DEVELOPMENT, APPLICATION AND COMPARISON OF SIX SIGMA METHODOLOGY IN SERVICE INDUSTRY

THESIS

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by

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CANDIDATE'S DECLARATION

I hereby declare that this thesis entitled **DEVELOPMENT, APPLICATION AND COMPARISON OF SIX SIGMA METHODOLOGY IN SERVICE INDUSTRY** by **VIRENDER NARULA**, being submitted in fulfillment of the requirement for the Degree of Doctor of Philosophy in **MECHANICAL ENGINEERING** under Faculty of Engineering & Technology of YMCA University of Science & Technology Faridabad, during the academic year 2016-2017, is a bonafide record of my original work carried out under guidance and supervision of **Dr. SANDEEP GROVER, PROFESSOR, MECHANICAL ENGINEERING** and has not been presented elsewhere.

I further declare that the thesis does not contain any part of any work which has been submitted for the award of any degree either in this university or in any other university.

Virender Narula

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CERTIFICATE OF THE SUPERVISOR

This is to certify that this Thesis entitled **DEVELOPMENT, APPLICATION AND COMPARISON OF SIX SIGMA METHODOLOGY IN SERVICE INDUSTRY** submitted in fulfillment of the requirement for the Degree of Doctor of Philosophy in **MECHANICAL ENGINEERING** under Faculty of Engineering & Technology of YMCA University of Science & Technology Faridabad, during the academic year 2016-2017, is a bonafide record of work carried out under my guidance and supervision.

I further declare that to the best of my knowledge, the thesis does not contain any part of any work which has been submitted for the award of any degree either in this university or in any other university.

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ABSTRACT

In today's highly competitive scenario, the markets are becoming global & economic conditions are changing fast. Customers are quality conscious & demand for high quality product at competitive prices with product variety and reduced lead-time. Companies are facing tough challenge to respond to the needs of customers while keeping manufacturing & other related costs down. The companies are striving for their very survival. Companies can cut down their costs by reducing the production of defective parts. This is what Six Sigma is all about. Six Sigma is disciplined, focused and scientific problem solving technique, which uses statistical and non statistical tools integrated with methodology to bring down number of defects to 3.4 defects per million opportunities in any process. Six Sigma is a quality management program to achieve 'Six Sigma' levels of quality. Motorola pioneered it in mid 1980s, which began seeing, benefits just two-years later. Six Sigma was developed by Mikel Harry. The program gained publicity when Motorola won the Malcolm Baldrige award (MBNQA). Some of the pioneering companies, which used Six Sigma at very beginning, are ABB, General Electric (GE), and Allied signal, Texas Instruments. General Electric spent $500 million on Six Sigma in 1995 & gained more than $ 2 billion from that investment. In 2000, Fort Wayne, Indiana became the first city to implement the program in city government. There have been many successful applications of Six Sigma in manufacturing over the last two decades. Service organizations have legged manufacturing organizations in applying Six Sigma. The myth is that service organizations are human driven and there are no defects to measure. In the last decade, there has been quantum increase in applications of Six Sigma in service organizations

The present work deals with development, application and comparison of Six Sigma methodology in selected service organization. Service operations comprise 80 % of GDP in America and are rapidly growing around the world. In Indian economy, service sector accounts for substantial share of GDP. The cost related to work that adds no value in customer eye is typically 50% of total service costs. It means there is enormous potential for achieving improvements in service operations.The present work explores Six Sigma DMAIC model in service as well as manufacturing organizations. Literature reviews of Six Sigma in all areas including services,

education, and manufacturing have been done and a different scheme of classification has been suggested. Six Sigma literatures has been categorised based on research contents and research methodology. Based on research methodology Six Sigma papers have been classified in five categories as case studies, conceptual papers, literature review, general review and research papers. Based on research methodology, Six Sigma papers have been classified in six categories; Six Sigma general aspects and fundamentals, Six Sigma tools techniques and frame work, Six Sigma applications in manufacturing organizations, Six Sigma applications in service organizations and Six Sigma project selection & implementation strategies and Six Sigma& its linkages with other quality improvement initiatives. Six Sigma literature has been reviewed in the way that would help research academicians and practitioners to take a closer look at the growth, development, and applications of this technique.

Interaction of Six Sigma methodology with Lean manufacturing and Total Quality Management (TQM) has been explored and Comparison of Six Sigma with lean manufacturing as well as TQM is presented. Six sigma has succeeded in organizations where as Total Quality management has failed due many pitfalls as compared to Six sigma. TQM have been a fuzzy concept and lacks integration of processes to key issues of business strategy and performance. The integration of lean manufacturing and six sigma is required because lean cannot bring the process under control and six sigma alone cannot dramatically improve process speed or reduced invested capital.

Six Sigma DMAIC methodology tools and their application in service organizations have been discussed in detail. Significance of these tools in a Six Sigma projects have been emphasized. Six Sigma Define-Measure-Analyze-Improve-Control (DMAIC) methodology in select service organizations including a technical institution, telecommunication organization and a manufacturing industry has been applied. Education is emerging as major commercial activity in the service sector, and institutions are realizing the significance of quality improvement in education. Quality in education is no more a desirable strategy; it has become essential for the survival of an institution. The present work explores how Six Sigma may be used to improve performance parameters of a technical institution. Critical to quality characteristics have been identified and team structure is proposed for successful implementation of a Six Sigma project in technical institution. The findings along with an

implementation control plan based on a Six Sigma case study of technical institution have been recommended. Another case study have been conducted in a telecommunication organization deals with reducing service resolution time for customer complaints and queries processes It was found that service resolution time is one of the most significant dimensions of quality of a service process.

Present work also discusses key elements in a Six Sigma system and suggests a model for Six Sigma system. The model encompasses four key elements namely Six Sigma philosophy, strategies for process improvement and management, Six Sigma methodologies, and organizational structure. In addition, comprehensive comparison of Quality enablers, Critical to Quality Characteristics and performance matrices in service organizations have been done. Common challenges, benefits, limitation and myths regarding Six Sigma for service organizations have also been reported.

It has been concluded that gathering data and applying statistical method is not the aim of Six Sigma methodology. The overall aim is to enhance process understanding which must be reflected in the process improvements. The real understanding of process involves insight contact with actual process control situations. The basic philosophy of Six Sigma is to analyze and reduce process variations. The study of variation should be considered as a step towards use of statistical methods. However, it is improper to blindly use Statistical method. It is recommended to consult experts who have proper knowledge and practice in statistical theory as to appropriateness of other techniques. In any case, processes and procedures followed must satisfy the customer requirements and the overall aim is customer delight.

Keywords: Six Sigma, Quality, Customer, Define-Measure-Analyze-Improve-Control (DMAIC), Services, Process Variation.

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LIST OF SYMBOLS AND ABBREVIATIONS

Symbol	Description
σ	Sigma - Standard Deviation of Population, Process Sigma Level
s	Standard Deviation Of Sample
μ	Mean Of Population
μ_0	Process mean in a process with zero off centering
μ_1	Process mean in a off centered Process.
X double bar	Grand Mean of Sample
X bar	Mean of Sample Subgroup
R	Range
C_p	Process Capability
C_{pk}	Process Capability Index (Minimum of C_{pu} and C_{pl})
C_{pl}	Lower Capability Index
C_{pu}	Upper Capability Index
DPMO	Defects Per Million Opportunities
PPM	Parts Per Million
DPO	Defects Per Opportunity
DPU	Defects Per Unit
SPC	Statistical Process Control
AIAG	Automotive Industry Action Group
LSL	Lower Specification Limit
USL	Upper Specification Limit
LCL	Lower Control Limit
UCL	Upper Control Limit
SIPOC	Supplier-Input-Process-Output-Customer
DOE	Design Of Experiments
Gage R and R	Gage Repeatability And Reproducibility Analysis
MSA	Measurement System Analysis
ANOVA	Analysis of Variance
DMAIC	Define-Measure-Analyze-Improve-Control

DMADV	Define-Measure-Analyze-Design-Verify
DFSS	Design For Six Sigma
GB	Green Belt
BB	Black Belt
MBB	Master Black Belt
FMEA	Failure Mode and Effects Analysis
DFQ	Design For Quality
SOPs	Standard Operating Procedures
TQM	Total Quality Management
CTQ	Critical to Quality
X Bar and R chart	Chart for process mean and range
A H T	Average handling Time
CSE	Customer Support Executive
AFS	American Foundry men's Society
GDP	Gross Domestic Product
QM	Quality Manager
UGC	University Grant Commission
NAAC	National Assessment and Accreditation Council
AICTE	All India Council for Technical Education
NBA	National Board for Accreditation
NPIU	National Project Implementation Unit
EDCIL	Educational Consultants of India Limited
NITTTR	National Institution for Technical Teacher Training and Research
MHRD	Ministry of Human Resource Development
QCI	Quality Council of India
RPN	Risk Priority Number

CHAPTER 1

INTRODUCTION

Six Sigma is a scientifically proven method widely used by manufacturing and service organizations across the globe to provide enhanced value to their customers by reducing variation and defects in organizational processes, products and services. The chapter presents overview, evolution and significant aspects of Six Sigma methodology. In addition, chapter identifies methodology adopted for present work and outlines the organization of the thesis.

1.1 INTRODUCTION TO SIX SIGMA

The survival of an organization depends on business growth which in turn largely determined by customer satisfaction. Customer satisfaction is governed by quality, cost and service time which is further controlled by process capability. To excel in their business areas, organizations are bound to reduce cost, defects and cycle time for various products, processes and services. Six Sigma is the methodology to achieve customer delight by reducing number of defects and cycle time to a level of 3.4 defects per million opportunities in products processes and service and thereby reducing all associated costs. Figure 1.1presents meaning of sigma.

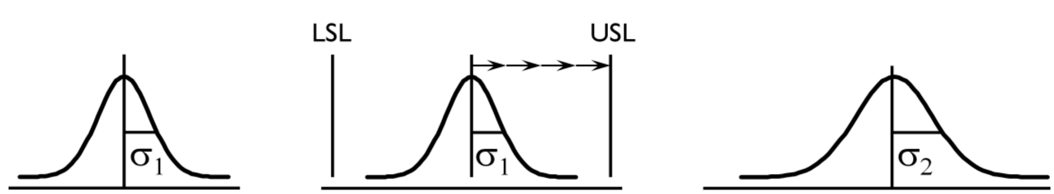

Figure 1.1 Meaning of sigma

Sigma is a letter in the Greek alphabet which is used to designate the distribution or spread about the mean of any process or procedure. In other words, sigma may be described as the number of standard deviations we can fit between the mean and the nearest specification or measure of the number of defects per opportunity produced by a process.

Sigma level is a business metric used to indicate the performance of a process relative to a specification. The sigma level is used to account for complexity which allows for the comparison of dissimilar goods and services. In other words Sigma level is a statistic used to describe the performance of a process to the specification limits. It is the number of standard deviations from the specification limits to the mean of the process.

1.2 MEANING OF SIX SIGMA

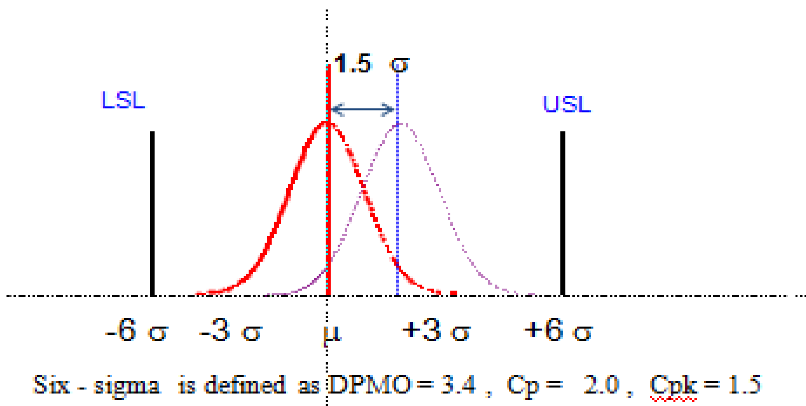

Figure 1.2 Six Sigma Process

Six-sigma is a Quality Management Program to achieve 'Six Sigma' levels of Quality. Six Sigma methodology Provides techniques & tools to improve the capabilities & reduce the defects in any process fewer than 3.4 defects in one million as presented in figure 1.2. The Six Sigma method is a project-driven management approach to improve the organization's products, services, and processes by continually reducing defects in the organization. It is a business strategy that focuses on improving customer requirements understanding, business systems, productivity, and financial performance. Dating back to the mid 1980s, applications of the Six Sigma methods allowed many organizations to sustain their competitive advantage by integrating their knowledge of the process with statistics, engineering, and project Management. Numerous books and articles provide the basic concepts and benefits of the Six Sigma method. The challenges and realities in implementing a Six Sigma method successfully are immense. However, the benefits of applying Six Sigma method to technology-driven, project-driven organizations are equally great. There have been various definitions of Six Sigma which are as follows:

Six Sigma is a disciplined method of rigorous data gathering and robust statistical analysis to pin point sources of error and ways of eliminating them (Harry and Schroeder, 2005). Six Sigma is a comprehensive, statistics-based methodology that aims to achieve nothing less than perfection in every single company process and product (Paul, 1999).Six Sigma is a formal methodology for measuring, analyzing, improving, and then controlling or "locking-in" processes. This statistical approach reduces the occurrence of defects from a three sigma level or 66,800 defects per million opportunities (DPMO) to a Six Sigma level of less than 4.0 DPMO (Bolze, 1998)

Chang and Wang (2008) have stressed that Six Sigma methodology is based on statistical and non statistical tools combined with quality management tools. The integration of these tools results in significant improvement in business processes. Wyper and Harrison (2000) have emphasized the application of Six Sigma methodology for human resource management is being widely used. Haikonen et al. (2004) have defined Six Sigma as business strategy for achieving customer delight and financial savings. Breyfogle (1999) have stated that Six Sigma quality level provides a measure of probability of occurrence of defect and number of defects derived from standard normal table.

1.3 HISTORY OF SIX SIGMA

Motorola pioneered it in mid 1980s, which began seeing, benefits just two-year later. Six Sigma was developed by Mikel Harry. The program gained publicity when Motorola won the Malcolm Baldrige award. Some of the pioneering companies, which use Six Sigma, are ABB, General Electric (GE), Allied signal, Texas Instruments. General Electric spent $500 million on Six Sigma in 1995 & gained more than $ 2 billion from that investment. In 2000, Fort Wayne, Indiana became the first city to implement the program in city government.

1.4 TWO PERSPECTIVES OF SIX SIGMA

Statistical viewpoint of Six Sigma: Six Sigma methods have two major perspectives. The origin of Six Sigma comes from statistics and statisticians. From the statistical point of view, the term Six Sigma is defined as having less than 3.4 defects per million opportunities or a success rate of 99.9997% where sigma is a term used to represent the variation about the process average. If an organization is operating at three sigma level for quality control, this is interpreted as achieving a success rate of 66,803 defects per million opportunities. Therefore, the Six Sigma method is a very rigorous quality control concept where many organizations still performs at three sigma level

Business viewpoint of Six Sigma: In the business world, Six Sigma is defined as a 'business strategy used to improve business profitability, to improve the effectiveness and efficiency of all operations to meet or exceed customer needs and expectations. The Six Sigma approach was first applied in manufacturing operations and rapidly expanded to different functional areas such as marketing, engineering, purchasing, servicing, and administrative support, once organizations realized the benefits. Particularly, the widespread applications of Six Sigma were possible due to the fact that organizations were able to articulate the benefits of Six Sigma presented in financial returns by linking process improvement with cost savings.

1.5 IMPORTANT ASPECTS OF SIX SIGMA

One may not try to achieve six-sigma performance in each and every process; it may not be required or may not be economical. In so called six-sigma companies also six-sigma performance is achieved in couple of processes only. The airlines fatality rate is more than Six Sigma where as baggage handling process is three to four sigma level. The six-sigma quality concept applies to a single Critical to Quality characteristics (CTQ) not to the entire product. When a product such as car is described as a Six Sigma product it does not mean that only 3.4 cars out of a million will be defective.

1.6 EVOLUTION OF SIX SIGMA METHODOLOGIES

Six Sigma process improvement methodology or roadmap is an operational model to move the projects from definition through root cause to maintain the gains of the project. It is a blueprint for managing projects effectively and efficiently. W.A shewart was first to describe a road map – P D C A (plan-do-check-act), which laid foundation for continuous improvement. Deming has popularized the methodology and is widely referred as Deming cycle. Later several authors developed variants of this methodology. The Juran described one such approach, after studying a large number of project implementations. The Juran methodology is called Universal sequence of events for making improvements and comprise of nine steps. The Juran remarks to most people in the breakthrough sequence seem obvious and logical. When they are asked, however, to critically evaluate the adequacy of execution of these steps in their organization, then the effectiveness of various companies is decidedly uneven. For many of these logical steps the actual execution is far from satisfactory. Several companies have also developed their own tools for process improvement projects. The 8- discipline (referred as 8D methodology) is commonly used at Ford Company and throughout the automotive community. The ISO-9000: 2000 has also given some guidelines for improvement.

There are two limitations with these methodologies. First, the detailed steps are not standardised. Second, the statistical and non statistical tools are not linked with the methodology. For example, most of tools used in Six Sigma such as Statistical process Control (SPC), Failure Modes and Effects Analysis (FMEA), and Measurement System Analysis (MSA) are part of ISO 9000. However, the exact applications of these tools in the problem solving steps are not specified.

Define-Measure-Analyze-Improve-Control (DMAIC) is widely talked about methodology in Six Sigma. However, a close review of deployment by different agencies reveals that neither the steps to be followed in each phase and nor the tools application, is standardized. Further, DMAIC is only useful for problem solving and for designing new products or processes another methodology called DFSS is used. DFSS stands for design for Six Sigma. It has been felt that more development and some amount of standardization are expected in this methodology of Six Sigma. Motorola has developed ‘Six steps to Six Sigma’ methodology as part of their Six

Sigma initiative. They have further refined the methodology to suit three applications manufacturing, services and Design for Six Sigma.

1.6.1. Six Steps for Six Sigma in Manufacturing

1. Identify product characteristics necessary to satisfy customer physical and functional requirements.
2. Classify identical characteristics as - critical and major.
3. Determine whether the classified characteristic is controlled by part process or both.
4. Determine maximum allowable tolerance for each classified characteristics, which will guarantee successful performance.
5. Determine process variation for each classified characteristic.
6. Change design of product, process or both to achieve Cp equal to or greater than 2.

1.6.2 Six Steps for Six Sigma in Services

1. Identify the work you do (your ‘product’).
2. Identify who your work is for (your ‘customer’).
3. Who do you need to do your work and for whom (your ‘supplier’).
4. Map the process.
5. Mistake - proof the process.
6. Establish quality and cycle time measurement and improvement goals.

1.6.3 Six Steps for Design For Six Sigma

1. Identify critical characteristics through such functions and activities such as marketing, industrial design, R & D, Engineering, etc.
2. Identify the product elements that influence the critical characteristics defined in step one.
3. Define process elements that influence the critical characteristics defined in step two.
4. Establish maximum tolerances for each product and process elements defined in step two and three.

5. Determine actual capabilities of the elements presented in step two & three.
6. Assure that Cp>=2.

1.6.4 DMAIC versus DMADV

DMAIC & DAMDV are very talked about methodologies in Six Sigma. DMAIC is used for problem solving in Manufacturing and services organizations. However, the steps for manufacturing and service applications are different. DMADV is used for DFSS (Design for Six Sigma). These approaches have been suggested by Mikel Harry. The phases in DMAIC include define, measure, analyze, improve & control whereas phases in DMADV include define, measure, analyze, design, verify. It seems that first three phases of these two methodologies are same. However, they have altogether different meanings. For example 'measure' phase in DMAIC is to determine the current process performance, whereas 'measure' phase in DMADV is to determine customer needs and specifications. The application is totally different in DMAIC as compared to DMADV. Occasionally a product is scoped as DMAIC and it actually requires application of DMADV. In present work more stress is given on DMAIC methodology. Following are the advantages of adopting the DMAIC methodology.

- Making a fresh start.
- Giving a new context to familiar tools.
- Creating a consistent approach.
- Giving priority to 'customer' and 'measurement'.
- Offering both 'process improvement' and 'Process Design / Redesign, paths to improvement.

1.7 RESEARCH OBJECTIVES

The present work deals with development, application and comparison of Six Sigma methodology in selected service organization. Six Sigma has been successfully implemented in many manufacturing organizations however service organizations are lagging behind in implementing Six Sigma. The myth is that service organizations are human driven and there are no defects to measure. The present work explores Six Sigma DMAIC model in service as well as manufacturing organizations. Following are the objectives of present work

- To perform comprehensive study of Six Sigma methodology in manufacturing sector and service sector.
- To compare application of Six Sigma in manufacturing sector and service sector.
- To Design & Develop generalized model for application of Six Sigma in service sector.
- To Apply Six Sigma DMAIC methodology in select service sector.
- To Compare Six Sigma methodology in service sector using application of systematic Methodologies.

1.8 METHODOLOGY ADOPTED FOR PRESENT WORK

Six-Sigma D-M-A-I-C methodology is adopted for present work. DMAIC methodology improves any existing process by constantly reviewing & re-tuning the process. Anderson et al., (2006) and Magnusson et al., (2003) have reported that Six Sigma is a structured way of solving problem in a process based on statistical analysis of data. Motorola originated various phases of Six Sigma process as MAIC i.e. measure, analyze, improve and control which became DMAIC i.e. define, measure, analyze, improve and control at GE. Following are the Six Sigma DMAIC methodology steps

Step1 – Define (D): Who are the customers and what do you provide your customers? What are their priorities? What is critical to quality for your customers? A six-Sigma project team identifies and defines project suitable for Six Sigma efforts based on business objectives as well as customer needs and feedback. Team identifies the attributes called CTQs (critical to quality characteristics) that the customer considers having the critical impact on quality. While defining the project, it is recommended to describe only the effects and not the causes of the problem. The tools and techniques applicable for service organizations in define phase are process mapping, SIPOC, quality function deployment, project charter, calculations for cost of poor quality

Step-2 Measure (M): Measure how the process is performing. Determine current performance of service process. We may use the DPMO, process yield, and Sigma rating of the process. Determine what to measure how the process is measured? Find out the frequency of defect the team identifies the key internal processes that influence CTQs (critical to quality characteristics) and measures the defects currently related to those processes.

Step-3 Analyze (A): When and where the defects occur? What are the most important causes of defects? The team discovers why defects are generated by identifying the key variables that are most likely to create process variation.

Step-4 Improve (I) : How can we fix the process? How to remove the causes of defects? The team confirms the key variables and quantifies their effects on CTQs. It also identifies the maximum acceptable ranges of the key variables and validates a system for measuring deviation of the variable. The team modifies the process to stay within acceptable range.

Step-5 Control (C): How can we maintain the improvements? Determine process capabilities to implement process controls. Tools are put in place to ensure that under the modified process the key variables remain within maximum acceptable ranges over the time.

1.9 ORGANIZATION OF PROPOSED THESIS

The Thesis has been categorized into eight chapters.

CHAPTER 1. INTRODUCTION TO SIX SIGMA

This chapter presents definitions, history, significant aspects, organization structure and, key players of Six Sigma Methodology. In addition, it discusses about various Six Sigma methodologies in manufacturing and service organizations.

CHAPTER 2. LITERATURE REVIEW

The chapter presents a different scheme for classification of Six Sigma literature that would help researchers and academicians to take a closer look at the growth, development, and applications of the technique. In addition, certain gap areas are identified that would help researchers in further research. Chapter discusses scheme of classification for literature review, classification of literature based on research contents, classification of literature based on research methodology and key findings and gaps identified from literature review.

CHAPTER 3. SIX SIGMA AND ITS INTERACTION WITH TQM AND LEAN MANUFACTURING

The chapter presents links of Six Sigma methodology with Lean manufacturing and Total Quality Management (TQM). In addition, comparison of Six Sigma with lean manufacturing as well as TQM is presented.

CHAPTER 4. SIX SIGMA TOOLS AND THEIR APPLICATIONS IN SERVICE ORGANIZATIONS.

The chapter discusses the significance of Six Sigma tools and their application in various phases of Six Sigma DMAIC methodology.

CHAPTER 5. DEVELOPMENT AND APPLICATION OF SIX SIGMA DMAIC METHODOLOGY

In this chapter, case studies of Six Sigma DMAIC methodology in a technical institution, telecommunication organization, health care and a foundry shop are presented and research outcomes in these domains are presented.

CHAPTER 6. GENERALIZED MODEL OF SIX SIGMA

The chapter presents key elements in a Six Sigma system explicitly, Six Sigma philosophy, strategies for process improvement and management, Six Sigma methodologies, and organizational structure. In addition, it has been emphasized that effective use of organizational structure including green belts, black belts, master blacks belts and champions synchronized with Six Sigma philosophy and methodology have a demonstrated impact on the successful deployment of Six Sigma projects.

CHAPTER 7. SIX SIGMA IN SERVICES - CRITICAL TO QUALITY CHARACTERISTICS AND CHALLENGES

The chapter presents a comprehensive comparison of Quality enablers, Critical to Quality Characteristics and performance matrices in service organizations. In addition, Common Challenges, benefits, limitation and common myths regarding Six Sigma for service organizations have also been reported.

