQ tree			D	D				D			D	D	D				D
FMEA										A						A	I
Descriptive statistics												A					
Five why technique			A	A				A			A		A				
MSA	M				M				M					M	M	A,I	M

Table 6: Benefits Gained by Case Industries

Name	Benefits
A	Rejection was reduced from 48.33% to 0.79% and savings of USD 8,000 per year
B	Defect level was reduced from 17.22% to 4.8% and savings of INR 2,00,000
C	Annual financial savings of 44% for Cooler plate, 45% for Hammer and 22.5% for Nose-ring segment
D	Rejection rate was reduced by 50% resulted into 40% financial savings
E	Rework was reduced from 18% to 2.2%, monthly man hours by 327 hours and annual savings of USD 18000
F	The sigma level increased from 3.41 to 4.43 without any huge capital investment
G	Reduction of about 50% in the "leaking" gloves defect
H	Annual financial savings of Rs.2,252,293
I	Cost saving of 0.01929 million/annum
J	Rejection rate reduced from 20.65% to 14.78% and saving of Rs 17000 during project period
K	Net turnover increased by 25% and reduction in cycle time by 27%
L	Reduced internal PPM from 18909 PPM to 2500 PPM for Lighting stalk assembly
M	50% less quantity to be delayed and 25% increase in turnover
N	Monthly savings of Rs.380,000
O	Annual financial savings of Rs. 0.260 million per annum
P	Reduced tool expenses for 40%, Reduced COPQ for 55%, Reduced labours expenses for 59% which resulted in annual benefits of $ 172000
Q	Reduction in COPQ by 99.567% which resulted in the cost savings of Rs. 4.366 million/annum

VII. CRITICAL SUCCESS FACTORS IN CASE STUDIES

Some essential ingredients are required for the success of Six Sigma projects in organization these are called critical success factors. Many a times the failures in Six Sigma implementation by companies are due to improper and impractical approach without proper groundwork and planning. For the successful implementation of Six Sigma for achieving required results, organizations should focus on the key ingredients or elements which can lead them towards their goals [38]. For successful initiation and implementation of Six Sigma projects top management involvement and commitments are required at each stage of the project. Involvement of top management will make the availability of resources and make the culture oriented or initiated towards Six Sigma project. Top management can easily involved the employees for the Six Sigma projects by setting some incentive plan based on the success of the project and their contribution in it [34]. This is one of the most critical factors for success of the project. From the review of many papers it can be concluded that the most important factors for the implementation of Six Sigma are: Top management involvement and commitment, Training and education, Linking projects to financial benefits, linking projects to business strategy, Availability of resources, Utilization of tools and techniques, Proper selection of team members, Data

availability, Effective communication and proper documentation. These all factors are compared for all the case studies which we have selected for the study and same is shown in table 7. From the table 7 it can be concluded that Top management involvement, availability of adequate resources and utilization of tools and techniques are the most critical success factors for the industries which have been selected for study.

VIII. CONCLUSION

From the study it is revealed that Six Sigma as a breakthrough strategy helps organizations to detect and eliminate defects and improve their financial performance drastically. From the study of different successfully implemented case studies in Indian SMEs it can be concluded that Six Sigma is applicable to all size of organizations. It can also be concluded that DMAIC methodology is mostly used by the industries for their performance improvement. We can also reveal the various tools and techniques which were used in different stages of the project and same can be used by other SMEs. It is also concluded that Six Sigma is the approach which has a great impact on the bottom line of the organization. For any successful Six Sigma project, most critical success factors are Top management involvement, availability of resources and proper utilization of tools and techniques. This study will help Indian SMEs to initiate Six Sigma projects in their organizations and improve their performance in terms of customer satisfaction as well as financial benefits with increase in competitiveness in global market.

Table 7: Critical Success Factors in Case Industries

Critical Success Factors	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Top management involvement	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Attaching the success to financial benefits	√	√	√	√	√	√	√	√		√	√	√	√	√	√	√	√
Training and education of the staff	√	√			√			√		√			√				
Linking Six Sigma to business strategy	√	√	√	√			√	√		√	√	√	√	√		√	√
Adequate resources for implementation	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Setting measurable goals and objectives	√		√	√			√	√		√		√	√	√		√	√
Data easily available	√	√			√	√	√	√	√	√		√		√	√	√	
Proper Selection of team members	√	√					√	√		√				√		√	√
Utilization of the tools/techniques	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Focus on customer requirement	√	√					√	√			√	√	√				√
Proper documentation	√	√	√	√	√	√		√	√		√		√	√	√	√	
Effective communication between departments		√															

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