CHAPTER 8. CONCLUSION AND SCOPE FOR FUTURE RESEARCH

The chapter presents Six Sigma system perspectives for successful execution of Six Sigma projects. Research outcomes have been demonstrated for the application of Six Sigma DMAIC methodology for a technical institution, telecommunication organization, health care and foundry shop. In addition, chapter presents conclusion and future scope of Six Sigma methodology

CHAPTER 2

LITERATURE REVIEW

There has been considerable number of papers published related to Six Sigma applications in manufacturing and service organizations. However, very few studies are done on reviewing the literature of Six Sigma in all the areas including manufacturing, construction, education, financial service, BPOs and healthcare etc. The chapter presents comprehensive review of Six Sigma literature. In addition, certain gap areas are identified that would help researchers in further research.

2.1 PREAMBLE

In the present work, research papers from various international journals and have been reviewed and a different scheme of classifying Six Sigma Literature has been suggested. The authors have made both hard copies search in established libraries and electronic search in World Wide Web. The websites searched include www.sciencedirect.com,www.Inderscience.com, and www. ieeexplore.com. and www.emeraldinsight.com. The search was carried out in all the journals of these websites with key word as ‘Six Sigma’. In addition, www.delnet.ac.in was searched for Six Sigma books and research papers. Paramount efforts have been done to collect and review all the existing Six Sigma papers. However, it is not claimed that literature review is complete or completely exhaustive in nature. During classification the papers in various categories, authors have found that, few papers were representing more than one category. Therefore, there may be certain overlaps in categorization for a few papers. The classification scheme proposed in this paper includes a categorization of publications that highlights the growth of literature from time to time. The authors have classified Six Sigma literature based on the criteria of research methodology as well as research contents. It is rational that very strict demarcation in classification is not possible since there are few overlaps in categorization. The objective of literature review is:

- To update the database and to ensure that it contains literature as current as possible.

- To arrange the publications in an orderly manner to enable easy and quick search
- To classify literature based on research methodology, research content, journal, and year
- To scrutinize the outcome of the papers
- To Identify gaps and provide hints for future research

Ricardo Banuelas Coronado and Jiju Antony (2002) in paper titled 'Critical success factors for the successful implementation of Six Sigma projects in organizations' have reviewed literature related to critical success factors for effective implementation of Six Sigma projects in organizations. The authors have linked Six Sigma to business strategies, customers, human resources and suppliers. Significance of aspects related to implementation strategies like project management skills in Six Sigma black belts ma projects and prioritization & selection of six sig have been discussed. P. Nonthaleerak and L.C. Hendry (2005) in paper titled 'Six Sigma: literature review and key future research areas' have reviewed more than 200 papers and classified them on bases of research content and research method. A comprehensive list of further research areas is also given. Future research issues related to Six Sigma methodology & Six Sigma implementation has also been discussed. Ayon Chakrabarty and Kay Chuan Tan (2007) in paper titled 'The current state of Six Sigma application in services' have carried out an analysis of relevant publications, citations and references using multiple databases. The impacts of various key researches have also been discussed. The paper contributes literature review of Six Sigma papers in services. The findings are based on analysis done both quantitatively and qualitatively. The authors have also discussed how their contribution can be utilized for further research on this particular topic. Arash Shahin and Mehdi Alinavaz,(2008) in paper title 'Integrative approaches and frameworks of lean Six Sigma: a literature perspective, have provided the comprehensive perspective of integrative approaches and frame work .The subject of Six Sigma and lean have been explained separately and compared, and then their integration approaches and frameworks have been studied and discussed. It is stresses that combination of both techniques can provide effective tools to solve problem and create rapid transformational improvement at lower cost which lead to higher performance. Tjahjono et. al. (2010) in paper titled 'Six Sigma: a literature review' have identified the seven key findings and two issues including interpretation of Six Sigma, tools and techniques, implementation of Six Sigma, benefits, adoption, enablers and links to other disciplines. Attempt has been done to answer the questions like what is Six Sigma all about, applications of Six Sigma, main barriers to its application, and emerging trends. The literature is analyzed and major emerging trends are presented. M.P.J. Pepper and T.A. Spedding (2010) in paper titled 'The evolution of lean Six Sigma' have examined and provide an insight into the evolution of lean sigma paradigm. It is suggested that clear integration of two approaches must be achieved, with sufficient scientific foundation. The paper also stresses on identifying value added and non value added processes. Mohamed Gamal Aboelmaged (2010) in paper titled 'Six Sigma quality: a structured review and implications for future research' has summarized Six Sigma literature from 1992 to 2008. The author has analyzed literature from journals relating to business & management, information systems, computer science, healthcare etc. A scheme consisting of four distinct dimensions i.e. publication year & journal, major themes, research type, and application sector has been discussed. The findings of the papers include great focus on Six Sigma tools & techniques, case study approach, growing gap between manufacturing & service industry.

2.2 CLASSIFICATION OF LITERATURE BASED ON RESEARCH METHODOLOGY

Based on research methodology Six Sigma papers have been classified in five categories as case studies, conceptual papers, literature review, general review and research papers. The figure 2 1 represents percentage of Six Sigma papers based on research methodology and figure 2.2 represents number of Six Sigma papers based on research methodology

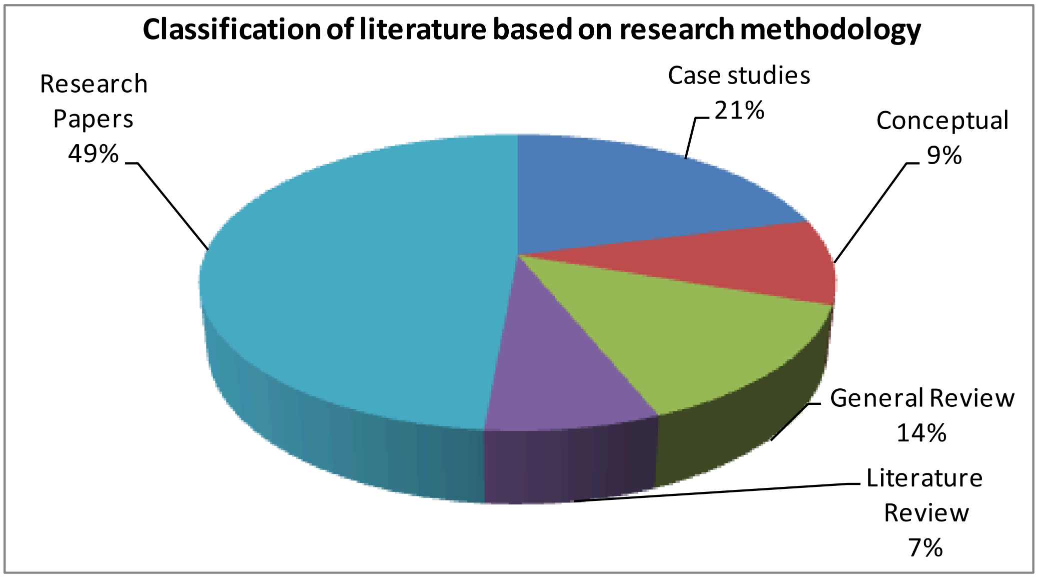

Figure 2.1 Pie chart representing percentage of Six Sigma papers based on research methodology

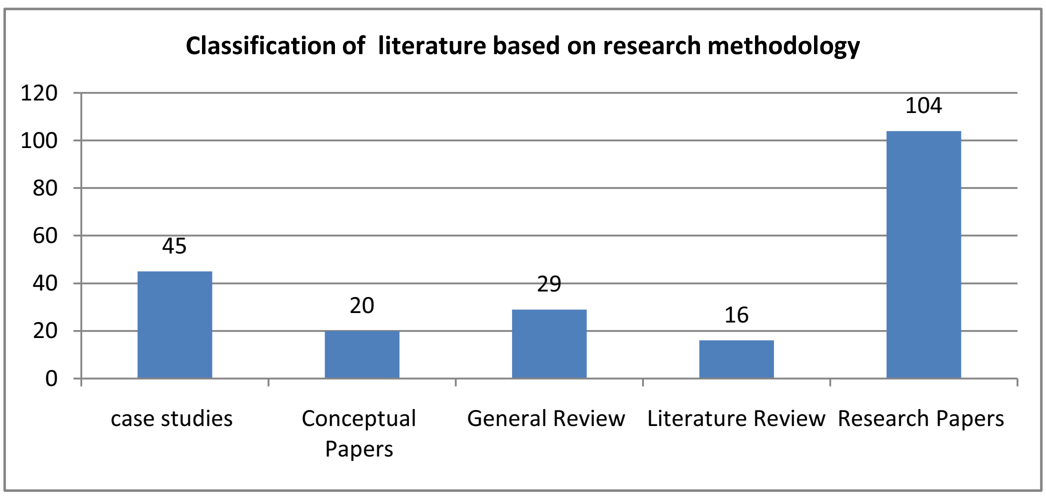

Figure 2.2 Bar chart representing number of Six Sigma papers based on research methodology

2.3 CLASSIFICATION OF THE LITERATURE BASED ON RESEARCH CONTENTS

Based on research methodology, Six Sigma papers have been classified in six categories; Six Sigma general aspects and fundamentals, Six Sigma tools techniques and frame work, Six Sigma applications in manufacturing organizations, Six Sigma applications in service organizations and Six Sigma project selection & implementation strategies and Six Sigma & its linkages with other quality improvement initiatives. The figure 2.3 represents the percentage of each category based on research contents whereas figure 2.4 represent classification of publications based on research contents. The figure 2.5 represents number of publication in chronological order

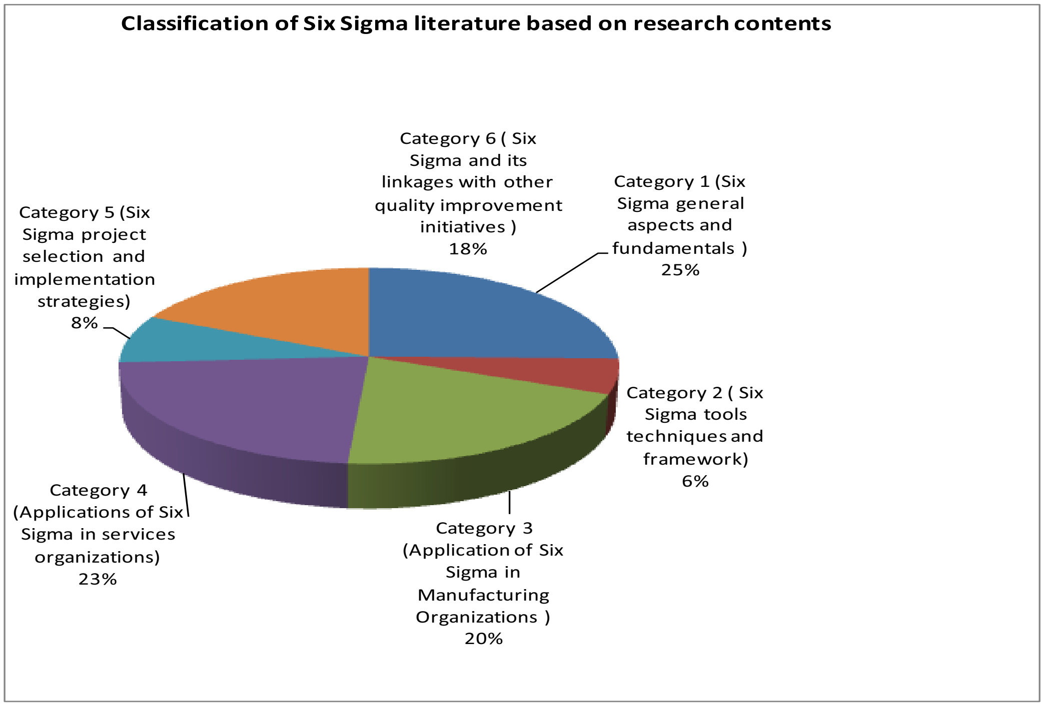

Figure 2.3 Pie chart representing the percentage of each category based on research contents

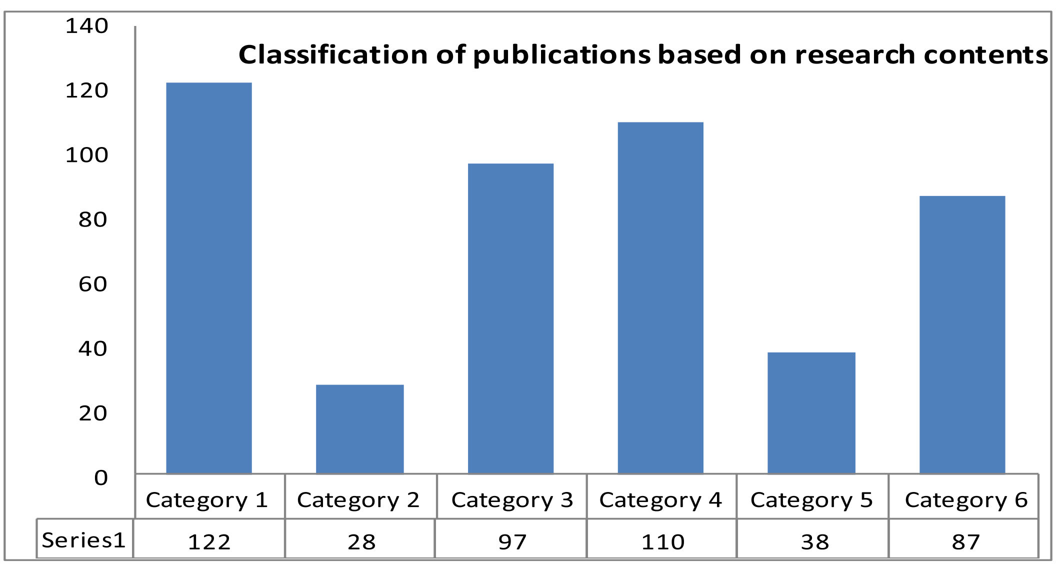

Figure 2. 4 Bar chart showing number of publications based on the research contents

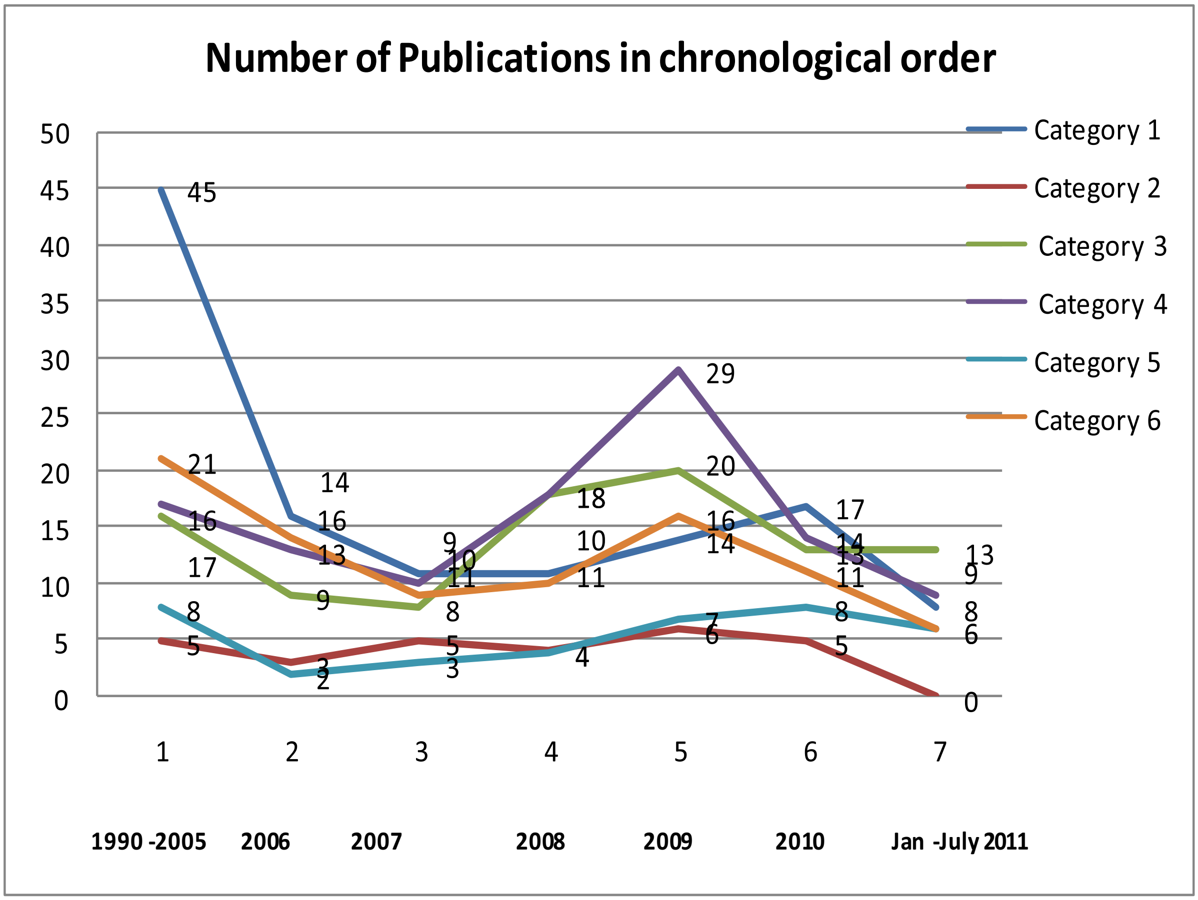

Figure 2.5 Number of the publications in chronological order

2.3.1 Six Sigma General Aspects and Fundamentals

This category includes publications on Six Sigma evolution, concepts, methodology, and performance matrices & employee perceptions. There are 45 publications on this category from time span of 1991 to 2005. The numbers of papers are highest in this category corresponding to time span of 1991 to 2005 as papers belonging to this category represent basic concepts of Six Sigma. Due to quantum growth of Six Sigma deployment in various other sectors, there is no sharp rise in numbers of papers belonging to this category in previous five years. Following are the few of the papers pertaining to above-mentioned category.

Majoomdar (2002) has worked on the problem of process variation in the industries. He has suggested that variation are single largest enemy of the industries and suggested the tools to deal with short term and long term variation. He has further suggested that statistics is a key ingredient in successful implementation of Six Sigma program. Man (2002) has linked Six Sigma with adult learner characteristics. He has presented a model that enable adult learner to engage in lifelong learning within their organization. He has further stressed that model enables learning throughout in their personal lives also. Antony (2004) has examined pros and cons of Six Sigma in a detailed manner. In addition, applications of statistical & non-statistical tools and techniques to tackle process variability have been described. He has stressed that applications of Six Sigma will grow in forthcoming years due to presence of statistical science within Six Sigma.

Kwak and Anbari (2004) have stressed upon the key factors like management commitment & involvement, training, cultural changes, linking Six Sigma to business. Authors have also described obstacles, challenges, and future of Six Sigma methodologies. Authors have suggested that primary focus should be on improving management performance rather than just pinpointing and counting defects. Authors have further concluded that effective implementation of Six Sigma principles are more likely to succeed by refining the organizational culture continuously. Senapati (2004) has suggested Six Sigma DMAIC approach through deming cycle, TQM, MBNQA, and Dorian Shanin's statistical engineering. He has suggested Six Sigma as improvement initiative, which does more than any other existing plan.

Kumar, M. et al. (2008) have found that Six Sigma is neither a fad nor just another quality initiative. It has base of factual data coupled with hard work & is a disciplined, focused, scientific, and structured problem solving methodology. Six Sigma should not be viewed as advertising banner for promotional purposes. The organizations implementing Six Sigma have benefits from it in three major ways like reduced defect rate, reduced operational cost, and an enhanced customer satisfaction. Six Sigma should be adopted as a way of life. Authors have suggested that right training and implementation will help people to understand that Six Sigma methodology is significantly different from other quality initiatives. It contains many concepts & philosophies that have been taught for years but then again it is different because it teaches practical method of achieving results. Schroeder et al. (2008) have provided definition & underlying theory of Six Sigma and discussed structural control and structural exploration of the same.

The term Six Sigma was endorsed by Motorola and General Electric, Honey well & Asia Brown Boveri followed the trend (Karthi et al., 2011). Six Sigma is defined as philosophy, metric and methodology implemented either to provide services or to manufacture a product at a quality level of 3.4 DPMO (Karthi et al., 2011 b). Six Sigma is viewed in three perspectives, such as a metric, methodology, management philosophy. The Six Sigma organizational structure provides another perspective of this strategy (Natarajan et al., 2010). Six Sigma as Business metric focuses on 3.4 DPMO and as a methodology encompasses five phases namely define, measure, analyze, improve, control (karthi et al., 2011).

The major goal of Six Sigma is to measure and reduce process variability which in turn reduces number of defects (Eckes, 2000). Basically Six Sigma has been evolved as methodology for producing defect free products in manufacturing perspective. Today, it extends and used effectively in services, public sectors, healthcare and government organizations (Antony et al., 2005; Montgomery, 2005; Pande, et al., 2000; Pyzdek, 2003; Breyfogle, 1999). According to Snee, (2004) Six Sigma is a business strategy developed to find and eliminate the number of defects or errors in processes, systems, or services in an organization with a focus on key process variables which are critical to quality for customers. Six Sigma may be defined as cost effective quality matrix developed for business processes where focus is to reduce defects (Bicheno, 2004). Antony and Fergusson (2004) have stresses that Six Sigma quality program focuses on the business parameters which are critical to quality for customer and reduces the causes or defects. Jones et al. (2011) have summarised Six Sigma as a statistical method as decisions are based on statistical analysis of quantitative data. The Six Sigma project is carried out by people who have been trained to perform at various levels in a Six Sigma organizational structure.

Mcadam and Evan (2004) have concluded that Six Sigma process include both process and people, but till now, only a few studies have been carried out to understand human satisfaction factors. Robinson (2005) has stressed that benefits of Six Sigma range from reduction in number of defects to enhancement of market share and competitive advantage over market opponents. Sadraoui and Ghorbel (2011) have proposed a new method of Six Sigma for minimization of customer complaints and reducing number of defects in any process. The authors have developed a model which consists of technical and human factors to effectively guide and implement Six Sigma Program in the companies dealing with casting process. Chua (2006) states that Six Sigma is a customer centric methodology which is beneficial to all the stake holders in organization including employees, suppliers and shareholders. Hensley and Dobie (2005) have studied regarding ability of organizations for implementing Six Sigma methodology by studying a conceptual model and conducting a survey in public transit company. Hong and Goh (2004) have stressed that Six Sigma is most sought after in software industry. The software used in space programs commercial aircraft manufacturing operates on 4.1 to 5.1 sigma quality level. If one line of programming code represent one opportunity for defect, in a product development process thousands of defects are likely to be found per million lines of source code. By implementing Six Sigma in software development processes, only 3.4 defects are visible in a million lines of software program.

2.3.2 Six Sigma Tools, Techniques and Framework

This category includes publications on Six Sigma tools, techniques and frame works. Following are the few of the papers pertaining to above-mentioned category.

Henderson and Evans (2000) have reviewed the basic concepts of Six Sigma, its benefits, & successful approaches for implementation & benchmarked the practices of General electric company. Authors have done study of Six Sigma DMAIC methodology in GE and found key factors for successful implementation of Six Sigma include upper management support & involvement, training, infrastructure, tools and linking HR based action like promotions, bonuses etc.

Rowlands and Antony (2003) have presented the application of design of experiment (DOE) in order to find out the key process parameters which affect the tensile strength of welded joints. Statistical analysis was carried out to identify process parameters that influence mean strength and variability in welded joint strength. The result of analysis may be applied to a manufacturing company to extend the application of DOE to other core processes. Lazreg and Gien (2009) have linked Six Sigma and maintenance excellence with quality function deployment. The authors suggested that linking maintenance excellence & Six Sigma leads to an improved model of organization maintenance function, eliminate the occurrence errors, and reduces the cycle time of maintenance. Authors have claimed that these two approaches can be coupled using quality function deployment.

Yeung (2009) has explored the use of supplier, input, process, output, and customer (SIPOC) in Six Sigma to monitor product and services provision for customer satisfaction. A case of integrating SIPOC of Six Sigma into social, responsible, & ethical retail shoe shop has been demonstrated in this paper. The author has suggested carrying out further research on use of quality concept in analyzing relationship between consumer behavior & business performance. Grover S., et al.(2006) have presented the role of human factors in TQM using graph theoretic approach

2.3.3 Applications of Six Sigma in Manufacturing Organizations

These publications illustrate the application and implementation of Six Sigma in manufacturing industries. Case studies of actual implementation of Six Sigma in manufacturing organizations are also presented in these papers. In addition, research papers from this category include general papers of Six Sigma in manufacturing, application of Six Sigma in jobbing industries, small and medium scale industries, application of Six Sigma in construction, chemical and process industries. There are 16 publications from 1991- 2005 belonging to this category. There is considerable increase in publication belonging to this category. Following are the few of the papers pertaining to above-mentioned category.

Doble (2005) has compared Six Sigma methodology and chemical plant safety methodology for the chemical process safety. Kumar and Sosnoski (2009) have examined one of the shop floor chronic quality issue during heat treatment process through Six Sigma DMAIC methodology. Radha Krishna and Dangayach (2007) have presented the implementation of Process level Six Sigma in auto component manufacturing plant.

Gerhorst et al. (2006) have worked on Design-For-Six-Sigma (DFSS) in product development at ford motor company through computational fluid dynamics and experimented design technique. Sahoo et al. (2008) have implemented DMAIC in order to optimize radial forging operation. The authors had the prime focus on minimizing the residual stresses developed in the components manufactured by radial forging. Antony and Desai (2009) have accessed the status of Six Sigma implementation in Indian industries. The authors have presented the results for exploratory empirical study. The questionnaire survey was applied in UK industries and adapted so that it could be applied in Indian industries. Awad et al. (2009) have worked on DFSS approach to improve the expectancy of track roller & idlers for an off road machine through CAE model.

Aggogeri, F. et al. (2009) have worked on implementation of DFSS project in SME to improve performance of extrusion process. Rajesh kumar et al. (2011) have explored the status and critical factors to evaluate the feasibility of Six Sigma in Indian automotive industry.

2.3.4 Applications of Six Sigma in Service Organizations

These publications present overview of Six Sigma DMAIC methodology in service organizations. In addition, case studies related to Six Sigma applications in services including financial organizations, education and health care have been discussed. The research papers in this category include general papers on Six Sigma, Six Sigma in education, Six Sigma in health care services, Six Sigma in e-business & financial services. During the time interval of 1991- 2005 number of publications corresponding to this category are 17. In this category, there is substantial increase in number of publications, because now a day service organizations like financial services, health care, e commerce, and logistics are playing a very vital role for economy of developed countries. Following are the few of the papers pertaining to above-mentioned category.

Hensley and Dobie (2005) have presented Six Sigma model in an urban public transit company. The model includes analysis of the transit company's readiness for Six Sigma. The survey analysis was used to identify the differences in perceptions between service employees and customers. He has suggested that Six Sigma programs work best in the organizations that are prepare to apply them. One of the limitations of study was that it was implemented in single organization. Antony (2006) has studied basic features of Six Sigma methodology for implementation in service organizations. He has investigated tools and techniques used within Six Sigma methodology for service processes performance.

Key factors for successful implementation of Six Sigma in service organizations include strong leadership and management commitment, organizational culture change, selection of Six Sigma team members and teamwork, Six Sigma training, linking Six Sigma to customers etc. Antony et al. (2007) have studied the UK service organizations and found out that average level of companies in UK was around 2.8 sigma. Authors have suggested key factors for successful deployment of Six Sigma in service organization include management commitment and involvement, customer focus, linking Six Sigma to business strategy, organizational structure, & project management.

Macarty and Fisher (2007) have described as how to get started and to overcome the resistance for service organizations. Authors have suggested that with guided implementation & disciplined used Six Sigma yields tangible results in service environments. Jenicke et al. (2008) have identified several aspects that differentiate an academic environment from manufacturing setting for Six Sigma application. Authors have proposed a three-tier framework for academic institutions where Six Sigma may be used as used by administrators, faculty, staff, and students as an implementation guide. He has suggested that role of management is very critical if Six Sigma is to be implemented successfully. He has further encouraged college and departmental heads to participate in Six Sigma training that will in turn encourage faculty and staff to participate in Six Sigma initiative.

Nakhai and Neves (2009) have found that extreme drive for adopting Six Sigma in service organizations has led both to limited field of application & unrealistic expectation as to what Six Sigma is truly capable of achieving particularly in service organizations. Authors have presented the service quality model and described the gap between Six Sigma and service quality. Chakrabarty and Kay Chuan, T. (2009) have done qualitative & quantitative analysis of Six Sigma organizations in Singapore and found out that application of Six Sigma in service sector is concentrated in a few services. Authors have provided parameters to be considered for successful implementation of Six Sigma. He has done a questionnaire survey of Singapore service organizations to understand the status of Six Sigma in Singapore. The survey shows that 23% of responses are not aware of Six Sigma methodology, 23% find it is not relevant. 15.38%, 17.95%, & 17.95% percentage of responses find that it not interesting, time consuming and difficulties in identifying process parameters. Services comprise majority of employees and 75 % source of income of the GDP in UK and USA. (Zeithaml and Bitner, 2003; Zeithaml, Parasuraman and Berry 1990).

Allway and Corbett, (2002) have emphasized that due to cut throat competition in services, it has become essential to relook service sectors to efficiently manage their operations. According to Zeithamal and Bitner, (2003) and Zeithamal and Berry, (1990) services is one of the most important components of GDP in developed countries and constitute the source 75% of income. Fournier, Dobscha, and Mik, (1998) and Fornell (2008) have claimed that customer satisfaction rates are very low in USA the service providers. Zeithaml, et al. (1990) and Quinn and Gagnon (1986) have found the trend of declining quality and increasing cost in services as well as manufacturing organizations. This could be due to fact that both types of organizations use some sort of business process.

Due to replication of mass production logics such as strict management control, low skill and meagre wages for labour have resulted in deteriorating quality in services. Ellis and Taylor (2006) have found that due to stern implementation of Taylors principles in IT services for reducing cost have resulted in detrimental effects on employee morale, process efficiency and customer satisfaction. (Thompson, 2003; Slack, chambers and Johnston, 2006; Johnston and clark, 2005)

2.3.5 Six Sigma Project Selection & Implementation Strategies

The research papers pertaining to this category include papers on Six Sigma project selection, Critical Success Factors (CSFs) affecting its implementation and Six Sigma implementation strategies. There has been eight papers belonging to this category corresponding to time interval of 1991- 2005.the number of papers corresponding to 2006 were two & numbers of papers corresponding to 2010 were eight. The trend shows that there has been sharp increase in publication belonging to this category. It is due to the large growth of Six Sigma implementation in service as well as manufacturing organizations. Following are the few of the papers belonging to this category.

Antony and Banuelas (2002) have reviewed critical success factors for deployment of Six Sigma in organizations. Banuelas et al (2006) have used survey as method to investigate that what measures are to be considered to select Six Sigma project and how potential projects are identified. He has concluded that Six Sigma converts quality improvements in to bottom line financial benefits and selection of appropriate project is a key factor to success.

Chakravorty (2009) has commented that Six Sigma program fails because an implementation model to effectively guide the program is lacking. He has recommended six steps implementation model for effectively implementing Six Sigma projects. Kumar, M. et al. (2009) have focused on the importance of project selection and its role in successful deployment of Six Sigma within the organizations. Authors have presented the methodology linking the project selection process to successful deployment of Six Sigma within the organization. Büyüközkan and Öztürkcan (2010) have presented a combination of ANP (Analytical Process Network) & DEMATELC (decision-making trail & evaluation laboratory) techniques to help companies to determine the critical Six Sigma projects & identify the priority of these projects especially in Logistics Company.

Desai and Patel (2010) have commented that Six Sigma is not being explored in Indian Industries to its full potential. Authors have presented two real life cases highlighting Six Sigma implementation difficulties in Indian industries. Six Sigma is a established methodology with proven result and is effectively used by corporate world for quantum gains in profits, cost savings and customer delight. Kumar, M. & Antony (2004) have claimed that all quality initiatives, which involve continuous improvement of products and services results in enhancing customer satisfaction and thereby connecting directly to the customer.

2.3.6 Six Sigma and Its Linkages With Other Quality Improvement Initiatives

Under this category literature on Six Sigma and its linkages with other initiative such as systems thinking, lean, ISO 9001: 2008, supply chain management, and Design for Six Sigma are considered. Following are the few of the papers pertaining to above-mentioned category.

Antony (2002) has stressed that during journey of excellence of any firm, they often need to redesign the products and processes in order to reduce defects and improve quality. Author has explained the underlying statistical concepts and methodology of design for Six Sigma (DFSS) for a firm moving toward the realization of Six Sigma quality. Banuelas and Antony (2003) have examined the similarities & differences in Six Sigma methodology and compared it with DFSS approach. Banuelas and Antony (2004) have stressed importance of DFSS to design and redesign processes to ensure achievement of high levels of quality. Authors have tested suitability of a multi criteria decision-making technique and the analytical hierarchy process to make a choice between Six Sigma and DFSS in two multinational companies. Raisinghani et al. (2005) have done conceptual study and found out that immediate goal of Six Sigma is reduction of defects. Reduced defects lead to process improvements and which enhance customer satisfaction. Authors have also described evolution of quality initiatives like TQM, Quality circles, kaizen, ISO 9000, and MBQNA. Authors have further conducted case studies on few organizations like GE, allied signal etc and suggested that Six Sigma project can have negative consequences if applied in wrong project.
Makrymichalos et al. (2005) have demonstrated the vital linkage between Six Sigma and statistical thinking. Authors illustrated key characteristics required for statistical thinking & common barriers in implementation of key principles of statistical thinking.. Klefsjo et al. (2006) have commented on both the TQM and Six Sigma. Authors have stressed that TQM has lost some of its charm before quality approaches such as Six Sigma and Lean enterprises. Yeung (2007) has stressed upon the integration of ISO: 9001 and Six Sigma in organizational culture. Pranckevicious et al. (2008) have worked on application of 5S technique in improve phase of DMAIC methodology. Antony (2009) has presented the fundamental and critical difference between TQM & Six Sigma philosophies of quality management. The author has presented the viewpoint of the nine leading practitioners and academicians in countries such as USA, Singapore, India, UK, & Korea. The viewpoint of this type would help a lot to set out a research agenda in the future. Etienne (2009) has presented that Six Sigma can be used to analyze the quality system of company.

Ohno (1998) has categorized the main objectives of Toyota's early management practice as increasing production efficiency through eliminating waste and significant respect for individual. The successful use of Lean manufacturing principles had been published in 'Machine that changed the world" have helped in transmission of lean practise to researchers and organizations. Womack, Jones and Roos (1990) and Duguay, Landry and Pasin, (1997) have found that industries implementing lean practices have a quantum jump in overall efficiency. Womack and Jones, (1996) have recommended adoption of lean management in services. The studies have been conducted to evaluate the implementation of lean principles in service organizations (Abdi, Shavarini & Hoseini, 2006; Atkinson, 2004; Corbett, 2007; May, 2005; Ehrlich, 2006).

Womack et al. (1990) have claimed that lean principles beyond manufacturing engineering were initially found in supply chain management. Sanderlands (1994), Avery (2003), and Hines, (1996) have proposed strategies to develop the network of major suppliers to create a platform for information sharing. The basic goal is that all organizations could develop a closer relationship among themselves and sustainable supply chain management thereby improving quality and reducing cost of services.

2.4 GAPS IDENTIFIED FROM LITERATURE REVIEW

The objective of review was to understand the status of Six Sigma as on yesterday, today and tomorrow. The conclusion is based on the review of various publications. The trend implies that Six Sigma research activities have increased significantly after 2005. The 77% of the total Six Sigma publications are from 2006 to 2011. Six Sigma research has scattered in a wide range across various journals domains and fields has attracted the attention of academics and practitioner. During last decade, Six Sigma has achieved a reasonable maturity and there has been substantial contribution made in Six Sigma framework to extend application from manufacturing to services context. Although the review does on claim to be exhaustive, it does provide reasonable insight in to state of art Six Sigma research. Based on the literature review presented in the chapter, following research gaps were identified in literature review:

- Scarcity of Six Sigma case studies in various domains of services, presenting application of Six Sigma for practical problems.

- There is great potential for research on Six Sigma and its linkages with other initiatives, Six Sigma and Statistical thinking, Six Sigma in Supply Chain Management.
- In service sector education is major areas where Six Sigma is either not visible or is at very nascent stage.
- Applications of Six Sigma projects in Indian states and central government run organizations and administration have also not been explored.

CHAPTER 3

SIX SIGMA AND ITS INTERACTION WITH TQM AND LEAN MANUFACTURING

The chapter presents links of Six Sigma methodology with Lean manufacturing and Total Quality Management (TQM). Comparison of Six Sigma with lean manufacturing as well as TQM is presented. In addition, two topics (i) Six Sigma and Total Quality Management (TQM) and (ii) Six Sigma and Lean manufacturing have been illustrated.

3.1 INTRODUCTION TO TQM

Total Quality management (TQM) is achieving and exceeding customer expectations in order to produce business for future. It is a system approach to quality management. It refers complete commitment to quality in all aspects of the organization. As per ISO 8402, TQM is a management approach of organization, centered on quality based on the participation of all its members and aiming at long term success through customer satisfaction and benefits to the members of organization and society. TQM sustains on four pillars Systems, Top management commitment, systems, teamwork, and SPC. The links to these pillars are culture, communication, commitment, and customer focus. The objectives of TQM include (i) Continuous improvement as a culture of organization which must be way of the life. (ii) Focused, and continuous cost reduction.(iii) Focused and continuous quality improvement. (iv) Customer focus, customer satisfaction and customer delight.(v) Creating a organization where the goal of everyone is aligned towards making the organization the best in its business and to transform the organization in to a world class organization. To achieve the goal customer focus should be ultimate goal. Figure 3.1 illustrate ultimate goal of TQM

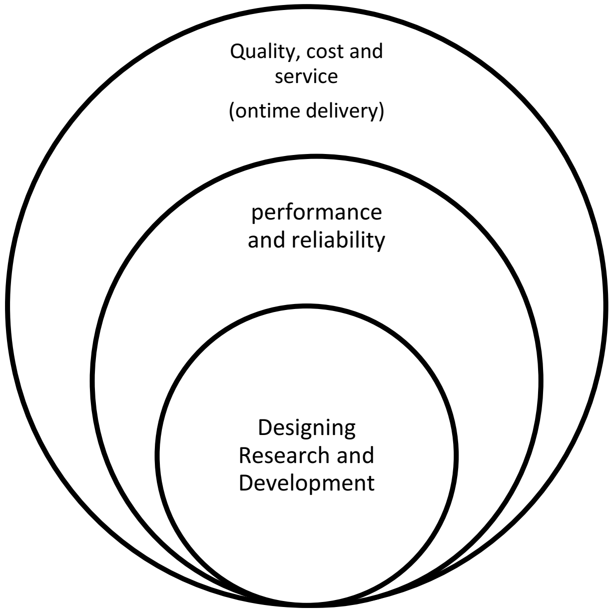

Figure 3.1 Ultimate goal of TQM

3.2 SIX SIGMA AND PITFALLS OF TQM

The Six Sigma has succeeded in organizations where as Total Quality management has failed due many pitfalls as compared to Six Sigma. TQM have been a fuzzy concept and lacks integration of processes to key issues of business strategy and performance. Six Sigma reveals a potential for success that goes beyond the levels of improvement achieved through many TQM efforts. Past quality programs often fell victim to mistakes that hurt both their results and reputation of TQM. Errors that could be repeated by many firms are now taking a crack of Six Sigma. One of the major limitations of TQM is that statistical and non statistical are not linked together and are not integrated with methodology where as in Six Sigma statistical tools given by different authors in different situations are nicely integrated with methodology. In TQM Quality often is a sidebar activity, separated from the key issues of business strategy and performance. Warning signs included a "quality council" made up of delegates rather than of core management team, or a staff quality "department" with no links to bottom line considerations. If TQM has left behind it a positive legacy, is still alive in many organizations, and has provided the impetus for creation for the Six Sigma system, why does it still have a black eye. The way many of the improvement initiatives were introduced and managed, left a bad taste in the mouths of many TQM veterans. Thus, people who have seen and done quality may be the toughest to convince that Six Sigma is really something new and superior to offer. Following provides with a view of some of major TQM errors, as well as hints on how the Six Sigma systems can keep them from derailing your efforts.

3.2.1 Linkages to Business Bottom Lines

Six Sigma organizations are putting process management, measurement, and improvement as a part of daily responsibilities. Six Sigma is focused and disciplined approach that is linked to bottom lines of business. Six Sigma organizations have achieved terrific successes in term of process improvements and financial gains. General Electric spent $500 million on Six Sigma in 1995 & gained more than $ 2 billion from that investment.

In TQM, quality is often a side bar activity separated from the key issues of business strategy and performance. Quality is a department with no links to the business bottom lines. Middle management managers are left out of decision processes and problem solving authority is handed over to the teams on which they have no official control. Despite the term total quality, the efforts are limited to product and manufacturing functions.

3.2.2 Organizational Structure

In Six Sigma projects, adequate efforts and resources are dedicated to educate and train staff members. Responsibilities and authorities are distributed in a structured way using a belt system namely champion, master black belt, black belt, green belts, similar to that used in karate. Depending upon the Six Sigma project management decides that how many black belts and green belts are required for a project. The black belts which are the primary drivers of improvement take three weeks of training with follow up exams and continued learning through conferences and other forums. Green belts take two weeks of training. Six Sigma organizational structure is presented in figure 3.2.

TQM has ineffective training structure and focus much more on teaching tools rather than providing a clear text about how to solve the problem through project and make improvements. The TQM training programs do not appear relevant to people’s daily responsibilities. The success is largely determined by number of people trained and number of teams formed.

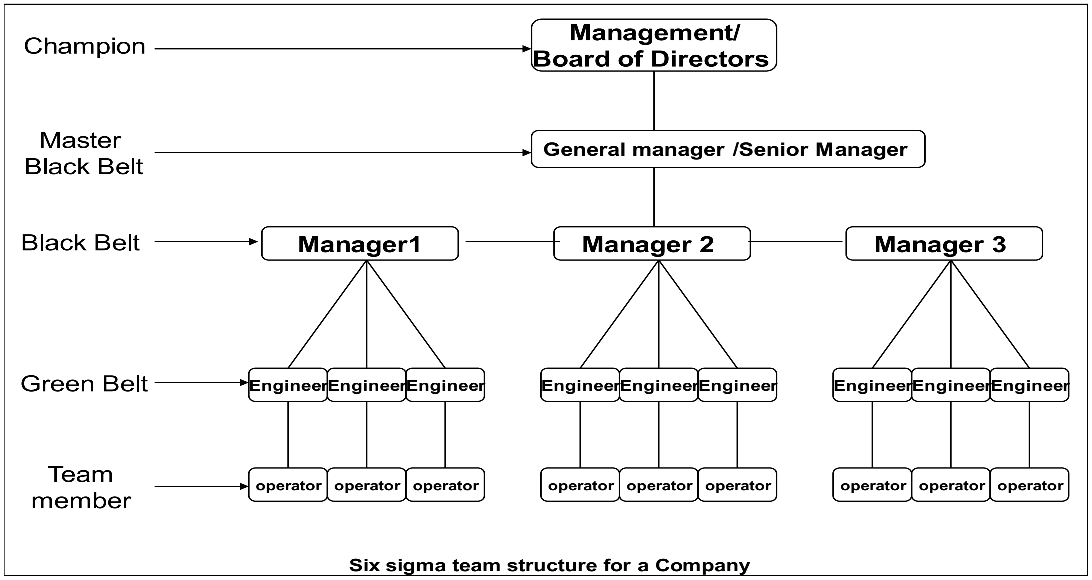

Figure-3.2 Six Sigma team structure for a company

3.2.3 Strategy for Achievement of Goals

A clear goal is the centerpiece of Six Sigma. It is a an extremely challenging to achieve the goal of 3.4 defects per million opportunities (DPMO) or 99.9997% yield but still believable unlike "zero defects". The team members and other people can see the results grow and it can be equated to monetary gains as well. Six Sigma companies have a dynamic system to focus track changes in customer needs and requirements and for measuring performance based on latest and most stringent demands of the customer. While goal may change over the time, the closed loop system will help the organization to adjust and align with the goal.

Many companies implementing TQM have made quality a fuzzy concept by positive surrounding goals like meeting or exceeding customer requirements. The companies have no way to track progress toward that goal. The quality methods taught and available in 1980s and 1990s have done a poor job dealing with reality of diverse and changing customer requirements. Without understanding the dynamic requirements of customers a number of quality success stories have turned into corporate horror stories.

3.2.4 Cross Functional Teams and Activities

Six Sigma places priority n cross functional teams and cross functional process management that eventually breaks down internal barriers. It helps to create smoother, more effective, and efficient company and eliminates disconnections as well as miscommunications. TQM had been always a departmental activity in many organizations and therefore it failed to breakdown internal barriers among departments.

3.2.5 Integration of Quality Tools and Techniques

The business leaders in Six Sigma organizations have recognized that Six Sigma has a bunch of tools including engineering analysis, statistical and non-statistical tools. Six Sigma has diversity of skills, not just technical expertise. Six Sigma have provided out of the box solutions and attitude is to use the tools and approaches that get results with the greatest ease and simplicity. It is believed in Six Sigma organizations that there is nothing wrong in applying advanced techniques to measure and improve processes if we can model and analyze problem in a effective manner.

One of the most frustrating effects of TQM expertise is to insist the individual on doing things in a certain way only. Innovative or out the box solutions are treated as if you are betraying the ideal of quality or teachings of quality gurus. The resources used to define and measure problem were not appropriate and make the problem even worse. Moreover the people trying to apply quality are not able to identify Critical to Quality characteristics and also not working for bottom line results. Table 3.1 compares attributes of Six Sigma and TQM.

Table 3.1 Comparison of attributes of Six Sigma and TQM.

S.No	Attributes	Six Sigma	TQM
1.	Process centric approach	High emphasis	Implicit
2.	Integration of tools	Tools are linked together and integrated with methodology	Lack of integration
3.	Goal	Focused	Fuzzy concept
4.	Organizational structure	strong organizational structure due to presence of champion, master black belt, black belt and green belt	Not so strong as compared to Six Sigma
5.	Training	Effective (also because of Six Sigma organizational structure) as black belts takes three weeks of training; green belts take minimum two weeks of training.	Ineffective as efforts are on teaching tools than on providing a clear context about how to make improvements in work
6.	Cross Functional activities	Priority on cross functional teams and activities	Departmental activity, therefore failed to break internal barriers among departments
7.	Gains	High -Quantum gains	Moderate –Incremental gains
8.	Cost	High	Moderate
9.	Duration	High	Moderate
10.	Easiness	Tough to implement	Easy to implement

3.3 INTRODUCTION TO LEAN MANUFACTURING

Lean manufacturing is a manufacturing philosophy, which focuses on delivering high quality products at the lowest price and at the right time. Lean manufacturing focuses on eliminating waste or non-value added activities.

Lean system emphasizes the prevention of waste. Any extra time, labor or material spent producing a product or service that does not add value to it. Leans manufacturing basic principles are that improving workflow, decreasing setup time, eliminating waste, and conducting preventive maintenance will speed up business processes and return quick financial gains. It is an integrated business approach adopted to eliminate non-value added activities from customer delivery cycle in the operations. This approach enables companies to respond quickly and profitability to changes in customer demands. It is not only restricted to shop floor. Holmes(2007); Juroff(2003); and Demers (2002) have conducted studies on extending Lean methodology from shop floor to pure service scenarios such as finance, accounting, human resource management, sales order processing. Grover,S.,et al.(2004) have emphasized on application of diagraph approach to evaluate various factors affecting total quality management in an industry. Chaneski (2005) has implemented principles of value stream mapping and problem solving in accounting and order processing which resulted in significant reduction in cycle time of these processes. Various studies have found that quality tools such as process mapping can be effectively used in services from start to end through a flow chart with focusing on voice of customer. These studies have successfully resulted in improving quality of services and reducing cycle time by finding the wastes in the processes. Polonsky and Garma (2006); Berkley(1996); Bitner et al. (20007); Flieb and Kleinaltenkamp (2004); Baum(1990); Coleman, (1989). Sprigg and Jackson(2006) have worked on application of Lean principles for call center operations management. The authors have emphasized that application of lean management in call centers is not encouraging due to low staff morale. Grover, S.,et al. (2005) have emphasized significance of human resource index in TQM environment. Maleyeff (2006) have conducted extensive studies to identify the similarities in the processes for manufacturing and service scenarios. Wallace (2006) has worked on improving operational efficiency of administrative and office functions of Boeing Corporation using lean principles. Actually lean is a way of thinking , an attitude .the technique of lean Manufacturing can be applied to every situation in company to find out what customer wants, eliminating waste from processes and making flow continuously according to customer pull. The four major components of lean Manufacturing are JIT, Flexible Manufacturing Systems, and Kaizen and supply chain integration. Following is a ten-step process to achieve lean production. These ten steps were taken from hundreds of successful functional manufacturing systems conversions to lean manufacturing .The steps are numbered and the order of implementation should exactly follow the step order. The ten steps and a brief description are given below:

Step 1- Reengineering the Manufacturing System: Restructure/reorganize fabrication and assembly systems into cells that produce families of parts/products. The cells should have one-piece parts movement within cells and small-lot movement between cells, achieved by creating a linked-cell system.

Step 2- Setup Reduction and Elimination: Setup time for a cell should be less than manual time, or the time a worker needs to load, unload, inspect, debur etc.

Step 3- Integrate Quality Control into Manufacturing: The operation should be "Make-one, check-one, and move-on-one" type; and the quality of products output from the system should be 100%.

Step 4- Integrate Preventive Maintenance into Manufacturing: There should be no equipment failure and the workers should be trained to perform routine low-level process maintenance.

Step 5- Level, Balance, Sequence and Synchronize: Fluctuations in final assembly should be eliminated, output from cells should be equal to the necessary demand for parts downstream and the cycle time should be equal to takt time for final assembly.

Step 6- Integrate Production Control into Manufacturing: Cells respond to demand by delivering parts and products only as they are needed, or just in time.

Step 7- Reduce Work-In-Process (WIP): Minimize the necessary WIP between cells, and parts are handled one at a time within cells.

Step 8: Integrate Suppliers: Reduce the number of suppliers and cultivate a single source for each purchased component or subassembly.

Step 9- Automation: Inspection should become part of the production process (100% inspection) and there should be no overproduction.

Step 10- Computer-Integrated Manufacturing: Production system to be as free of waste as the manufacturing system. These ten steps are used as the default methodology for lean implementation in this research.

3.4 SIX SIGMA IN OPPOSITION TO LEAN MANUFACTURING

Six Sigma does not directly address process speed and so the lack of improvement in lead-time in companies applying Six Sigma methods alone is understandable. In a similar manner, those companies engaged in Lean methodology alone show-limited improvements across the organization due to the absence of six-sigma cultural infrastructure. Six Sigma projects take months to finish, and they produce elite black belts who are disconnected from the shop floor, while, lean boost productivity but does not provide any tool to fix unseen quality issue. Lean brings action and intuition, and quickly attacks low hanging fruit with kaizen events, while Six Sigma uses statistical tools to uncover root causes and provide metrics as mile markers. A pure six-sigma approach lacks three desirable lean Characteristics (i) No direct focus on improving the speed of a process. (ii) No direct attention to reductions in the amount of inventory investment. (iii) No quick financial gains due to the time required learning and applying its methods and tools for data collection and analysis. The shortcomings of pure lean improvement efforts include (i) Processes are not brought under statistical control.(ii) There is no focus on evaluating variations in measurement systems used for decisions. (iii) No process improvement practices link quality and advanced mathematical tools to diagnose process problems that remain once the obvious waste has been removed. Table 3.2 compares attributes of Six Sigma and Lean manufacturing.

Table 3.2 Comparison of attributes of Six Sigma and Lean Manufacturing

S.No	Issues/problems/objectives	Six Sigma	Lean Manufacturing
1.	Process control planning and monitoring	Yes	No
2	Focuses on reducing variation and achieve uniform process outputs	Yes	No
3.	Focuses heavily on the application of statistical tools and techniques	Yes	No
4.	Employs a structured, rigorous and well planned problem solving methodology	Yes	No
5.	Focuses on bringing the process in control	Yes	No
6.	Focuses on improving process speed or to reduce the invested capital	No	Yes
7.	Focuses on reducing the investment in inventory management	No	Yes
8.	Attacks waste due to waiting, over processing, motion, over production, etc.	No	Yes
9.	Attack work in process inventory	No	Yes
10.	Focuses on good house keeping	No	Yes
11.	Creates standard worksheets	No	Yes

3.5 SYNERGIC EFFECTS OF SIX SIGMA AND LEAN MANUFACTURING

Lean Sigma is a methodology that maximizes shareholder value by achieving the fastest rate of improvement in customer satisfaction, cost, quality, process speed and invested capital. The integration of lean manufacturing and Six Sigma is required because lean cannot bring the process under control and Six Sigma alone cannot dramatically improve process speed or reduce invested capital. Some authors have described lean sigma as ‘doing quality quickly’ which may be counterintuitive. At first one may presume that faster we go more mistakes we make but in lean Six Sigma, the process speed is not achieved by speeding up the worker or machine but by reducing the unproductive time in process and eliminating the no value added process. The principle of lean Six Sigma is that activities that cause the customer critical-to-quality issues and create the longest time delays in any process offer the greatest opportunity for improvement in cost, quality, capital, and lead time. In any lean enterprise 'Team' is its major focal point. Keeping this in mind team formation is also emphasized throughout the methodology. The starting point in any step after the formation of a team is to identify the Critical to Quality (CTQ) characteristic, and the rest of the methodology centers around achieving this CTQ. Lean techniques prove to be an excellent tool for eliminating process noise, while Six Sigma and its highly ordered methods and statistical measures the DMAIC sequence of designing/measuring, analyzing, improving, and controlling and provide foresight into potential problems and solutions to chronic difficulties. Utilizing Six Sigma solely, however, fails to maximize potentials of an organization.

3.6 CONCLUDING REMARKS

While Six Sigma is definitely succeeding in creating some impressive results and culture change in some renowned organizations, TQM seems less visible in many businesses than it was in early 1990's.one of the problems that plagued many TQM initiatives was the pre-eminence placed on quality at the expense of other aspects of business. Some organizations had a bad taste of TQM in terms of financial loss as well as quality loss. The gap between management systems designed to measure customer satisfaction and those to measure profitability led to failures in TQM practices. However, TQM may not be totally blamed for it as it is philosophical and we have to understand the myths associated with TQM. Six Sigma has made the best use of statistical tools to solve a problem. It is the same dish with somewhat change in recipe and the manner of presentation. It is believed that there is nothing new Six Sigma, then also it is unique in its approach and deployment. Six Sigma is a strategic business improvement approach that increases customer satisfaction and an organization's financial health. It has been claimed that eight characteristics that account for Six Sigma's increasing bottom line success and popularity with executives are; Senior management commitment and leadership, disciplined DMAIC approach, rapid project completion, focus on voice of customer and process, clearly defined measures of success infrastructure roles for Six Sigma practitioners and leadership, bottom line results expected and delivered, and sound statistical approach to improvement. Other quality initiatives including TQM have actually achieved a few of these characteristics but Six Sigma have been successful in achieving all these characteristics simultaneously. Six Sigma is regarded as vigorous rebirth of quality ideas and methods. Six Sigma has scientific, foused and disciplined approach with well structured organizational structure and training. However some of the mistakes of yesterday's TQM efforts certainly might be repeated in Six Sigma initiative if we are not careful. Six Sigma and will be prevailing in industries as long as Six Sigma projects yield measurable or quantifiable bottom line results in financial or monetary terms.

To achieve quantum gains rather than incremental improvements in any process we should see that whether DMAIC approach should be followed or any other methodology like DFSS should be implemented. We should also establish criteria for minimum process improvement speed and direct attention should be given to waste due to waiting, over processing, motion etc. Moreover focus should be there on attacking the work in process inventory. True and quantum gains can be achieved by customizing the problem and paying attention to each and every variable which is responsible for manufacturing the desired product at minimum possible cost. Pure Six Sigma and lean manufacturing lack many desirable characteristics. The integration of Six Sigma, lean manufacturing and supply chain management along with innovative management techniques will be ideal solution for achieving maximum productivity.

CHAPTER -4

SIX SIGMA TOOLS AND THEIR APPLICATIONS IN SERVICE ORGANIZATIONS

Six Sigma improves any existing process by constantly reviewing & re-tuning the process. To achieve it, Six Sigma uses a methodology DMAIC and various quality tools. In this chapter, various Six Sigma tools deployed during various stages of Six Sigma methodology along with their applications are demonstrated.

4.1 INTRODUCTION

Six Sigma is a long term forward thinking initiative designed to change the way of doing business of an organization. It is a strategy for achieving quantum financial gains to the bottom line of the organization. To achieve this objective, various tools are used at various stages of a Six Sigma DMAIC methodology. The first and foremost objective of Six Sigma project is to identify and define Critical to Quality Characteristics (CTQs) of a project. In this phase (define) tools including Supplier - Input - Process - Output – Customer (SIPOC) model, 'as is' process mapping, pareto analysis are used. In measurement phase performance standard of selected CTQs are defined and validation of measurement system is done. Cause and effect diagram, Gage repeatability and reproducibility analysis (Gage R & R), capability analysis are some of the significant tools used in measurement phase. During Analysis phase process capability is established, performance objectives are defined and sources of variation are identified. Some of the significant tools used in this phase include process analysis, graphical analysis, hypothesis testing, and regression analysis. In improvement phase potential causes are screened, relationship among variables is discovered and operating tolerance are established. Principal tools used in this phase include experimental design, hypothesis testing and 'should be' process map. In control phase, process capability is determined and process controls are implemented so that process should not degrade over time and stays in control. The some of the significant tools during control phase include process control charts, mistake proofing, and failure modes and effect analysis. Six Sigma was originated at Motorola and it has revolutionized the scope and implementation of quality tool such as statistical process control, gage repeatability and reproducibility analysis, hypothesis testing, failure mode effect analysis (Handerson and Evans, 2000). Following are the some of the significant tools used during various phases of Six Sigma DMAIC methodology.

4.2 PROCESS CONTROL CHARTS

Basic philosophy of Six Sigma methodology is to reduce variation in key product quality characteristics around specified target value. In that way, process control chart is a major constituent of a Six Sigma project as it provides a statistical test to determine whether average variation with in subgroup is consistent with variation between subgroups.

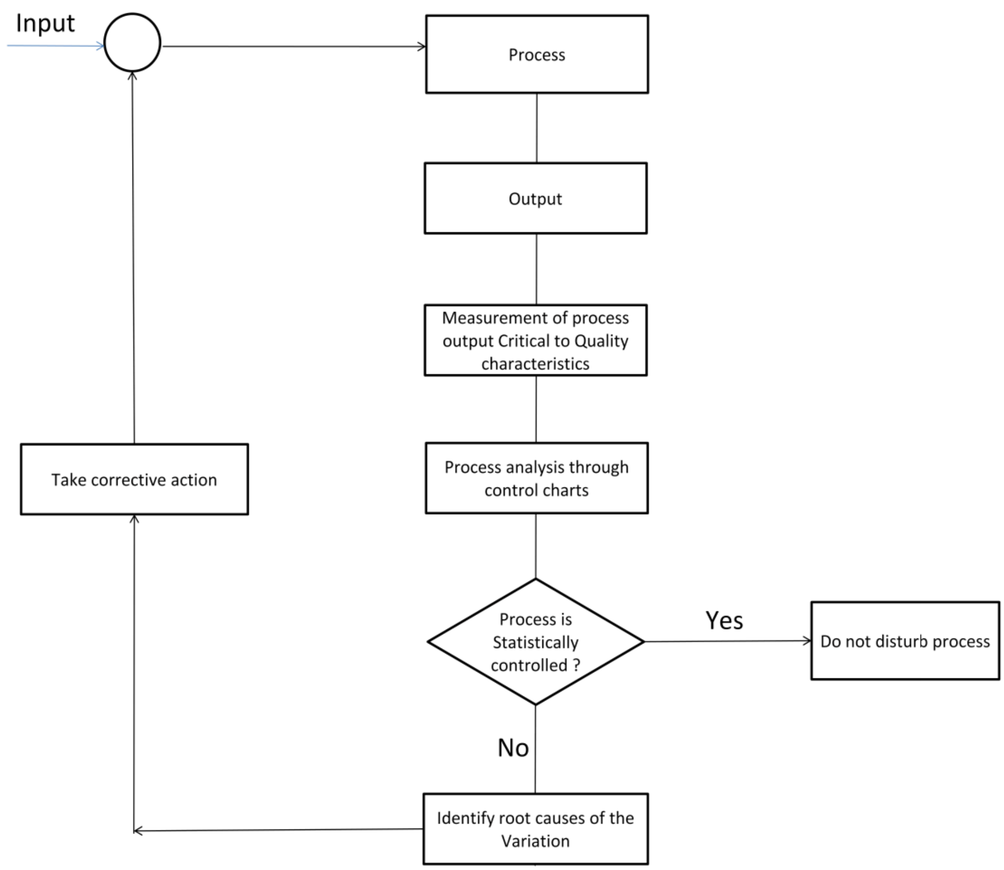

Figure 4.1 Control chart as feedback system in a process.

In other words, control chart must answer the question whether the variation among the subgroup is consistent with averaged pattern of variation with in subgroups. If yes then, all the points are within statistical control limit and no special or assignable cause is present. If no then, one or more points are outside the control limits and assignable causes are present. Figure 4.1 illustrate how control chart serve as feedback system in a process. If process is out of statistical control, it indicates that corrective action should be taken to bring back process in statistical control.

4.2.1 Rational Sub Grouping of Data

Rational sub grouping plays a important role in use of control charts (X bar and R charts). The subgroups are chosen so that variation within each subgroup is as small as feasible and there are utmost chances of process average to shift between subgroups. Incorrect sub grouping leads to useless control charts that do not detect the sources of variation in a process. The following topic demonstrates the importance of rational sub grouping in process control charts. Three different methods for sub grouping of the data have been proposed to plot X bar and R chart for Average Handling Time (AHT) taken by service executives for customer complaints and query processes.

4.2.2 Application of Process Control Chart in Customer Complaints and Queries Processes.

Most variable control charts compare with in subgroup variation to between subgroup variation for drawing the inference from a control chart. Therefore it is of paramount significant to understand whether sources of variation are within subgroup or between subgroup. In addition, it is equally important to analyze basis for subgroup formation. Incorrect sub grouping of data leads to statistical process control (SPC) charts which may be aesthetically appealing but not effective at identifying out of control conditions. According to W A Shewart, ‘an engineer who is successful in dividing the data in rational subgroups based upon rational hypothesis is inherently better off in long run than the one who is not thus successful’. In present case study, an organization was doing a poor job of responding to customer complaints and queries. The target Average Handling Time (A.H.T.) of four services was 15 minutes. There were lot of complaints from customers regarding quality of services and company was losing substantial amount of revenue because of customer dissatisfaction. The process was being monitored regularly by using control charts. But no signals regarding presence of special causes were evident from analysis of control charts. All the points on Control charts were showing a random pattern and process appeared to be stable and with in control limits. Four service executives were doing the job of dealing with customer queries and complaint processes. Each one of these executives (operators) had been assigned four types of customer services namely customer relationship form related complaints (A), change in scheme of services related complaints (B),information of new services related queries (C) invoice related complaints (D). The data collection pattern of Average Handling Time (A.H.T.) of all the operators for one week is shown in table 4.1 and table 4.2. After studying the process and observing the data it was found that based upon the sources of variation, three sub grouping schemes are possible in this case (i) operator to operator variation, (ii) service to service variation and (iii) time to time variation.

Operator to Operator Variation

In this sub grouping scheme, operator to operator variation is used as basis of comparison. This sub grouping scheme yields 80 sub groups of subgroup size equal to four. Operator to operator variation is captured by different rows of array presented in Table 4.1. For X bar chart in figure 4.2, grand average X double bar of A.H.T is 15.27 minutes with Lower Control Limit (LCL) being 8.01 minutes and Upper Control Limit (UCL) being 22.53 minutes. For range chart, average range is 9.96 minutes with Lower Control Limit (LCL) being zero and Upper Control Limit (UCL) being 22.73.

Table 4. 1 Weekly average handling time in minutes of four operators for service processes A, B, C, D. Data sub grouped on basis of operator to operator variation

Service Processes - A, B, C, D																									
Day	Operator	10:00 A.M.				X bar	R	12:00 P.M.				X bar	R	2:00 P.M.				X bar	R	4:00 P.M.				X bar	R
		A	B	C	D			A	B	C	D			A	B	C	D			A	B	C	D		
Mon	Ajay	9	10	9	20	12	11	9	12	12	19	13	10	10	12	11	22	13.75	12	11	13	9	19	13	10
	Biswas	12	16	12	22	15.5	10	11	12	10	21	13.5	11	16	15	20	19	17.5	5	10	9	10	22	13	13
	Chirag	17	18	18	24	19.3	7	15	17	17	23	18	8	16	16	20	25	19.25	9	14	15	15	22	17	8
	Deepak	10	11	12	23	14	13	12	15	12	24	15.75	12	10	11	12	23	14	13	12	11	12	23	15	12
Tue	Ajay	13	12	8	21	13.5	13	14	9	12	19	13.5	10	9	11	9	20	12.25	11	9	12	13	22	14	13
	Biswas	13	15	13	19	15	6	12	11	11	23	14.25	12	14	13	12	22	15.25	10	17	16	19	19	18	3
	Chirag	17	18	19	20	18.5	3	15	15	16	23	17.25	8	17	18	16	24	18.75	8	16	17	19	25	19	9
	Deepak	11	12	13	23	14.8	12	8	12	10	22	13	14	10	12	12	23	14.25	13	12	11	10	23	14	13
Wed	Ajay	11	12	10	19	13	9	14	13	13	19	14.75	6	8	10	11	20	12.25	12	10	12	9	23	14	14
	Biswas	11	14	9	22	14	13	9	10	12	22	13.25	13	12	15	11	22	15	11	16	16	20	19	18	4
	Chirag	16	17	18	22	18.3	6	16	15	15	23	17.25	8	17	18	17	23	18.75	6	16	16	20	24	19	8
	Deepak	12	14	12	24	15.5	12	12	12	10	23	14.25	13	10	12	12	23	14.25	13	10	12	11	22	14	12
Thu	Ajay	10	9	13	18	12.5	9	12	11	9	21	13.25	12	12	11	14	19	14	8	11	12	10	19	13	9
	Biswas	13	12	12	22	14.8	10	13	15	13	20	15.25	7	13	13	11	23	15	12	11	14	9	22	14	13
	Chirag	15	16	15	23	17.3	8	16	18	19	19	18	3	14	14	15	24	16.75	10	16	17	18	22	18	6
	Deepak	12	14	11	23	15	12	11	12	12	23	14.5	12	10	12	13	23	14.5	13	12	14	12	24	16	12
Fri	Ajay	9	12	13	24	14.5	15	12	10	9	20	12.75	11	11	12	13	19	13.75	8	14	12	12	19	14	7
	Biswas	16	16	20	20	18	4	12	15	12	23	15.5	11	11	13	9	21	13.5	12	11	11	9	23	14	14
	Chirag	17	16	20	24	19.3	8	18	17	17	24	19	7	15	17	16	24	18	9	15	15	17	22	17	7
	Deepak	11	10	12	23	14	13	11	10	12	22	13.75	12	12	16	12	23	15.75	11	13	13	13	23	16	10

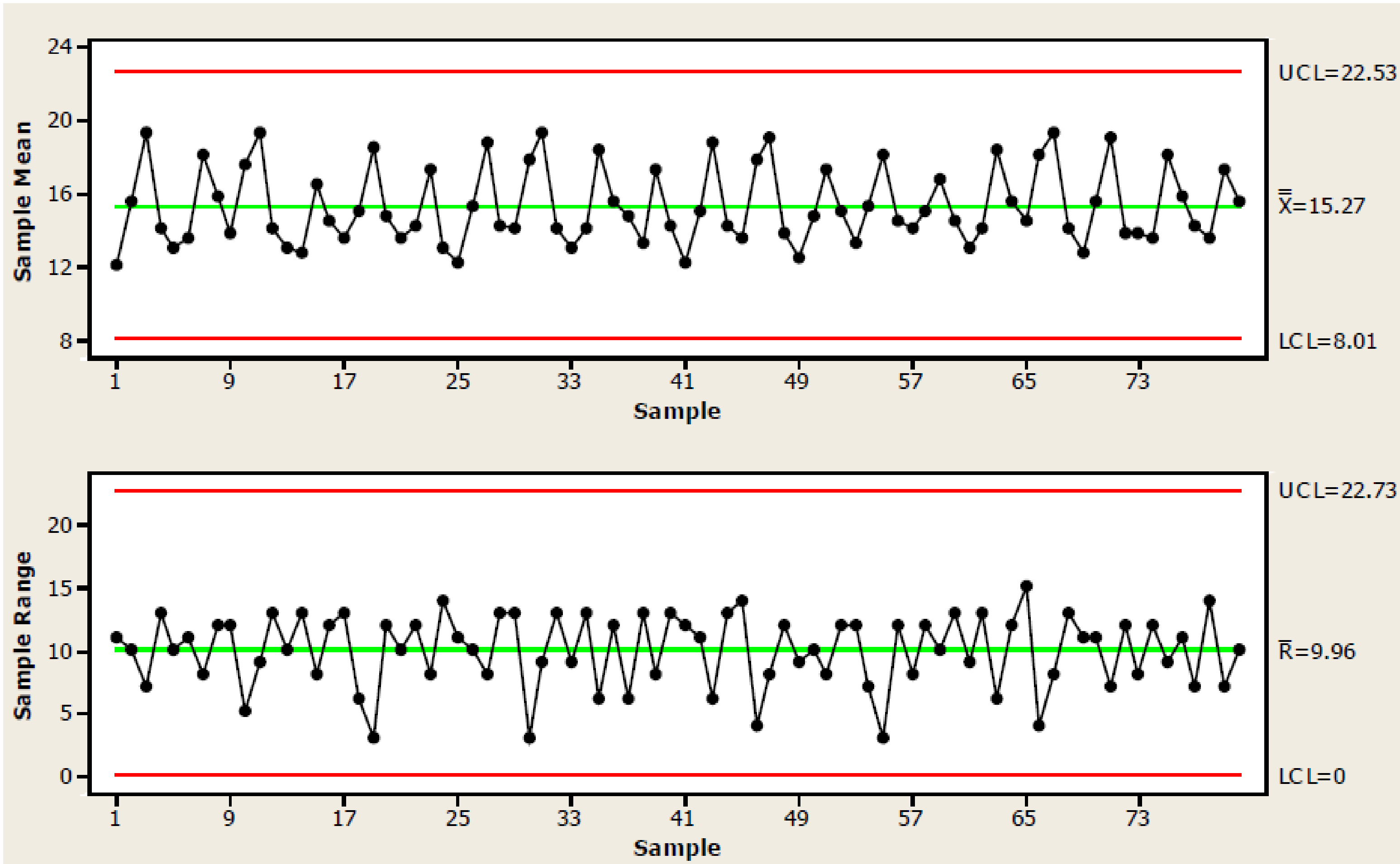

Figure 4.2 X bar and R chart for data sub grouped on basis of operator to operator variation.

Service to Service Variation

In this sub grouping scheme, service to service variation is used as the basis for comparison. This sub grouping scheme also yields 80 sub groups of subgroup size equal to four. Service to service variation is captured by different columns of array presented in Table 4.2. For X bar chart in figure 4.3, grand average X double bar is equal to 15.27 minutes with Lower Control Limit (LCL) being 10.90 minutes and Upper Control Limit (UCL) being 19.64 minutes. For range chart average range is 6.0 minutes with Lower Control Limit (LCL) being zero and Upper Control Limit (UCL) being 13.69.

Time to Time Variation

The third method of sub grouping would be to draw the sample of Average Handling Time (AHT) from the combined output of all the four operators. In this sub grouping scheme, sub group is mixed one and consists of one or more operator or services. It no longer differentiates that a specific operator has taken time to provide a particular service. This method gives us an insight into the AHT from time to time variation i.e. AHT of all the operators say before and after lunch time.

Table 4.2 Weekly average handling time in minutes of four operators for service processes A, B, C and D. Data sub grouped on basis of service to service variation

Service Processes - A, B, C, D																	
Day	Operator	10:00 A.M.				12:00 P.M.				2:00 P.M.				4:00 P.M.			
		A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Monday	Ajay	9	10	9	20	9	12	12	19	10	12	11	22	11	13	9	19
	Biswas	12	16	12	22	11	12	10	21	16	15	20	19	10	9	10	22
	Chirag	17	18	18	24	15	17	17	23	16	16	20	25	14	15	15	22
	Deepak	10	11	12	23	12	15	12	24	10	11	12	23	12	11	12	23
	X bar	12	13.8	12.8	22.3	11.8	14	12.8	21.8	13	13.5	15.8	22.3	11.8	12	11.5	21.5
	R	8	8	9	4	6	5	7	5	6	5	9	6	4	6	6	4
Tuesday	Ajay	13	12	8	21	14	9	12	19	9	11	9	20	9	12	13	22
	Biswas	13	15	13	19	12	11	11	23	14	13	12	22	17	16	19	19
	Chirag	17	18	19	20	15	15	16	23	17	18	16	24	16	17	19	25
	Deepak	11	12	13	23	8	12	10	22	10	12	12	23	12	11	10	23
	X bar	13.5	14.3	13.3	20.8	12.3	11.8	12.3	21.8	12.5	13.5	12.3	22.3	13.5	14	15.3	22.3
	R	6	6	11	4	7	6	6	4	8	7	7	4	8	6	9	6
Wednesday	Ajay	11	12	10	19	14	13	13	19	8	10	11	20	10	12	9	23
	Biswas	11	14	9	22	9	10	12	22	12	15	11	22	16	16	20	19
	chirag	16	17	18	22	16	15	15	23	17	18	17	23	16	16	20	24
	Deepak	12	14	12	24	12	12	10	23	10	12	12	23	10	12	11	22
	X bar	12.5	14.3	12.3	21.8	12.8	12.5	12.5	21.8	11.8	13.8	12.8	22	13	14	15	22
	R	16	17	18	24	16	15	15	23	17	18	17	23	16	16	20	24
Thursday	Ajay	10	9	13	18	12	11	9	21	12	11	14	19	11	12	10	19
	Biswas	13	12	12	22	13	15	13	20	13	13	11	23	11	14	9	22
	Chirag	15	16	15	23	16	18	19	19	14	14	15	24	16	17	18	22
	Deepak	12	14	11	23	11	12	12	23	10	12	13	23	12	14	12	24
	X bar	12.5	12.8	12.8	21.5	13	14	13.3	20.8	12.3	12.5	13.3	22.3	12.5	14.3	12.3	21.8
	R	5	7	4	5	5	7	10	4	4	3	4	5	5	5	9	5
Friday	Ajay	9	12	13	24	12	10	9	20	11	12	13	19	14	12	12	19
	Biswas	16	16	20	20	12	15	12	23	11	13	9	21	11	11	9	23
	Chirag	17	16	20	24	18	17	17	24	15	17	16	24	15	15	17	22
	Deepak	11	10	12	23	11	10	12	22	12	16	12	23	13	13	13	23
	X bar	13.3	13.5	16.3	22.8	13.3	13	12.5	22.3	12.3	14.5	12.5	21.8	13.3	12.8	12.8	21.8
	R	8	6	8	4	7	7	8	4	4	5	7	5	4	4	8	4

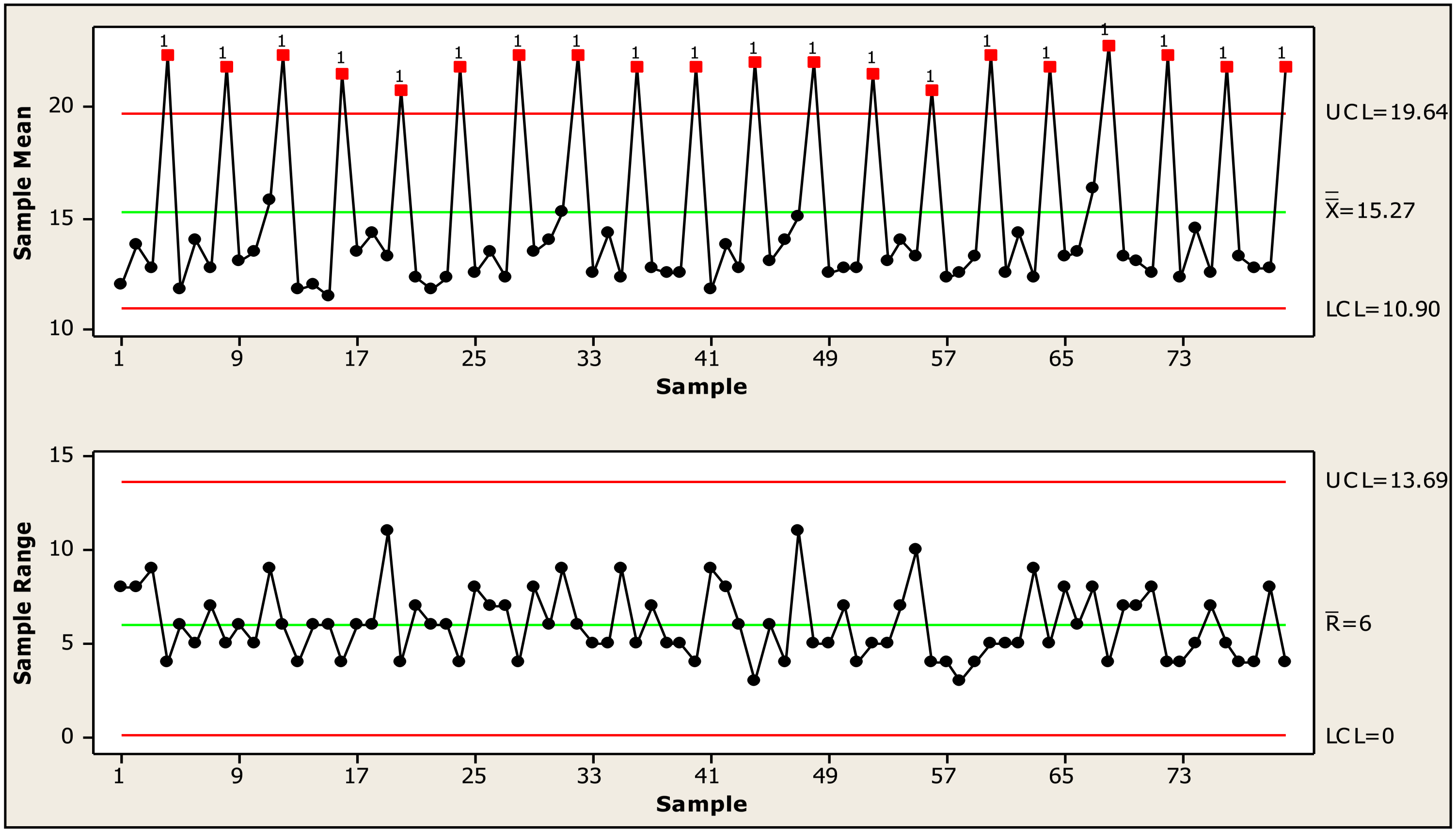

Figure 4.3 X bar and R chart for data sub grouped on basis of service to service variation.

4.2.3 Outcomes of Application of Process Control Charts

The control charts for aforementioned sub grouping schemes are very different although they are derived from same data. The method of sub grouping the data used by quality executive was on the basis of operator to operator variation as presented in figure 4.2. The X bar chart for this method of sub grouping does not reveal service time variation because observations from each type of service are averaged to obtain average of a subgroup. The control limits of both X bar and R chart are too wide and no point is out of control limit. AHT of all service processes shows a random pattern and variation with in subgroup appears to be in control which is certainly not true. After studying and analyzing aforementioned sub grouping schemes, it was recommended to sub group the data on the basis of service to service variation. The X bar chart for data sub grouped on the basis of service to service time variation shows a pattern. All the points corresponding to service process 'D' in figure 4.3 were noticeably higher and above higher control limit, so service process 'D' was certainly out of statistical control. It clearly indicates assignable cause(s) were present. To identify assignable cause(s), brain storming session with service executives were carried out. On further investigations, it was found that routine steps as well process map for the Service process 'D' was not clear because the service process has been recently initiated by the Company. It was recommended to establish Standard Operating Procedures and to establish crystal clear process map so that process 'D' could be carried out smoothly and assignable sources of variation could be eliminated.

4.3 GAGE REPEATABILITY & REPRODUCIBLITY ANALYSIS (Gage R& R)

One of the biggest challenges in a service or manufacturing organization is to reduce process variation. To reduce process variation, the variation caused due to the measurement system must be identified and separated from actual process variation. Neither quality improvement nor quality control can be done without reliable measurements. Two significant aspects of the quality of measurement are accuracy and precision. Accuracy relates to bias of measurement and precision relates to spread of a measurement process. Gage R&R is the evaluation of measurement system variation by determining whether measurement taken with a gage is repeatable (related to gage variation) and reproducible (related to appraiser variation). According to Automotive Industry Action Group (AIAG) guidelines, measurement system is acceptable if it has less than 10% of total process variation. Measurement variation more than 10 % and less than 30% is acceptable depending upon the criticality of the application and should be approved by customer. Measurement system variation more than 30 % is not acceptable. Gage R&R is an estimate of the combined variation of repeatability and reproducibility for a measurement system. The Gage R&R variance is equal to the sum of within-system and between-system variances. Attribute measurement systems are the class of measurement systems where the measurement value is one of a finite number of categories. Jorge & Brose (2013) have explained Gage R&R with a hypothetical case. The authors have stressed that both instrument resolution and part selection are important for conducting Gage R&R analysis. The authors have also listed out preparation steps for conducting Gage R&R analysis as per Automotive Industry Action Group (AIAG). Erdmann & Ronald (2009) have stressed the significance of the repeatability and reproducibility analysis in health care. The authors have conducted a case study in a hospital with a ear thermometer for ten patients, three nurses and two trials. In addition, authors have developed a model for statistical analysis. Sweeny (2006) has analyzed one dimensional and two dimensional Gage R&R for measuring imbalance in a rigid rotor. The results are interpreted in terms of capability. The authors have claimed that treating measurement data for aforementioned case as one dimensional may underestimate the variation that is occurring in 2D measurement process. Sweet et al. (2005) have presented an improved procedure for estimating gage bias and repeatability of an attribute Gage R&R analysis "Analytical Method". In addition, authors have developed a probabilistic model for analytical method. De Mast & Albert (2005) have presented the solution of fundamental problem of Gage R&R for destructive measurements. The authors have claimed that experimenter can obtain a good approximation of measurement variation if he can exploit certain forms of homogeneity. Majeske & Andrews (2002) have evaluated measurement system and manufacturing process using three quality measures (i)P/T ratio i.e. precision to tolerance ratio (ii) Cp i.e. process capability and (iii) correlation in repeat measurements. The authors have further recommended that manufacturers should consider all aforementioned quality measures rather than dimensional data for communication with suppliers. Floyd & Carl (1995) have stressed that significance of measurement is underestimated in the application of statistical process control. In addition, authors have stressed the significance of calibrating the instrument. The authors have conducted three case studies & investigated that reasons of process variation could be untrained operators and inappropriate gages used.

4.3.1 Application of Attribute Gage R&R Analysis in a Service Process

Gage repeatability and reproducibility analysis is one of the most significant tools used in measurement phase of Six Sigma Define-Measure-Analyze-Improve-Control (DMAIC) methodology. Adequate measurement system results in accurate estimation of process capability to meet customer requirements. The following topic presents a case study of attribute gage repeatability and reproducibility (Gage R&R) analysis to improve quality of customer complaints and queries process. The authors have analyzed Gage R&R data and provided recommendations based on case study. Authors have further emphasized that gage R and R, is a simple yet effective tool that may result a substantial amount of savings to a company.

In present case study, a service organization was doing a poor job of responding to customer complaints and queries The customers had lot of dissatisfaction and complaints regarding quality of service provided. The company had sufficient numbers of customer support executives (CSEs) to handle customer queries and complaints. In addition, a team of trainers and quality managers (QMs) were available to train evaluate, and certify customer support executives. As company was losing substantial amount of revenue because of customer complaints, top management decided to hire external experts to look in to the matter. The experts had a brainstorming session with CSEs and QMs and drawn a high level process map of the CSE selection process represented in figure 4.4. The experts found that either there could be problem in the process of customer support executives interaction with customers or training and evaluation procedure of customer support executives.

The external experts decided to measure the quality of evaluation system by conducting attribute Gage R&R analysis for quality inspectors (appraisers) who generally evaluate and certify customer support executives. For conducing Attribute Gage R&R analysis in the company a meeting of senior QMs and quality inspectors was called and Gage R&R concept was introduced to them. The appraisers for the study were selected and it was explained that purpose of study is to evaluate measurement system and not the people. During the study, 30 pre recorded events including procedure for evaluating and certifying customer support executives were selected. Each recorded event was numbered and evaluated by experts. The 18 out of 30 recorded events were declared accepted (A) by the expert and 12 events were declared rejected (R) by experts. In a simulated environment these events were passed on a first selected appraiser in a randomized sequence and his responses were recorded.

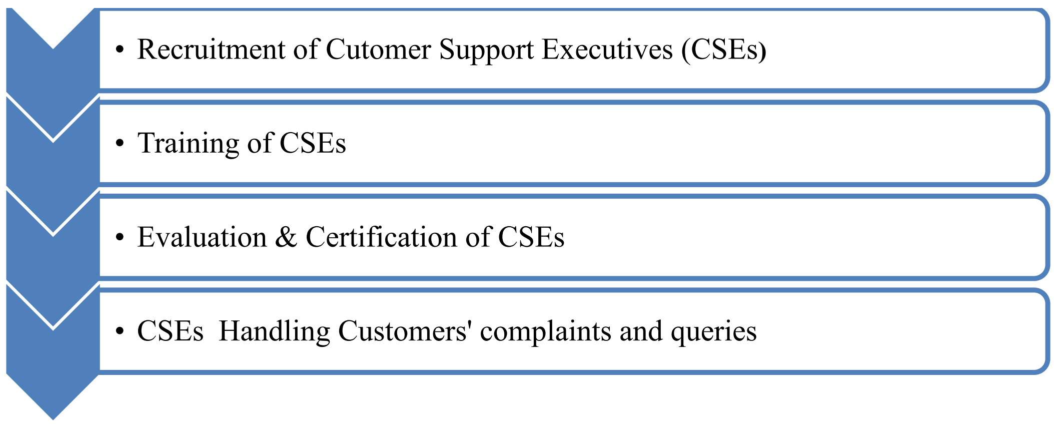

Figure 4.4 Procedure for selecting customer support executives.

The same sets of 30 events were played back again and passed on to same appraiser in randomised manner and responses were again recorded to estimate the repeatability of the measurement system. The same study was replicated to another appraiser to estimate reproducibility of the system. The measurement data is presented in table 4.2. The Randomised trial run numbers for both the appraisers are shown in Table 4.3. The Assessment agreement of appraisers is presented in table 4.5 and 4.6. In above study, as the item being measured is event and it cannot happen the same way twice. For this basic reason it was essential to conduct Gage R&R study in simulated environment. It is not possible to conduct Gage R&R study without recording such events.

Table 4.3 Attribute Gage R&R data collection sheet

Sample number	Standard	Appraiser one		Appraiser two	
		First trial	Second trial	First trial	Second trial
1	R	R	R	A	A
2	A	A	A	R	R
3	A	R	R	A	A
4	R	R	R	A	A
5	A	A	A	A	R
6	A	A	A	A	A
7	R	A	A	A	A
8	A	R	R	A	A
9	R	A	A	A	R
10	A	R	R	A	A
11	R	A	R	R	R
12	A	A	A	A	A
13	A	A	A	A	A
14	R	A	A	A	A
15	R	A	A	A	A
16	A	A	A	A	A
17	A	A	A	A	A
18	R	R	R	A	A
19	R	A	R	A	A
20	A	A	A	A	A
21	A	A	A	A	A
22	R	R	R	R	R
23	A	A	R	R	R
24	R	R	R	A	A
25	A	A	R	A	A
26	A	A	A	A	A
27	A	A	R	A	A
28	R	A	A	A	A
29	A	A	A	R	R
30	A	A	A	A	R

Table 4.4 Randomization order for passing on the recorded events to appraisers

Recorded event number	Appraiser one		Appraiser two	
	First trial run number	Second trial run number	First trial run number	Second trial run number
1	8	6	17	3
2	18	16	26	9
3	10	8	10	18
4	23	21	4	10
5	17	25	28	19
6	29	18	12	11
7	5	24	3	5
8	14	7	14	2
9	6	2	1	28
10	15	10	23	25
11	20	9	8	20
12	26	2	2	29
13	9	11	29	13
14	4	28	25	7
15	12	20	22	1
16	7	27	21	12
17	1	3	27	22
18	28	12	10	14
19	24	4	5	27
20	21	13	13	21
21	11	14	30	24
22	2	23	6	30
23	13	7	15	13
24	30	1	7	8
25	22	25	16	16
26	16	5	9	15
27	25	1	19	6
28	9	26	11	17
29	3	22	24	4
30	27	19	18	26

Table 4.5 Assessment agreement of each appraiser

Attribute agreement analysis of each appraiser	Appraiser 1			Appraiser 2		
	Inspected	Matching	%	Inspected	Matching	%
Assessment agreement with in appraiser (repeatability)	30	25	83	30	27	90
Assessment agreement of each appraiser with standard (accuracy)	30	17	56	30	15	50
Type I error committed by appraisers	3 out of 30			2 out of 30		
Type II error committed by appraisers	5 out of 30			9 out of 30		

Table 4.6 Assessment agreement of both appraisers

Attribute agreement analysis of both appraisers	Both Appraisers		
	Inspected	Matching	%
Assessment agreement between appraisers (repeatability and reproducibility)	30	13	43
Assessment agreement of both appraisers with standard (overall repeatability, reproducibility and accuracy)	30	9	30

4.3.2 Outcomes of Application of Gage R&R

The data analysis indicates that both the appraisers have reasonably good repeatability. Appraiser one agreed with himself in 83 % of the cases and with standard 56 % of the cases. Appraiser two agreed with his own results 90 % of the time and with standard 50% of the time. Assessment agreement between appraises and assessment agreement of both the appraisers with standard is very poor. The percentage of time both appraisers agreed with each standard was 30%. In 43% of the cases, both appraisers agreed with each other on both trials but not necessarily with standard. Further analysis of results indicate that appraiser one is more consistent than appraiser two regarding assessment with standard. Appraiser two has a bias to accept the unacceptable events. The Gage R&R results for this study are not acceptable as per Automotive Industry Action Group (AIAG) guidelines. The Experts had a discussion with Top management and it was decided to (i) review customer support executive's evaluation procedure and (ii) to establish tangible guidelines for certifying them. In addition, it was also decided to include much supplementary hand on training for customer support executives during training program.

4.4 OTHER SIX SIGMA SIGNIFICANT TOOLS

Process mapping: During the Define and measure phase it is important to completely understand the process, with its key input & output variables. Process map is a graphical representation of how the process is actually performed. All the rework operations and non value added movements are included in process map. A process map helps document the process in order to maintain control and reduce variations, due to process changes overtime .Objectives of drawing process map include (i) understanding the step by step methodology in creating a process map, (ii) understanding the various components of a process map and their purpose and (iii) understanding the requirements when a process map should be created, updated and when a process map is completed. A detailed process map includes (i) both value added and non-value added steps. (ii) The input and outputs of each process step (X's and Y's). (iii) The current known requirements of each X and Y. (iv) Data collection points. (v)The defect rate associated with each X and Y.(vi) The cycle time of each process step.(vii) Process owners of each process step. (viii) Process maps are created for every project and are never completed. They should be updated whenever one of the parameters is changed. The team approach is required to create a process map. The Green Belt candidate is required to facilitate the team in the creation process. Team participants should include, at a minimum, representatives from the areas like Design, Quality, and Operations, and process owner who actually is performing the process.

Cause and Effect Diagram: Cause and Effect Diagram (Ishikawa Diagram or Fishbone Diagram) is used to organize brainstorming information about potential causes of a problem. In other words it is an analysis tool to display possible causes of a specific problem or condition. Cause and effect diagram is generally applied during define and/or analysis phase of Six Sigma DMAIC methodology. The objectives for using cause and effect diagram include (i) Identifying potential causes of a problem or issue in an orderly way and (ii) Summarizing major causes under four or six categories including; men, machines, materials, methods, measurements, mother nature, or policies, procedures, people, and plant. The figure 4.5 represents possible reasons of a front line executive in a service organization for not answering a phone call

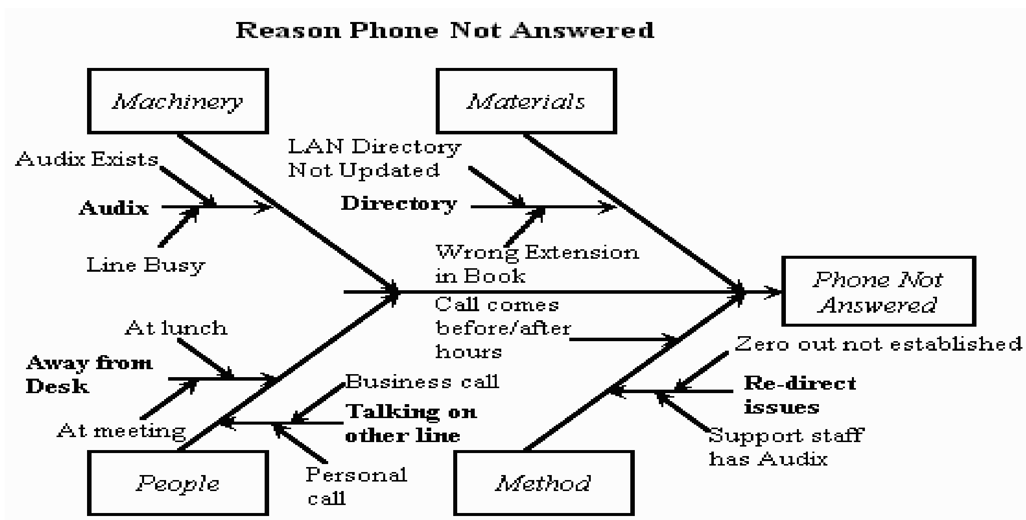

Figure 4.5 Possible reasons of a front line executive not answering a phone call

Scatter Diagram: Scatter Diagram is used to interpret data by graphically displaying the relationship between two variables. A scatter diagram is used for (i) Validating "hunches" about a cause-and-effect relationship between types of variables. (ii) Displaying the direction of the relationship (positive, negative, etc.) (iii) For displaying the strength of the relationship. Data patterns may be positive, negative, or display no relationship. A positive relationship is indicated by an ellipse of points that slopes upward demonstrating that an increase in the cause variable also increases the effect variable. A negative relationship is indicated by an ellipse of points that slopes downward demonstrating that an increase in the cause variable results in a decrease in the effect variable. A diagram with a cluster of points such that it is difficult or impossible to determine whether the trend is upward sloping or downward sloping indicates that there is no relationship between the two variables.

Pareto Chart: A Pareto Chart is a special form of a bar graph and is used to display the relative importance of problems or conditions. A pareto chart is used for (i) Focusing on critical issues by ranking them in terms of importance and frequency. (ii) Prioritizing problems or causes to efficiently initiate problem solving (iii) Analyzing problems or causes by different groupings of data. (iv) Analyzing the before and after impact of changes made in a process. Pareto chart may be applied before and after Cause and effects Diagram.

Failure Mode and Effect Analysis: Failure mode and effect analysis, or FMEA, is an attempt to delineate all possible failures, their effects on the system, the likelihood of occurrence and the probability that the failure will go undetected. FMEA provides an excellent basis for classification of characteristics such as identifying CTQs and other critical variables. FMEA came into existence on the space program in the 1960s. It was later incorporated into military standards. FMEA is an integral part of early design process and it should take place during the improve phase of DMAIC or the design phase of DMADV. FMEAs are living documents that must be updated to reflect design changes, making them also useful in the control or verification phases. The analysis is used to assess high-risk items and the activities underway to provide corrective actions. The FMEA process is also used to define special test considerations, quality inspection points, preventive maintenance actions, operational constraints, useful life, and other pertinent information and activities necessary to minimize failure risk. All recommended actions that result from the FMEA must be evaluated and formally executed by appropriate implementation or documented rationale for no action. As with Pareto analysis, one objective of FMEA is to direct the available resources toward the most promising opportunities. An extremely unlikely failure, even one with serious consequences, may not be the best place to concentrate preventative efforts. FMEA can be combined with decision analysis methods such as Analytical Hierarchy Process (AHP) and quality function deployment (QFD) to help guide preventive action planning. Risk Priority Number (RPN) is useful in setting priorities. Larger RPNs should receive greater attention than smaller RPNs. Some organizations have guidelines requiring action based on the absolute value of the RPN. Boeing recommends that action be required if RPN > 120.FMEA rating for severity, occurrence and detect ability is presented in table 4.8.

Hypothesis Testing: A hypothesis is a claim or statement or belief about a property of a population such as mean, variance, proportion as presented in table 4.7. Hypothesis testing is used for determining if there is real difference between population and a sample or between two samples and for estimating the possibility of having significantly different sample. The research hypothesis is the claim that is being studied. The data must demonstrate beyond a reasonable doubt that the research hypothesis is true. The judicial system may be used to illustrate the concept of null and alternate hypothesis. In Judicial system we assume innocence until guilty is proven. This corresponds to null hypothesis. Ho = Person is not guilty (Null hypothesis).Ha = Person is guilty (Alternate hypothesis).As a result of any hypothesis test, either null hypothesis (the Alternative Hypothesis is likely true), or not rejected (Not enough evidence to conclude that the Alternative Hypothesis is true).

Table 4.7 Common hypothesis tests and their applications

Common Hypothesis Tests	Applications
t Test, z Test	Comparing Population Means
F Test, Bartlett's Test	Comparing Population Variances
Proportion Tests, Chi Squared Test	Comparing Population Proportions or Percentages

4.5 CONCLUDING REMARKS

Statistical Process Control (SPC) is an integral Aspect part of Six Sigma methodology. In many service organizations, SPC initiatives fail to deliver adequate results due to lack of understanding of the statistical concepts and their applicability within organization. In many cases, people blindly believe that SPC is about plotting charming charts & sticking them on wall for satisfying customers. In many other cases, control charts are set aside because of unsatisfactory results and potential user conclude that control chart do not work with this process. The potential user must ask an important question that what I am hoping to achieve by using control chart. The broad objective of using control chart may be detection of process change and reduction in long term variability in a process. It is reasonable to assert that either or both objectives will be easily achieved if the action lines on control charts are properly laid and data is sub grouped based on rational hypothesis. The successful application of SPC in Six Sigma projects requires planning skills, statistical skills and management skills. As a general rule, sub groups should be selected so that if Special causes are present, chances for variation between subgroups will be maximized, while the chances for variation due to these special causes with in a sub groups will be minimized. In addition, steps in setting of control chart; high priority to characteristics that are running with high defect rate, identification of Critical to Quality characteristics and, verifying that measurement process have sufficient accuracy should be followed. Measurement variation may also hide important signal for detecting sources of variation.

Measurement System is the first step that leads to control and virtually improvement. If we cannot measure something we cannot understand it. If we cannot understand it, we cannot control it, and if we cannot control how can we improve it. Measurement system variation includes equipment error, human error, and human-equipment interaction and may be reduced through conducting Measurement System Analysis (MSA). Attribute Gage R&R is presented in a very simple form in this chapter. The analysis may be expanded to include confidence interval and kappa value calculations as explained in AIAG's measurement system analysis manual. The ultimate purpose of Statistical quality tools is to enhance the quality of service process rather than certify that the process meets statistical Control limits.

CHAPTER 5

DEVELOPMENT AND APPLICATION OF SIX SIGMA DMAIC METHODOLOGY

There have been many successful applications of Six Sigma in manufacturing over last two decades. Service organizations have legged manufacturing organizations in applying Six Sigma. However in the last decade, there has been quantum increase in applications of Six Sigma in service organizations. The chapter demonstrates application of Six Sigma DMAIC methodology for a Technical Institution, Telecommunication Organization, Healthcare and Foundry Shop.

5.1 INTRODUCTION TO SIX SIGMA IN SERVICE INDUSTRY

Service operations comprise 80 % of GDP in America and are rapidly growing around the world. In Indian economy, service sector accounts for substantial share of GDP. The cost related to work that adds no value in customers' eye is typically 50% of total service costs. It means there is enormous potential for achieving improvements in service operations. In addition, service quality is an increasingly priority for organizations that wish to differentiate their services. To meet and exceed customers expectations, service organizations must deliver services with capable processes. For delivering high quality services at competitive prices, it is necessary to completely understand the process and & how does the variation in various process parameters affect the process output. In addition, knowledge about process control and statistical methods and expected benefits by implementing Six Sigma Methodology is significant to achieve process improvement. Six Sigma for service operations is a business improvement methodology that maximizes shareholder value by achieving fastest rate of improvement in customer satisfaction, cost, quality and service time. Following is some recent work on Six Sigma in services.

According to Snee and hoerl (2002), Six Sigma is a statistically based quality improvement program that helps to improve business processes by in waste and costs resulting from poor quality and by improving levels of efficiency and effectiveness of the process. Chakrabarty & kay Chan Tan (2013) have presented issues highlighted by service industries during Six Sigma implementation through questionnaire survey. The authors have presented empirical research through surveys to understand issues involving Six Sigma implementation in service organizations. Heckl et. al (2010) have conducted a comprehensive survey in banks, insurance companies and related service providers in Germany and other European countries and found that desire to exploit market opportunities, pressure to reduce market cost and dissatisfied customers are the main drivers of Six Sigma projects. The authors have presented the result of survey to analyze acceptance level of Six Sigma methodology with in financial services industry. Chakrabarty & Tan (2009) have done qualitative & quantitative analysis of Six Sigma organizations in Singapore and found out that application of Six Sigma in service sector is concentrated in a few services. He has provided parameters to be considered for successful implementation of Six Sigma. He has done a questionnaire survey of Singapore service organizations to understand the status of Six Sigma in Singapore. The survey shows that 23% of responses are not aware of Six Sigma methodology, 23% find it is not relevant, the percentage of responses who find it is not relevant, not interesting, time consuming and difficulties in identifying process parameters are 15.38%, 17.95%, & 17.95% respectively. Grover et al.(2007) have emphasized on effect of functions and facilities in an organization to enhance service quality.

5.2 SIX SIGMA IN TECHNICAL EDUCATION

Education is emerging as major commercial activity in the service sector, and institutions are realizing the significance of quality improvement in education. Quality in education is no more a desirable strategy; it has become essential for the survival of an institution. Present work illustrates how Six Sigma may be used to improve performance parameters of a technical institution. The authors have identified critical to quality characteristics and proposed a team structure for successful implementation of a Six Sigma project in technical Institution. The authors have further recommended findings along with an implementation control plan based on a Six Sigma case study of technical institution. From Ancient to Modern India, higher education has always occupied a place of prominence in Indian history. In ancient times, universities like

Nalanda, Taxila were attracting students not only from all over India, but from far off countries. Today India manages one of the largest higher education systems in the world. The Indian education system has been subjected to revolutionary change over the recent years and indeed this change is still in progress. This change is impacted by the changes in global economics, social and cultural changes in Indian society. Education now a days have become much more of a education industry with student as internal as well as external customers. Following is some recent work on quality initiatives in higher education.

Madu et.al (1994) has classified customers in an education system in three categories i.e. input customers, transformation customers and output customers. Students and parents may be categorized as input customers, faculty & staff of institution as transformation customers and organizations recruiting students as well as society as output customers. It has been recognized that quality of services in education like any other services are associated with customer satisfaction. Hence, it is necessary to identify customer requirement and redesign critical to quality characteristics (CTQs) that make up education system. It is essential to identify the stake holders in a technical education system. Many authors have identified students, parents, faculty and staff, alumni, recruiters, government and society as stakeholder in technical education system. Quinn et al. (2009) and Jenickle et al. (2008) have identified students as customers in engineering institutions. Elmuti (1996) has used survey based approach to investigate the limitation, usefulness & status of TQM program of institutions of higher education located in Midwestern USA. Swift (1996) has used a real life story based research to identify the problem area of selected technical institutes and reported the benefit of group projects. He has discussed the improvements in quality of education with application quality control and management.

Motwani et al (1997) have applied TQM in education and suggested five stage model including deciding preparing, starting, integrating and evaluating phase. These phases can be used by any university for implementing TQM. Crawford et al (1999) have highlighted the TQM operation in industrial scenario and compared its application with education. The authors have also compared the application of Crosby’s and Deming’s models of quality. Hargrove et al (2002) have conducted a pilot survey to assess, evaluate and monitor the variation in student performance and recommended the methods for improvement. The authors have stressed on performance of minority and underrepresented students in science and under graduate program. Authors have further identified three critical factors namely faculty development, improvement in teaching methodology and need of increased financial aid. Bitner (2007) has recommended Six Sigma methodology at macer university school of engineering. The author has selected projects like retention and success of student in mathematics classes, reduction in amount of time taken by student to get a bachelor's degree in engineering program and achievement of female as engineering graduate. Mitra (2004) has discussed on significance of incorporating statistical education in the curricula of business and engineering. He has further stressed on one or two semester level courses for engineering and management program. He has also discussed the course contents and stressed on the significance of quality tools like SPC, DOE, FMEA, QFD, Gauge R and R and basic quality tools in course of Six Sigma. He has also recommended the integration of DMAIC and DFSS methodology with realistic projects. Sahney et al. (2004) have identified customer requirements and design characteristics from a pilot survey. The authors have applied SERQUAL approach to identify the gap between perception and expectations to determine the levels of service quality. The authors have further identified minimum set of designed characteristics to meet customer requirements.

Thakkar et al. (2006) have implemented QFD and force field analysis approach to self financing technical institutes for total quality management. It has emphasized that continuous improvement is most significant and budget priority is second most significant in importance rating. Grover et al. (2008) have proposed a QFD approach for evaluation of quality parameters in an educational institute. Kumi and Morrowal (2006) have implemented Six Sigma DMAIC methodology in academic library of University of Newcastle UK. The authors have suggested that Six Sigma project has provided them a formal fault reporting system to reduce the down time of a unit. The Six Sigma project has recommended them number of conclusions like reducing the staff on issue desk, moving self issue unit to appropriate location, increasing the number of users at self issue desk. In addition, authors have advocated that Six Sigma project has given them a new problem solving mechanism for future projects Antony (2007) has emphasized on the limitation of Six Sigma which need attention of academics in Technical institutes and Business schools around the world. Jenicke et al. (2008) have presented frame work for Six Sigma DMAIC methodology at University level, College level & School level. The authors have also found out performance indicators at these levels. Owlia and Aspinwall (1998) have recommended a revised framework for measuring and improving dimensions of quality in educational services. The authors have categorized these characteristics in four groups namely attitude, content, competence and academic resources. Bordia (2001) has stated that engineering degree in India is considerably significant for well being of an individual and his family. Hence there is cut throat competition among students and institutions to get quality institution and quality student respectively. Tan and Kek (2004) have provided SERVQUAL model and satisfaction analysis grid to find an immediate action requirement for improvement. Mahapatra and Khan (2007) have demonstrated an EDUQUAL model for measuring the quality of engineering institution. To determine and satisfy customer needs,

Many manufacturing and Service Organizations have been certified for ISO 9001:2008 as a model of quality assurance. ISO 9001:2008 is assumed as a first step to the journey of quality excellence. The general people also have a belief that ISO certification assures the quality of the organization. Few papers in education have reported application ISO 9001 certification. ISO certification for engineering institutions resulted in quality improvement in all the business processes of the institutions. karthi et al. (2011).

Sakthivel et al., 2005 have conducted a study in ISO certified and Non ISO certified self financing engineering colleges for measuring students' satisfaction. He has proposed '5Cs' TQM model in which 5Cs include course delivery, courtesy, campus facilities, commitment of top management, customer feedback and improvement. Student satisfaction survey was conducted through a questionnaire consisting of five quality dimensions. Ardi et al. (2012) have stated implementation of TQM in Indonesia State University Engineering College for measuring student's satisfaction. The author have developed a survey model with seven dimensions of quality namely course delivery, faculty commitment, department commitment, campus facilities, courtesy, feedback mechanism and improvement initiatives. Chaudhuri et al.(2011) have stated that Six Sigma metric and yield analysis of engineering colleges in west

Bengal. The authors used a survey questionnaire with eight quality enablers and 75 quality parameters. Antony et al. (2012) have discussed the challenges and barriers for implementing Lean Six Sigma in higher education. The authors listed critical success factors, appropriate tools and techniques of lean Six Sigma and concluded that lean Six Sigma can be effectively implemented in Engineering Institutions. Burli et al. (2012) studied European Foundation for Quality Management Excellence Model and developed a survey questionnaire. The author analyzed questionnaire using SPSS software. Chen et al. (2006) worked on employee satisfaction and significance of academic degrees for improvement in higher education. In addition, he developed Importance Satisfaction model for studying employee satisfaction and importance of degrees. Patil and Codner (2007) have discussed accreditation and assessment of technical institutions and universities.

5.2.1 Statutory and Regulatory Bodies Implementing Quality Initiatives in Technical Education

Technical education plays a vital role for development of country by creating skilled manpower, enhancing industrial productivity & improving the quality of life. Over a decade there has been exponential growth in India .Currently there is a gap between quality a quantity of technical educations in India. The technical education system in India can be broadly classified into three categories. Central funded institutions in India (e.g. Indian Institute of Technology (IITs), National Institute of Technology (NITs), state government institutes & self financing institutions. The quality of education and training being imparted in the Engineering Education institutions varies from excellent to poor, with some institutions comparing favorably with the best in the world and others suffering from different degrees of handicaps. Following are the agencies contributing to the quality improvement initiatives in India.

All India Council for Technical Education (AICTE): The AICTE was constituted in 1945 as an advisory body in all matters relating to technical education. It is playing a very important role in the development of technical education in the country. In 1987, AICTE became a statutory body through an Act of Parliament 52. The Council, i.e. AICTE was established with a view to the proper planning and coordinated development of the technical education system throughout the country. The Council was empowered by the Act to establish Boards of Studies as it may think fit.

Presently, there are 10 All India Boards of Studies in various sectors of technical education. For more details please visit www.aicte-india.org

National Board of Accreditation (NBA): The NBA was initially established by All India Council of Technical Education (AICTE) under section 10(u) of AICTE act, in the year 1987, for periodic evaluations of technical institutions & programs basis according to specified norms and standards as recommended by AICTE council. NBA in its present form came into existence as an autonomous body with effect from 7th January 2010,The Goal of NBA is to promote the international quality standards in India for technical education through the mechanism of accreditation of programs offered by technical institutions..The scope of NBA includes especially of the programs in professional and technical disciplines, i.e., Engineering and Technology, Management, Architecture, Pharmacy and Hospitality. NBA has introduced a new process, parameters and criteria for accreditation. These are in line with the best international practices and oriented to assess the outcomes of the programs. For more details please visit www.nbaindia.org

University Grant Commission (UGC): The UGC was formally established only in November 1956 as a statutory body of the Government of India through an Act of Parliament for the coordination, determination and maintenance of standards of university education in India. The UGC has the unique distinction of being the only grant-giving agency in the country. The UGC's mandate includes: Promoting and coordinating university education., determining and maintaining standards of teaching, examination and research in universities, framing regulations on minimum standards of education, monitoring developments in the field of collegiate and university education, disbursing grants to the universities and colleges, serving as a vital link between the Union and state governments and institutions of higher learning and advising the Central and State governments on the measures necessary for improvement of university education. For more details please visit www.ugc.ac.in

National Assessment and Accreditation Council (NAAC): The NAAC is an autonomous body established by the University Grants Commission (UGC) of India to assess and accredit institutions of higher education in the country. It is an outcome of the recommendations of the National Policy in Education (1986) that laid special emphasis on upholding the quality of higher education in India. The NAAC was established in 1994 with its headquarters at Bangalore. It functions through its General Council (GC) and Executive Committee (EC) where educational administrators, policy makers and senior academicians from a cross-section of the system of higher education are represented. The Chairperson of the UGC is the President of the GC of the NAAC, the Chairperson of the EC is an eminent academician in the area of relevance to the NAAC. The Director of the NAAC is its academic and administrative head, and is the member-secretary of both the GC and EC. For more details please visit www.naac.gov.in

Educational Consultants India Limited (EdCIL): The EdCIL is public sector enterprise under the Ministry of Human Resource Development Govt. of India. It was conceived and incorporated by the Government of India in 1981. It provides consultancy and technical services at global level. Having established credentials in education sector for providing quality services at a reasonable cost, EdCIL has diversified in the other areas of social sector (Health, Agriculture and Rural Development) and has been accepted as a preferred organization for undertaking consultancy assignments. EdCIL's performance has been rated as excellent by the Department of Public Enterprises for 4 years during the last one decade. EdCIL has also been awarded the Prime Minister's Award of Excellence for the year 1998-99 and is categorized as a 'Mini Ratna Organization' by the Government of India. For more details please visit www.edcilindia.co.in

National Project Implementation Unit (NPIU): The NPIU was established by ministry of human resource development in 1990 for coordination, guidance and monitoring institutions in all aspects of projects. N P I U has implemented three technical education projects of Government of India assisted by World Bank. These projects have helped to strengthen and upgrade the technical education system and benefited 552 polytechnics in 27 states. With the aim of transformation of India’s technical education system to make it globally competitive govt. of India lunched TEQIP i.e. technical education quality improvement program as a long term program in 2 to three phases. National Project Implementation Unit (NPIU) is responsible at the central level for overall guidance, policy decisions and project management, coordination and implementation of TEQIP -1 and TEQIP -II. For more details please visit www.npiu.nic.in

National Institutes of Technical Teachers' Training and Research (NITTTRs): The NITTRs (Formerly TTTIs), are four institutes established by the Government of India for the development of technical education in the country with focus on the states of the northern, southern, eastern and western regions. There are 4 NITTTRs in India namely NITTTR Chandigarh, NITTTR Bhopal, NITTTR Kolkata, NITTTR Chennai. For more details please visit www.nitttrchd.ac.in, www.nitttrc.ac.in, www.nitttrbhopal.org, www.nitttrkol.ac.in.

Quality Council of India (QCI): The QCI was set up in 1997 jointly by the Government of India and the Indian Industry represented by the three premier industry associations i.e. Associated Chambers of Commerce and Industry of India (ASSOCHAM), Confederation of Indian Industry (CII) and Federation of Indian Chambers of Commerce and Industry (FICCI), to establish and operate national accreditation structure and promote quality through National Quality Campaign. QCI is registered as not-for-profit society with its own Memorandum of Association and Rules & Regulations. The Department of Industrial Policy & Promotion, Ministry of Commerce & Industry, is the nodal ministry for QCI. The QCI runs accreditation programs through its Boards. For more details please visit www.qcin.org.

5.2.2 Application of Six Sigma DMAIC Methodology in a Technical Institution

Engineering education became a main attraction after 1990 when India became a major contributor to the global IT industry revolution. In the last two decades, many State Governments and Self financed technical institutions have been established. Nearly 80% of technical institutions in India are being managed by private managements. In these institutions, profitability is emerging as primary motto. Hence there is utmost need for quality improvements initiatives. Major performance parameters of these institutions are placement and passing rate of the students

In the present case study, a self financed technical institution located in National Capital Region (NCR) India was selected for case study. The institution has five branches of engineering and having strength of around 1200 students and 69 faculty members. Average student passing ratio of students for last five year was collected which was very low (49.67%) and hence taken as project goal. The goal statement for Six Sigma project is to enhance student passing ratio by 15%. For successful implementation, the Management, Principal, and Heads of Department (HODs) must be convinced that Six Sigma methodology provides quantum jumps in improvement. A presentation regarding Six Sigma methodology and its benefits was made before management, senior faculty members, HODs and Principal to ensure necessary support during the project. The Six Sigma implementation Team was formulated which encompass 12 members including a member of board of governors, Principal, three HODs, five faculty members and two students. The organization structure of team is shown in figure 5.1. Before solving any problem, the roadmap of achieving goal must be understandable. If the roadmap and methodology adopted is not comprehensive enough, the improvements obtained will not be for correct and Problem will recur sooner or later.

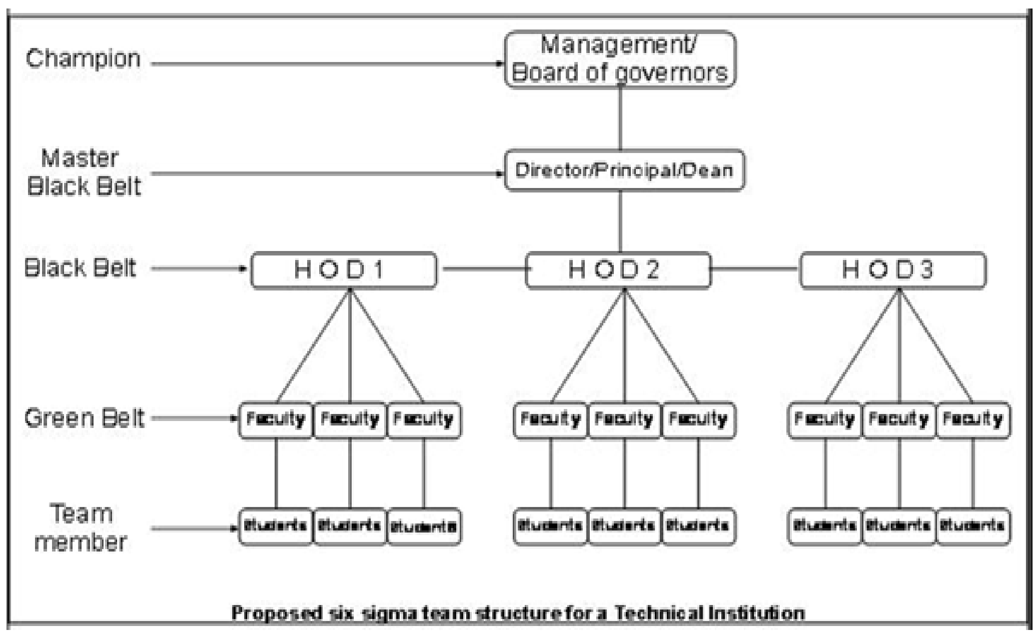

Figure 5.1 Six Sigma team structure for a technical institution

Define: In define phase of Six Sigma project team identifies and defines project suitable for Six Sigma efforts based on critical to quality characteristics. CTQs (critical to quality characteristics) are established from critical Business Issue, critical Process, business objectives, customer needs and feedback. CTQs (critical to quality characteristics) are the attributes that the customer considers to have the critical impact on quality. Project team also defines who are the customers and what do you provide your customers, what are their priorities, what is critical to quality for your customers. While defining the problem it is strongly recommended to describe only the effects not causes. It is also essential to scope the problem i.e. what are the boundaries and the constraints in which project is to be completed. Jiju Antony (2006) have stated that the tools and techniques applicable for service organizations in define phase are process mapping, SIPOC, quality function deployment, project charter, calculations for cost of poor quality. A High level process map supplier, input, process, and output (SIPOC) was drawn to understand stake holders in process of technical education as shown in table 5.1.

Table 5.1 High level SIPOC process map

Supplier	Input	Transformation Process	Output	Customer
Schools, Parents	Incoming Students	Faculty, Staff, Teaching Learning process	Passing out Students	Placement Organizations, Society

The Six Sigma team had a series of brainstorming sessions with Principal, Head of Departments (HODs), faculty members and senior students. Cause and effect diagram was drawn with causes identified as Faculty members, Engineering pedagogy, Examinations, Environment, Management and Infrastructure as presented in figure 5.2.

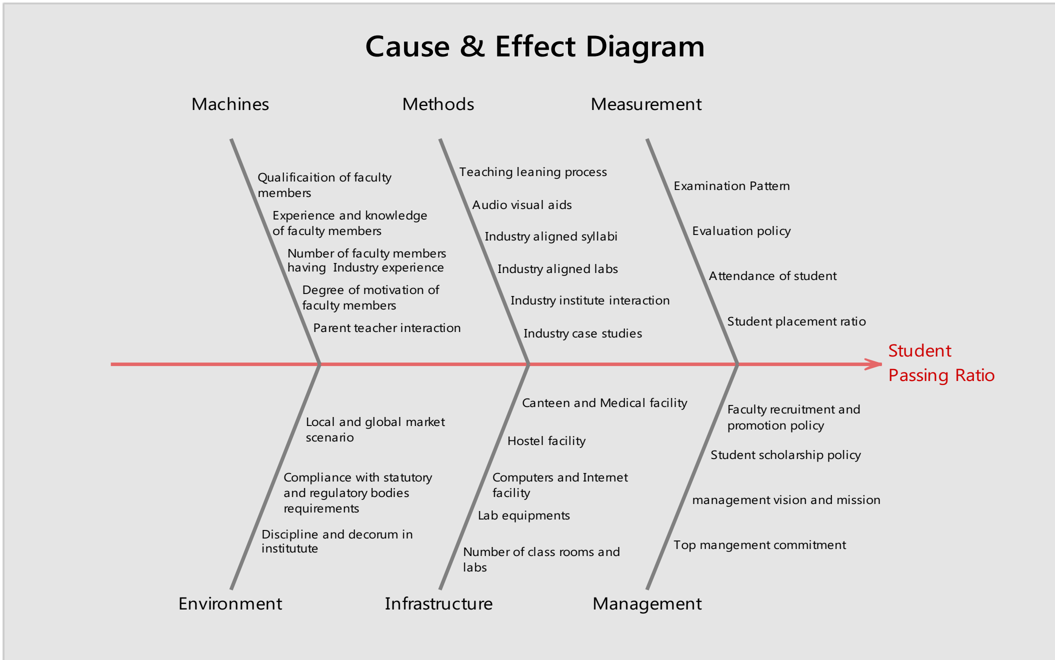

Figure 5.2 Cause and effect diagram for students passing ratio

To identify critical to quality characteristics (CTQs) in institution, a questionnaire survey was conducted among faculty and students of institution. The questionnaire consists of focused 20 CTQs observed from Cause and effect diagram. The questionnaire was reviewed by academicians having substantial knowledge of implementing quality initiatives in academic institutions. The questionnaire was designed on the pattern of likert type scale from 1 to 5 in which 5 was most significant and 1 was least significant. Out of 500 questionnaires, 200 questionnaires were received for usable data analysis. The response rate may be regarded satisfactory for this kind of analysis. Figure 5.3 presents mean score of five CTQs in technical institutions. The following CTQs were identified:

- Student passing ratio i.e. number of students completing degree in stipulated time/ total number of students admitted;
- Student placement ratio i.e. number of on campus placements / total number of students;
- Qualifying marks of incoming Students;
- Faculty Qualification;
- Teaching learning Process**.**

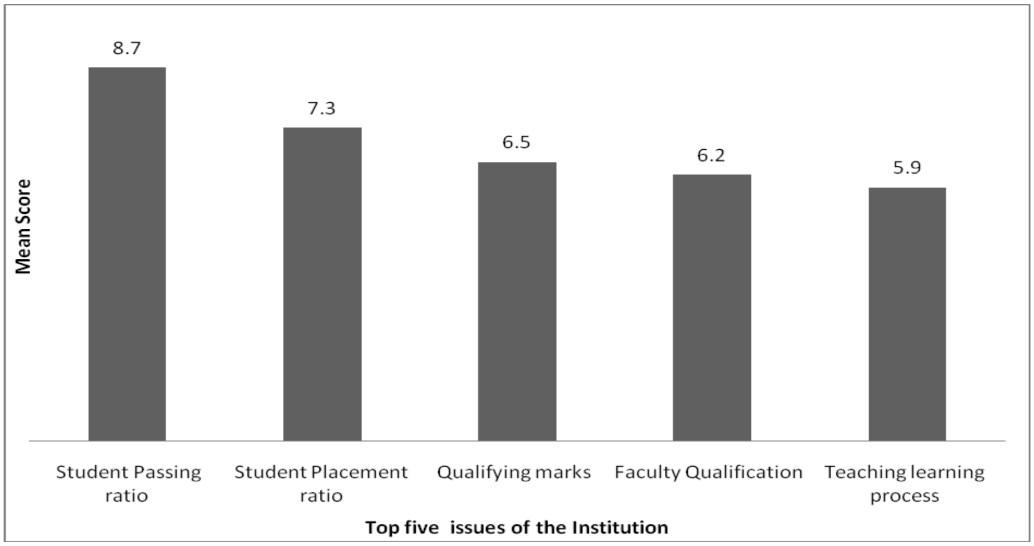

Figure 5.3 Mean score of five critical to quality characteristics in technical institutions

Measure: In measure phase, it is measured how the process is performing by using process yield and sigma rating of the process. In addition it is determined that what to measure and, how to measure. The other significant task during measurement phase is validating Measurement System by performing Measurement system Analysis. In the present work, gage repeatability and reproducibility study (Gage R&R) was conducted to identify whether variability in evaluation process affects student passing ratio. In a technical institution, the evaluation policies and appraiser (teacher) are the measurement instruments whereas student being evaluated is the object being measured. In following repeatability and reproducibility analysis, ten answer sheets (samples) are selected for evaluation (inspection) by three teachers (appraisers). Each appraiser inspects the sample twice and provides his opinion. The appraisers are not aware that they are inspecting (evaluating) the same sample twice. The whole exercise is randomized for three appraisers so that their opinions should be unbiased. Table 5.2 presents Gage R&R. data collection sheet as recommended by Measurement System Analysis (MSA) manual of Automotive Industry Action Group (AIAG).

Table 5.2 Gage R&R data collection sheet (AIAG)

Gage Repeatability and Reproducibility Data Collection Sheet											
Appraiser / Trial	Answer sheets coded number										Average
	1	2	3	4	5	6	7	8	9	10	
Appraiser A											
A1	60	80	68	68	44	80	76	68	80	62	69
A2	56	80	64	76	36	80	76	64	80	56	67
Average	58	80	66	72	40	80	76	66	80	59	X_a bar =68
Range	4	0	4	8	8	0	0	4	0	6	R_a bar = 3
Appraiser B											
B1	52	80	64	64	32	80	76	60	80	44	63
B2	44	76	60	72	36	80	72	56	76	40	61
Average	48	78	62	68	34	80	74	58	78	42	X_b bar = 62
Range	8	4	4	8	4	0	4	4	4	4	R_b bar = 4
Appraiser C											
C1	56	80	64	64	36	80	76	64	80	68	67
C2	52	80	64	64	40	80	76	64	78	64	66
Average	54	80	64	64	38	80	76	64	79	66	X_c bar = 67
Range	4	0	0	0	4	0	0	0	2	4	R_c bar = 1
Part Average	53	79	64	68	37	80	75	63	79	56	X double bar = 65
Average Range (R double bar)= (R_a bar + R_b bar + R_c bar) / (numbers of appraisers)											3
X bar $_{Difference}$ = (X bar $_{Maximum}$ - X bar $_{Minimum}$)											6
part range (Rp) =											43

Gage R&R analytical analysis and graphical analysis estimates total process variation, part variation, percentage of total variation for the measurement system and its components repeatability and reproducibility. In above gage repeatability and reproducibility (Gage R& R) study, repeatability is variation observed when same appraiser evaluates one answer sheet twice. In this case, appraiser C is more repeatable as compared to appraiser A and B which concludes that C has used better techniques for evaluation as compared to A and B. In R chart as presented in figure 5.4, each point is the range of two trials on one answer sheet (sample) by single appraiser. If all points are in control, appraisers are doing same job. If one point is out of control, the method used differs from others. If more points are seen outside the control limit, measurement system is unstable.

Reproducibility is the variation observed when different appraisers evaluate the same answer sheet. In X bar chart as presented in figure 5.4, each point is the average of two trials by same appraiser. The distance between upper and lower control limit represents measurement error. Most points outside the control limit on x bar chart indicate that measurement system is acceptable because between sub groups variation is more than within subgroup variation. Approximately one half or more averages should fall outside the control limit. If less than half point falls outside the control limit then either the measurement system lacks adequate resolution or sample does not represent expected process variation. Part to part variation is the difference between points on X bar chart.

As per Automotive Industry Action Group (AIAG) guidelines, if Gage R&R value less is than 10%, measurement system is acceptable, but for R and R value more than 30% measurement system is not acceptable as shown in table 5.4. Gage R&R value from 10% to 30% may be acceptable depending upon the criticality of the application. In present work, Gage R&R value is 27% and repeatability error is 19% as shown in table 5.3. It was recommended to establish standard operating procedure for evaluation of answer sheets.

Table 5.3 Variable Gage R&R- analytical analysis of the result

Source	%age total study variation	Formulae for calculation of %age total study variation	Formulae for calculation of EV, AV, GRR, PV, TV & NDC
Repeatability - Equipment variation (EV)	18.9	%age EV = 100 (EV/TV)	EV = (R double bar) * k1
Reproducibility - Appraiser variation (AV)	18.5	%age AV = 100 (AV/TV)	$AV = \sqrt{(\text{X bar diff } - K2) - \left(\frac{EV}{n\,r}\right)}$
Repeatability & reproducibility (GRR)	26.5	%age GRR = 100 (GRR/TV)	$GRR = \sqrt{EV^2 + AV^2}$
Part variation (PV)	96.4	%age PV = 100 (PV/TV)	PV = Rp *k3
Total variation (TV)	100.00		$TV = \sqrt{GRR^2 + PV^2}$
Number of distinct categories (NDC)	5		NDC = 1.41*(PV/GRR)
K1, K2, K3, K4 are constants, n= sample size, and r= number of trials			

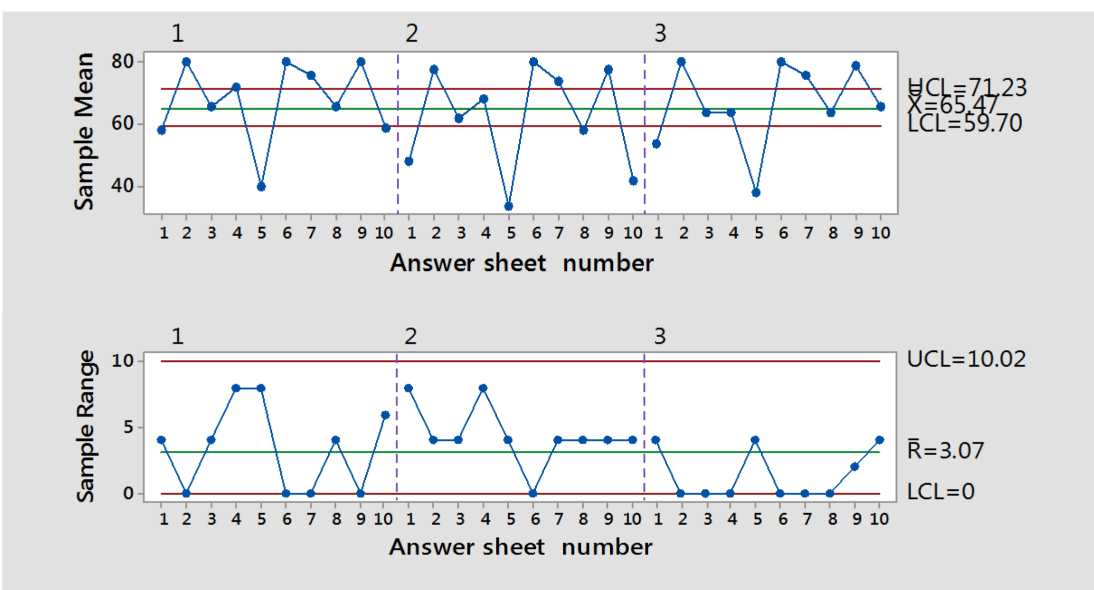

Figure 5.4 Variable Gage R&R – X bar and R chart (graphical analysis of the result)

Table 5.4 Gage R&R acceptability criteria

%age Gage R&R value	Acceptability
0% to 10%	Very good gage
10% - 30%	May be acceptable
More than 30%	Not acceptable
Range Chart not in statistical control	Not acceptable
Distinct Categories less than five	Not acceptable

Analyze: During the analysis phase process baseline is once again established and performance goals are redefined. It is also found when and where the defects occur? What are the most important causes of defects? The team discovers why defects are generated by identifying the key variables that are most likely to create process variation. In the present work the most important CTQ identified was low student passing ratio. The student passing ratio data of Mechanical Engineering Department for batch admitted in 2007, 2008 and 2009 was collected from 3rd semester to 7th semester. The data was analyzed year wise, semester wise, section wise and subject wise for three consecutive years. Table 5.5 presents pass percentage of students from 3rd to 7th semester.

Table 5.5 Pass percentage of mechanical engineering students from 3rd to 7th semester for three consecutive years

Semester	Batch		
	2007-2011	2008-2012	2009-2013
3rd	64.13	57.38	65.62
4th	47.50	42.50	48.61
5th	54.51	48.77	55.78
6th	59.96	53.65	61.36
7th	65.95	59.01	67.49

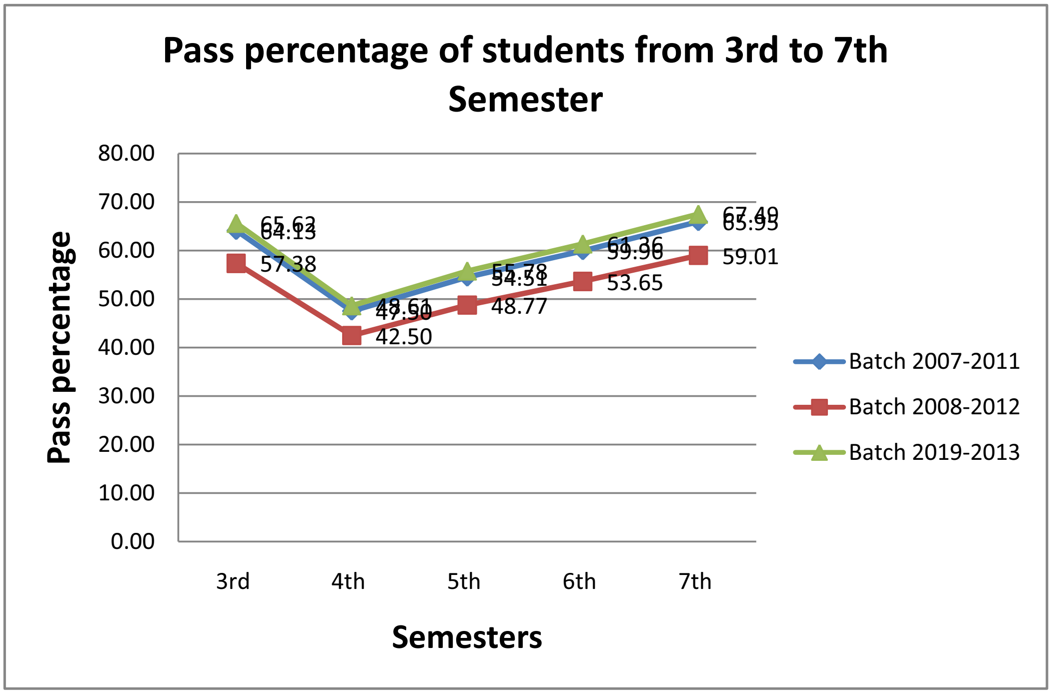

Figure 5.5 Pass percentage of mechanical engineering students from 3rd to 7th semester for three consecutive years

Table 5.5 and figure 5.5 reveal that students of 4th semester have minimum passing ratio. It provides an indication that there exists problem in 4th semester student pass percentage. Pass percentage of 4th Semester students for three consecutive batches is shown in table 5.6.

Table 5.6 Pass percentage of 4th semester mechanical engineering students for three consecutive years

Subjects	Batch		
	2007-2011	2008-2012	2009-2013
Strength of Materials	29	27	30
SOM Lab	97	99	100
Thermal Engineering -II	60	51	55
Fluid Mechanics	50	46	51
FM Lab	95	92	98
Manufacturing Technology	66	62	67
Kinematics of machines	36	33	40
KOM Lab	95	98	97

The pass percentage data for the 4th Semester of all the students of mechanical engineering was analyzed. The 4th semester includes eight subjects namely Strength of Materials (SOM), SOM Lab, Thermal Engineering –II, Fluid Mechanics (FM) , FM Lab, Manufacturing Technology –II, Kinetics of Machines and (KOM) Lab. Among all the subjects, pass percentage of Strength of material was least followed by Kinetics of Machines and Fluid Mechanics as shown in figure 5.6. So, it was further decided to analyze strength of Materials Subject. There were two sections in each batch of students from 2007 to 2007. It was decided to conduct two way ANOVA for analyzing the effect of batches and Sections on Strength of Materials subject of 4th semester. Table 5.7 presents two way ANOVA data for analyzing the effect of batches and sections on Strength of Materials subject of 4th semester where as table 5.8 presents Minitab input for analyzing the effect of batches and sections on Strength of Materials subject of 4th semester

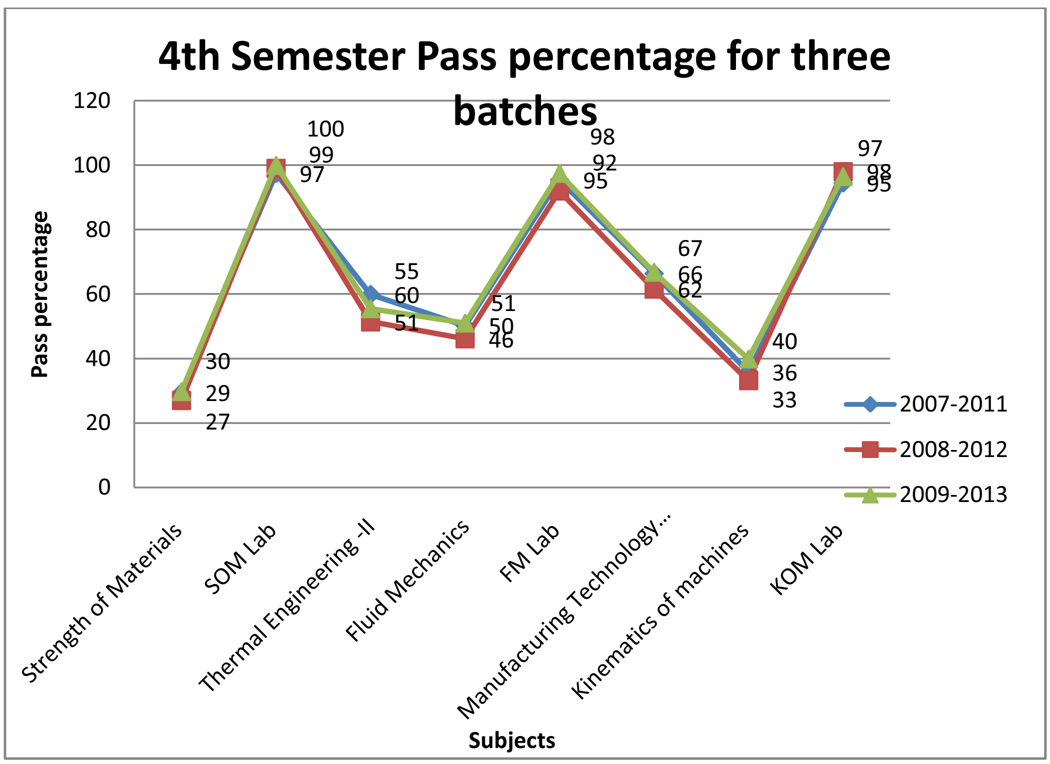

Figure 5.6 Pass percentage of 4th semester mechanical engineering students for three consecutive years.

Table 5.7 Two way ANOVA data for analyzing the effect of batches and sections on Strength of Materials subject of 4th semester

Batch 2007-2011		Batch 2008-2012		Batch 2009-2013	
Section 1	Section 2	Section 1	Section 2	Section 1	Section 2
10	14	11	14	9	13
19	26	21	27	17	24
25	34	28	36	23	32
39	37	32	39	36	39
32	43	35	46	29	40
34	46	37	49	31	43
38	39	32	36	34	42
23	31	25	33	21	29
17	23	19	24	15	21
12	16	13	17	11	15
33	39	32	38	38	39
55	74	61	79	50	69
70	81	77	82	63	79
59	80	65	84	53	74
45	62	50	64	41	57

Table 5.8 Minitab input for analyzing the effect of batches and sections on Strength of Materials subject of 4th semester

Std Order	Run Order	Batches	Sections	Marks	Std Order	Run Order	Batches	Sections	Marks
1	76	12	1	10	46	27	13	2	33
2	79	12	2	14	47	10	14	1	21
3	9	13	1	11	48	63	14	2	29
4	32	13	2	14	49	33	12	1	17
5	30	14	1	9	50	36	12	2	23
6	46	14	2	13	51	54	13	1	19
7	56	12	1	19	52	90	13	2	24
8	31	12	2	26	53	19	14	1	15
9	42	13	1	21	54	48	14	2	21
10	23	13	2	27	55	21	12	1	12
11	26	14	1	17	56	16	12	2	16
12	12	14	2	24	57	15	13	1	13
13	38	12	1	25	58	22	13	2	17
14	58	12	2	34	59	62	14	1	11
15	67	13	1	28	60	59	14	2	15
16	8	13	2	36	61	14	12	1	33
17	20	14	1	23	62	5	12	2	39
18	88	14	2	32	63	13	13	1	32
19	68	12	1	39	64	83	13	2	38
20	28	12	2	37	65	34	14	1	38
21	65	13	1	32	66	84	14	2	39
22	11	13	2	39	67	6	12	1	55
23	71	14	1	36	68	69	12	2	74
24	60	14	2	39	69	2	13	1	61
25	25	12	1	32	70	74	13	2	79
26	7	12	2	43	71	3	14	1	50
27	66	13	1	35	72	77	14	2	69

Std Order	Run Order	Batches	Sections	Marks	Std Order	Run Order	Batches	Sections	Marks
28	89	13	2	46	73	40	12	1	70
29	70	14	1	29	74	50	12	2	81
30	72	14	2	40	75	55	13	1	77
31	44	12	1	34	76	49	13	2	82
32	61	12	2	46	77	47	14	1	63
33	80	13	1	37	78	35	14	2	79
34	52	13	2	49	79	87	12	1	59
35	18	14	1	31	80	41	12	2	80
36	4	14	2	43	81	45	13	1	65
37	57	12	1	38	82	75	13	2	84
38	86	12	2	39	83	24	14	1	53
39	1	13	1	32	84	43	14	2	74
40	37	13	2	36	85	78	12	1	45
41	17	14	1	34	86	29	12	2	62
42	53	14	2	42	87	81	13	1	50
43	85	12	1	23	88	82	13	2	64
44	64	12	2	31	89	73	14	1	41
45	51	13	1	25	90	39	14	2	57

Table 5.9 Minitab result for two way ANOVA results for effect of batches and sections on Strength of Materials subject of 4th semester

Analysis of two way ANOVA					
Source	DF	Adj SS	Adj MS	F-Value	P-
Model	5	2130.5	426.1	1.08	0.376
Linear	3	2125.4	708.48	1.8	0.154
Batches	2	244.1	122.03	0.31	0.734
Sections	1	1881.4	1881.38	4.78	0.032
2-Way Interactions	2	5.1	2.53	0.01	0.994
Batch*Section	2	5.1	2.53	0.01	0.994
Error	84	33073.5	393.73		
Total	89	35204			

The Table 5.9 represents Minitab results for two way ANOVA results for effect of batches and sections on Strength of Materials subject of 4th Semester. It is clear from above analysis that for all the batches, there is significant difference between result of section 1 and section 2. Figure 5.7 and 5.8 illustrate results of two way ANOVA analysis for main effects and interaction between batches and sections on Strength of Materials subject of 4th semester. A multi voting analysis was also conducted among the students of 4^{th} Semester which reflects that students have voted Strength of material as very difficult subject. The results of multi voting analysis are presented in table 5.10.

Table 5.10 Multi voting analysis result of 50 students for 4^{th} semester subjects

S.No.	Subject	Very Easy	Easy	Average	Difficult	Very Difficult
1	Manufacturing Technology	22	12	10	6	
2	Thermal Engineering - II		22	13	9	6
3	Strength of Materials		6	12	12	20
4	Fluid Mechanics		12	16	12	10
5	Kinematics of Machines		10	12	13	15

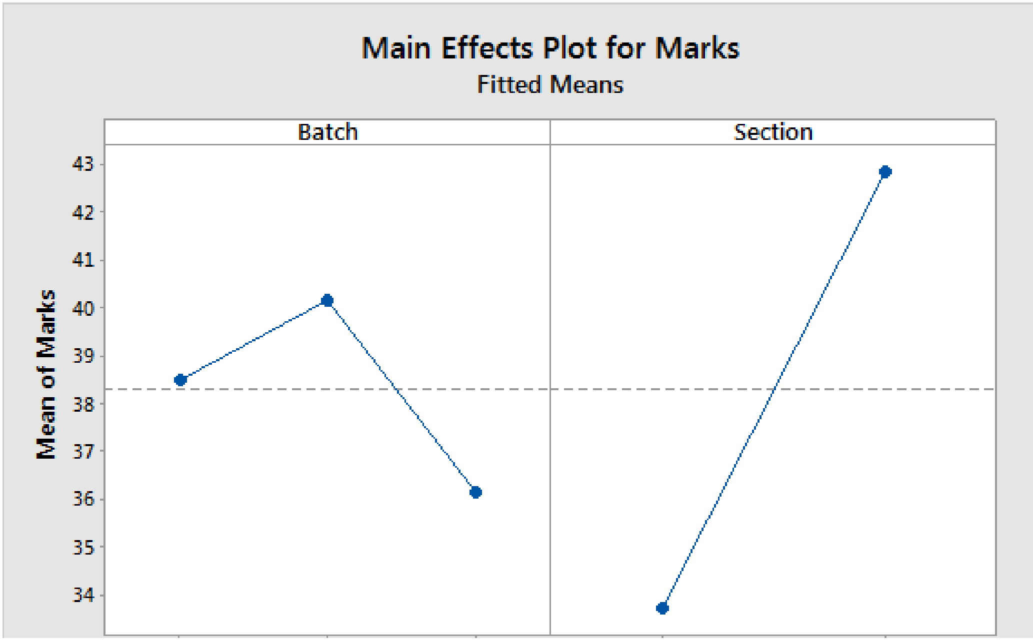

Figure 5.7 Two way ANOVA analysis for main effects between batches and sections on Strength of Materials subject of 4th semester

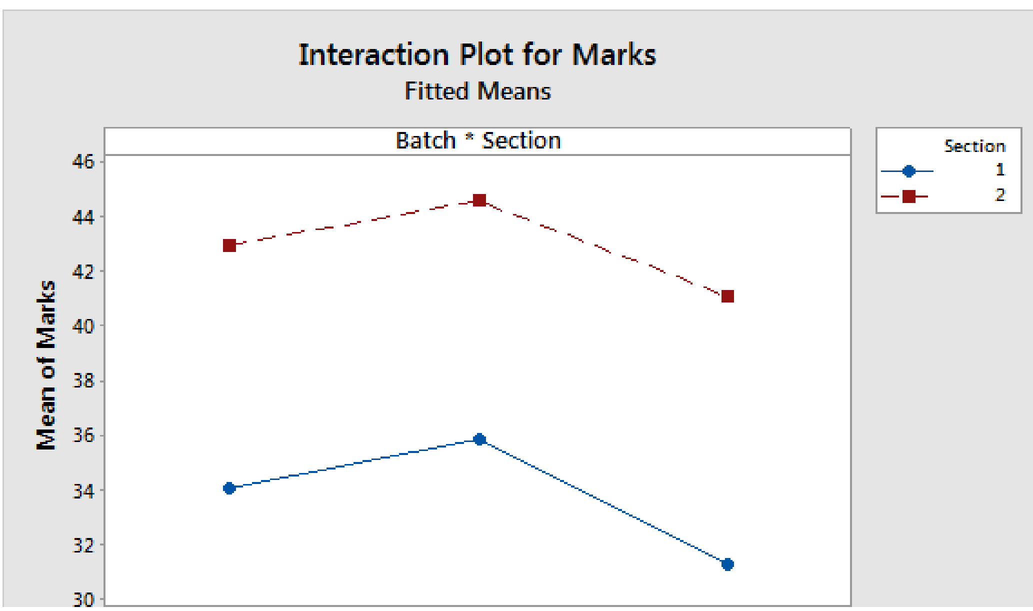

Figure 5.8 Two way ANOVA analysis for interaction plots between batches and sections on Strength of Materials subject of 4th semester

Improve and Control: During improve phases it is decided that how can us fix the process?, How to remove the causes of defects? The team quantifies effect of key variables on CTQs. It also identifies the maximum acceptable ranges of the key variables and validates a system for measuring deviation of the variable. In the present work, it was recommended to introduce standardization in the teaching learning as well as evaluation process. When more than one teacher is teaching a subject, the lesson plan and subject course material should be prepared by experienced teacher and shared among all teachers. In addition, during evaluation process, evaluator should be provided with answers of question paper. Suggested areas of improvement and Control plans are presented in Table 5.11. After implementing the recommendations, along with established control plan it was found that student passing ratio was improved by 8.45% and achieved a rate of 58.12%.

Table 5.11 Suggested areas of improvement and control plans

S.No.	Areas for Improvement	Targeted Persons	Suggested Improvements	Implementation Agency	Control parameters	Frequency	Status
1.	Student Passing Ratio	Students	To identify weaknesses in all students and take remedial steps. Plan and execution of bridge courses/remedial teaching (e.g. extra classes, tutorials) will bring all students to the required level of proficiency to cope with the main subjects.	Concerned Head of Department.	Analysis of Percent of students transiting from First to Second semester with all first semester courses passed.	Diagnostic tests and plans completed within first month of each academic semester, remedial measures carried out continuously thereafter.	Implemented
2.	Student Passing Ratio	Students	To appoint faculty counselor for students. A faculty counselor can be appointed to a group of 15 to 20 students. The students may ask for academic and non academic help when they need.	Faculty Counselor	Analysis of counselor weekly student interaction report	Counselors are to be appointed every year for students entering first year. Each	Counselor identified and 30 students assigned to each

S.No.	Areas for Improvement	Targeted Persons	Suggested Improvements	Implementation Agency	Control parameters	Frequency	Status
						counselor is to interact closely with assigned students.	counselor
3.	Student Placement Ratio	Students	To improve presentation skills through their wide use in curricula and where needed special skills training should be provided to students with priority to the weak students. In addition, personality of students may be nurtured by (i) conducting workshops by external experts & (ii) encouraging the students to make presentations to enhance self confidence(iii) conducting mock interviews.	Concerned Head of Department.	Monitoring improvement in Presentation skills of students, especially among those with disadvantaged backgrounds.	Monthly	Implemented

S.No.	Areas for Improvement	Targeted Persons	Suggested Improvements	Implementation Agency	Control parameters	Frequency	Status
4.	Student Placement Ratio	Students	To establish Industry institute collaboration cells in Institution. Industry. Industry-Academia collaboration will overcome the distrust between the two partners in terms of sharing technical knowledge and enhancing student placement ratio.	Training and placement officer	Monitoring Improvement in placement ratio of students.	Yearly	In process
5	Infrastructure	Students	To modernize the labs and to establish centre of excellence. Centre of excellence will create knowledge in thematic, multi disciplinary areas in collaboration with industry and other knowledge users.	Concerned Head of Department	Analysis of improvement in lab marks of students every semester.	After every semester	In process

S.No.	Areas for Improvement	Targeted Persons	Suggested Improvements	Implementation Agency	Control parameters	Frequency	Status
6	Faculty Qualification	Faculty Members	To provide under-qualified teachers priority in opportunities to upgrade qualifications. Institution to identify needs and indicate in their Faculty Development Plan how they would build equity to upgrade faculty qualifications.	Director	Monitoring increase in the percentage of teachers enrolled in M.Tech. and PhD.	After every six months	In process
7	Teaching Learning Process	Faculty Members	To impart training to faculty members and lab staff in subject matter and pedagogy, particularly to improve the performance of weak students. Training Needs Analysis (TNA) to be carried out for all faculty members in institution by appropriately qualified/trained experts, especially to teach weak students.	Director	Monitoring Percentage of planned training completed as reported/ aggregated six monthly.	TNA to be done before the preparation of Institutional Development Proposals; reporting every six months and remedial actions on a continuous basis.	Two short term courses conducted for faculty members and annual calendar planned for faculty development program.

5.2.3 Research Outcomes of Six Sigma in a Technical Institution

- The student passing ratio was improved by 8.45% and achieved a rate of 58.12%.
- It was recommended to standardize evaluation process by establishing standard operating procedures. Evaluators should be provided with answers of all the questions by concerned subject coordinator.
- It was suggested to identify opportunities for improvements in all students and take remedial steps. Plan and execution of bridge courses/remedial teaching (e.g. extra classes, tutorials) will bring all students to the required level of proficiency to cope with the main subjects.
- It was recommended to standardize teaching learning process by appointing subject coordinator when more than one teacher is taking the same subject. The subject lesson plan and study material should be prepared by subject coordinator.
- It was decided to establish Industry institute collaboration cells in Institution. Industry-Academia collaboration will overcome the distrust between the two partners in terms of sharing technical knowledge and enhancing student placement ratio.
- It was suggested to provide under-qualified teachers priority in opportunities to upgrade qualifications. It was further recommended to identify needs and indicate in their faculty development plan how they would build equity to upgrade faculty qualifications.

5.3 SIX SIGMA IN TELCOMMUNICATION

Before the advent of the Internet and other data networks, telecommunications clearly means telephone (and earlier the telegraph) was an application of technology that allowed people to communicate at a distance by voice (and earlier by encoded electronic signals), and telephone service was provided by the public switched telephone network (PSTN). Much of the U.S. network was owned and operated by American Telephone & Telegraph (AT&T); the rest consisted of smaller independent companies. Today Telecommunication includes landline mobile and broadband services. The customers think of telecommunication in terms of both products and services. The Services domain is considered as the area of present study. Lall & Gupta (2010) have proposed define-measure-analyze-improve-control methodology for service organization. They have further analyzed relevant Six-sigma tools for service industry and emphasized that Six Sigma methodology is next logical step for achieving improvement in customer service. Nakhai & Neves (2009) have found that extreme drive for adopting Six Sigma in service organizations has led both to limited field of application & unrealistic expectation as to what Six Sigma is truly capable of achieving particularly on service organizations. The authors have provided the application of Six Sigma in various service sectors like financial services, healthcare, education, construction, utility and government offices. They have also presented the service quality model and described the gap between Six Sigma and service quality. Natrajan & Morse (2009) have identified challenges in implementing Six Sigma to a core service process and recommended the use of information technology as powerful enabler for implementing Six Sigma methodologies. Banuelas et al (2006) have used the survey as method to investigate that what criteria is to be considered to select Six Sigma project and how potential projects are identified. Authors have further concluded that Six Sigma converts quality improvements in to bottom line financial benefits and project selection is a key factor to success.

5.3.1 Application of Six Sigma DMAIC Methodology in a Telecommunication Organization

Service resolution time is one of the most significant dimensions of quality of a service process. The present case study deals with reducing service resolution time for customer queries process in a service organization. The organization was doing a poor job towards resolution of customer complaints and quarries. The repeated customer complaints and dissatisfaction were causing a financial loss of rupees one million every year to the organization. CTQs identified from previous data were service resolution time, level of expertise, system down time, system reliability, and accuracy of information are presented in figure 5.10. Service resolution time was most critical among all CTQs. Hence it was taken as Problem of Six Sigma project. The goal statement of problem was to reduce mean service resolution time by 25% which was approximately 10 hours. The project team includes a champion, a black belt, two green belts, process owner, and one management trainee. A snap shot representing high level process map for entire approach is shown in figure 5.9.

Define: In define phase of Six-sigma project team defines project suitable for Six Sigma efforts based on critical to quality characteristics. In the present study, Six Sigma team had brain storming sessions with process owner and concerned people, and cause & effect diagram was drawn as presented in figure 5.11.The causes were identified as personnel, method, measurement, material, machine and environment.

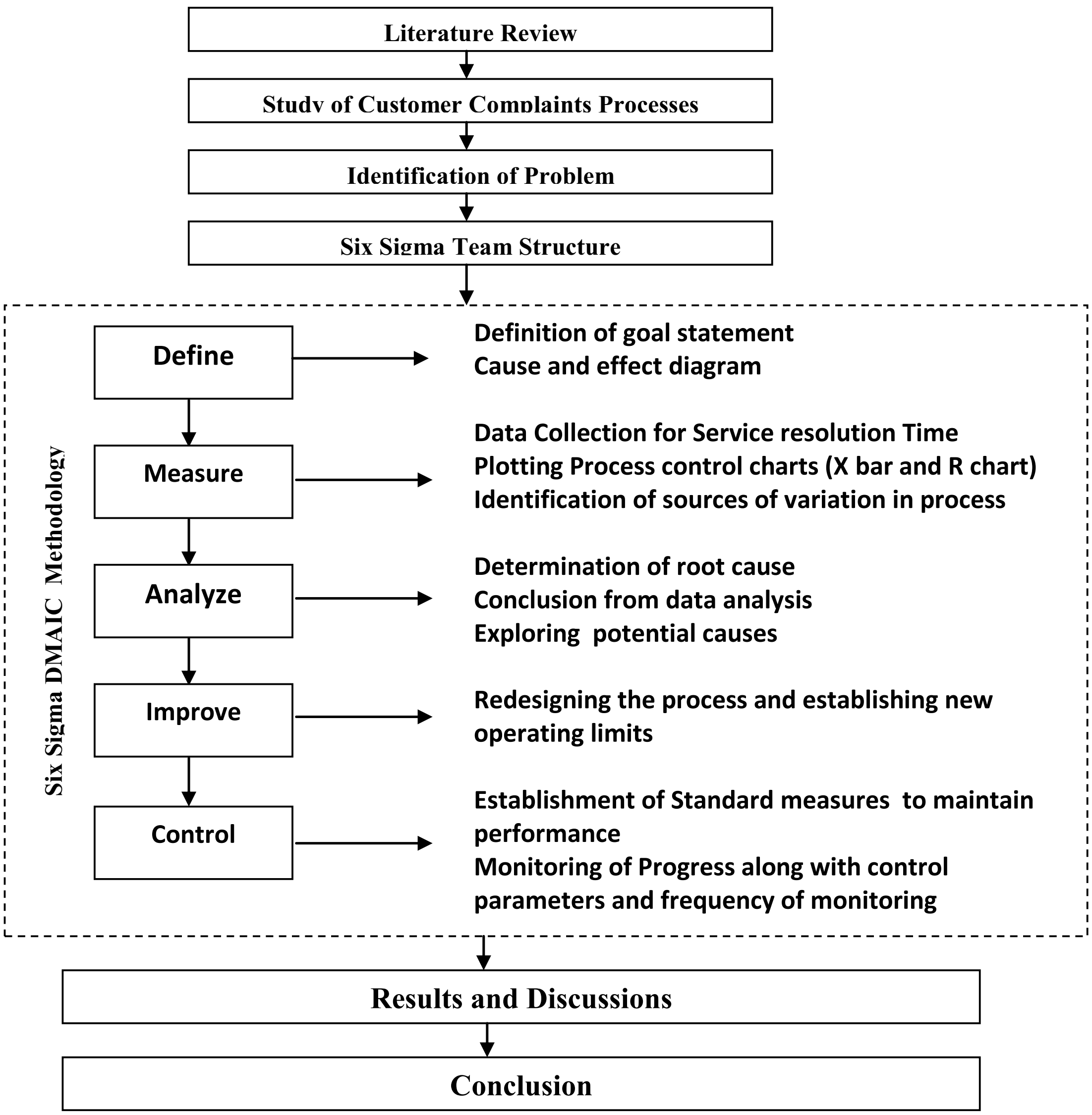

Figure 5.9 High level process map for Six Sigma approach

Measure: In measure phase, it is measured how the process is performing. In addition it is determined that what to measure and, how to measure. In present study, it was decided to collect data for service resolution time for four weeks (20 days) so that data could be analyzed further. Table 5.12presents sservice resolution time in hours for customer complaints processes

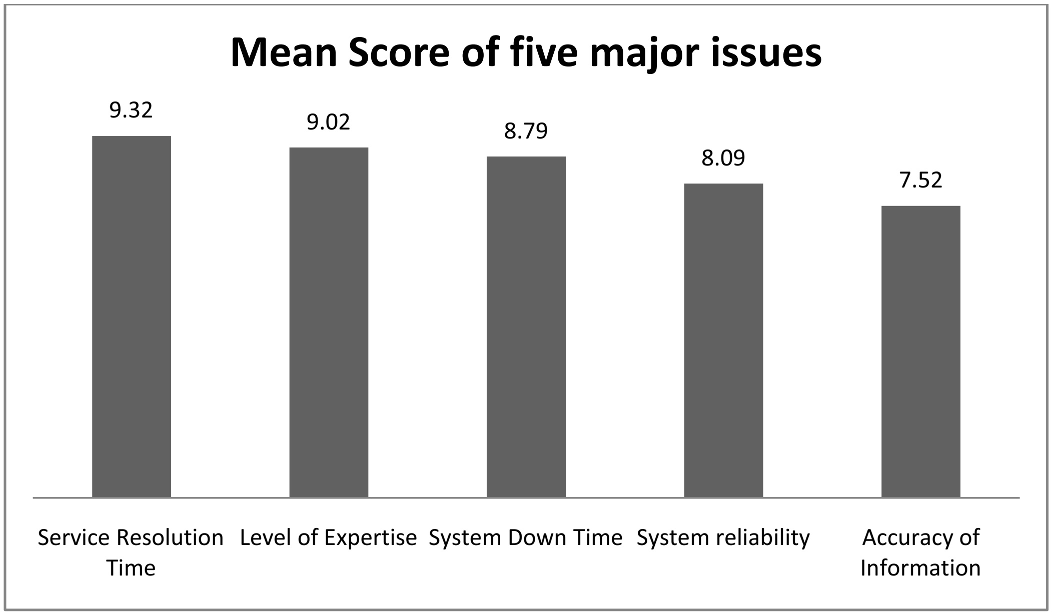

Figure 5.10 Mean score of five major issues in a telecommunication organization

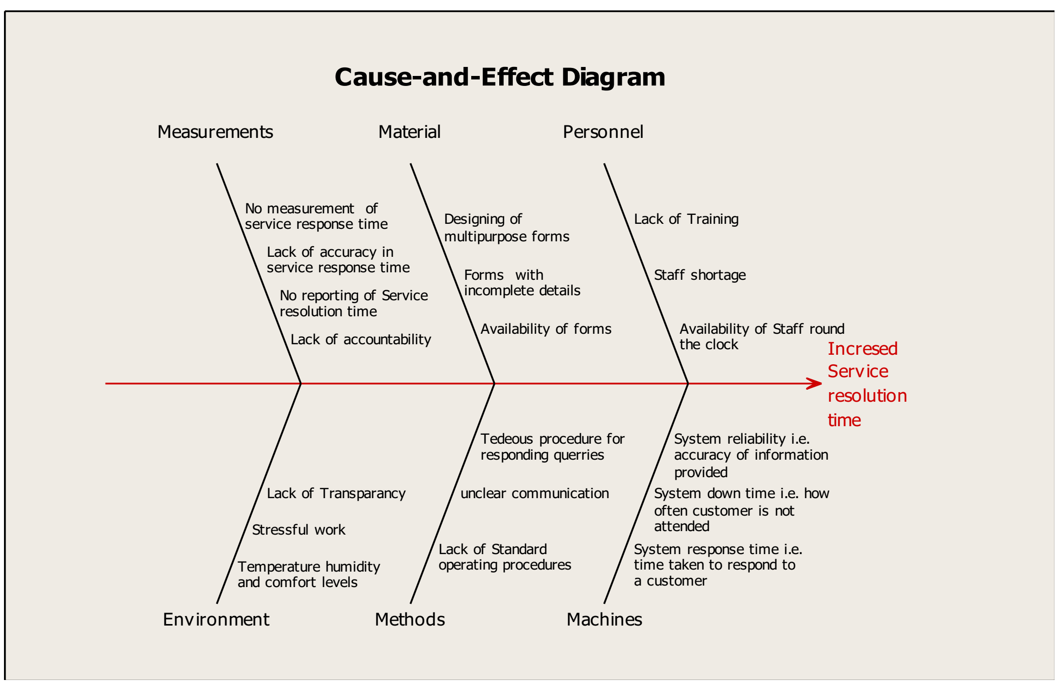

Figure 5.11 Cause and effect diagram for increased service resolution time.

Table 5.12 Service resolution time in hours for customer complaints processes

Subgroup number	Day of the week	Service resolution time in hours					
1.	Tuesday	11.2	8.2	10	9.5	8.1	11.3
2.	Wednesday	7.8	11	10.7	11.7	9.8	8.7
3.	Thursday	10.2	10.7	8.9	10.9	10	11.5
4.	Friday	10.3	8.1	10.7	10.8	10.2	8.5
5.	Saturday	14.2	12.2	11.7	10.8	13.2	12.7
6.	Tuesday	9.8	8.7	11	8.6	10	9.3
7.	Wednesday	10.2	10.8	10.3	8.2	9.8	11
8.	Thursday	10.3	9.2	8.7	10.2	8.1	10.5
9.	Friday	10	8.2	11	11	10.5	11.5
10.	Saturday	13	11.8	10.8	12.5	12.8	13.8
11.	Tuesday	10.2	7.9	10	10.2	9.2	8.1
12.	Wednesday	9.8	9.2	9.9	10.5	8.3	8
13.	Thursday	8.1	9.5	8	10.7	10.8	10.3
14.	Friday	7.8	8.1	10.5	10.3	11.7	10.5
15.	Saturday	12.5	11	11.8	14.3	12.7	13.5
16.	Tuesday	9.8	10.5	10.7	10.8	11	8
17.	Wednesday	9.2	8.3	10.3	10.5	8.2	10.8
18.	Thursday	8.8	10	10.7	10.5	10.2	9.8
19.	Friday	7.7	8.9	10.2	11	10.3	11
20.	Saturday	12.5	10.7	12	14.2	13.3	12.2

Analyze: Figure 5.12 reveals that average service time for 5th, 10th, 15th, and 20th subgroup has jumped above UCL. On further investigation, it was discovered that on every Saturday concerned service executive was on leave for his personal reasons and a trainee was dealing with clients, hence it took more time on Saturdays. It was decided to effectively supervise and provide hands on training sessions to all the trainees in organization. To ensure that on other working days, service resolution time was with in control, Saturdays were excluded from data provided in table 5.13 and again control limits were recalculated from remaining 16 subgroups and x bar and R chart were again plotted as shown in figure 5.13.

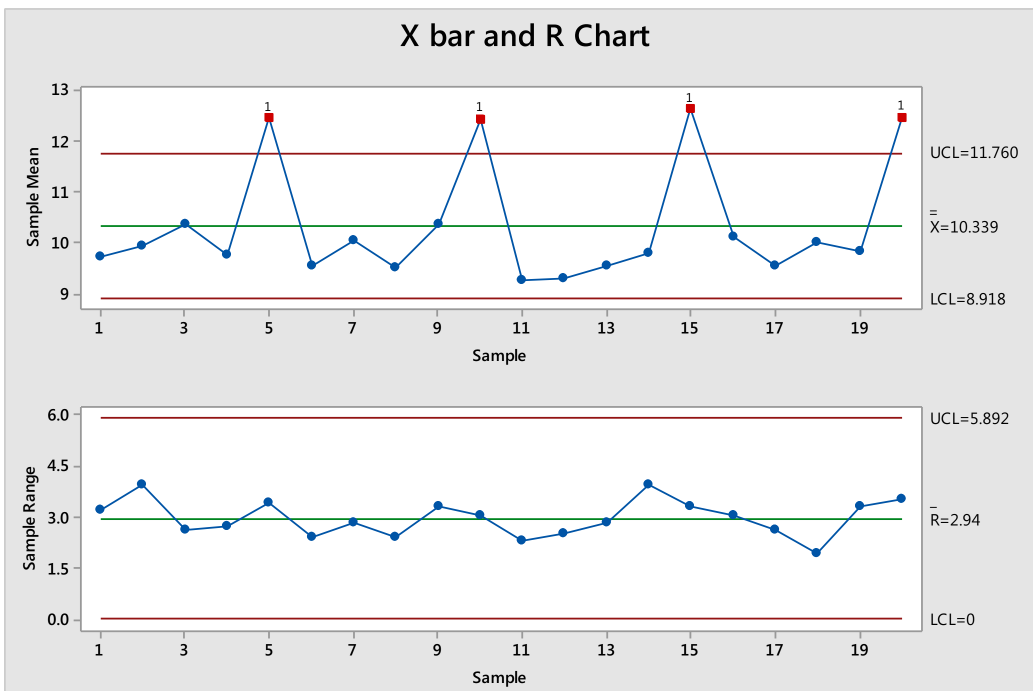

Figure 5.12 X bar and R chart of 20 sub groups for customer complaint processes

Table 5.13 Service resolution time in hours for customer complaints processes excluding Saturdays

Subgroup number	Day of the week	Service resolution time in hours					
1.	Tuesday	11.2	8.2	10	9.5	8.1	11.3
2.	Wednesday	7.8	11	10.7	11.7	9.8	8.7
3.	Thursday	10.2	10.7	8.9	10.9	10	11.5
4.	Friday	10.3	8.1	10.7	10.8	10.2	8.5
5.	Tuesday	9.8	8.7	11	8.6	10	9.3
6.	Wednesday	10.2	10.8	10.3	8.2	9.8	11
7.	Thursday	10.3	9.2	8.7	10.2	8.1	10.5
8.	Friday	10	8.2	11	11	10.5	11.5
9.	Tuesday	10.2	7.9	10	10.2	9.2	8.1
10.	Wednesday	9.8	9.2	9.9	10.5	8.3	8
11.	Thursday	8.1	9.5	8	10.7	10.8	10.3
12.	Friday	7.8	8.1	10.5	10.3	11.7	10.5
13.	Tuesday	9.8	10.5	10.7	10.8	11	8
14.	Wednesday	9.2	8.3	10.3	10.5	8.2	10.8
15.	Thursday	8.8	10	10.7	10.5	10.2	9.8
16.	Friday	7.7	8.9	10.2	11	10.3	11

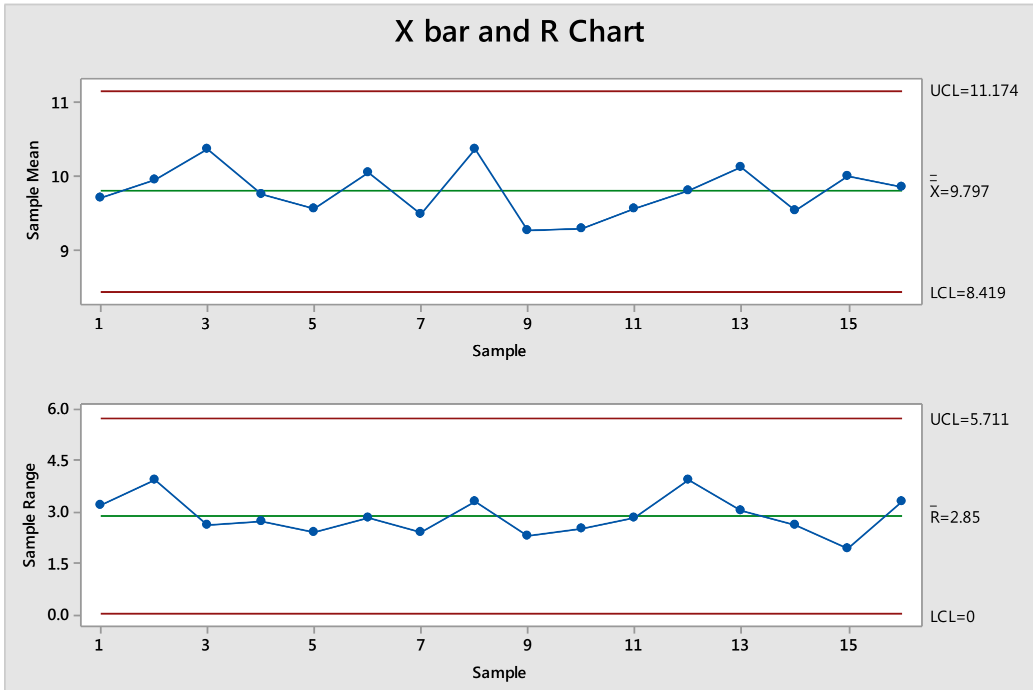

Figure 5.13 X bar and R chart for 16 subgroups excluding Saturdays

The Cp and Cpk of the process as shown in figure 5.14 are calculated as follows: $Cp = \frac{USL - LSL}{6\,\sigma}$ $\quad Cp = \frac{8-7}{6*6.774} = 0.148$ and & σ = R bar/d2

σ = 2.85/ 2.534 = 1.124

Where cp = process capability, USL = upper specification limit, LSL = lower specification limit, σ = standard deviation, R bar = mean range of all subgroups and d2 = constant depending upon subgroup size (subgroup size is 6 for present case)

$$Cpu = \frac{USL - x\ double\ \ bar}{3\ \sigma} \qquad Cpu = \frac{8\ - 9.79}{3 * 1.124} = -0.53$$

Where cpu = upper process capability index, USL = upper specification limit, x double bar is mean of subgroups mean, R bar = mean range of all subgroups and d2 = constant depending upon subgroup size (subgroup size is 6 for present case)

$$Cpl = \frac{x\ double\ \ bar - LSL}{3\ \sigma} \qquad Cpl = \frac{9.79\ - 7}{3 *\ 1.124} = 0.83$$

Where cpl = lower process capability index, USL = upper specification limit, x double bar is mean of subgroups mean, R bar = mean range of all subgroups and d2 = constant depending upon subgroup size (subgroup size is 6 for present case). The process capability index cpk is minimum of cpk and Cpl and equal to - 0.53. The process was within statistical control after excluding Saturdays with x double bar = 9.79, process capability Cp= 0.83 and process capability index Cpk = - 0.53, but the process was off centered and target to achieve average service resolution time of 7.5 hours has not yet achieved It means that even experienced service executives were not meeting the goal

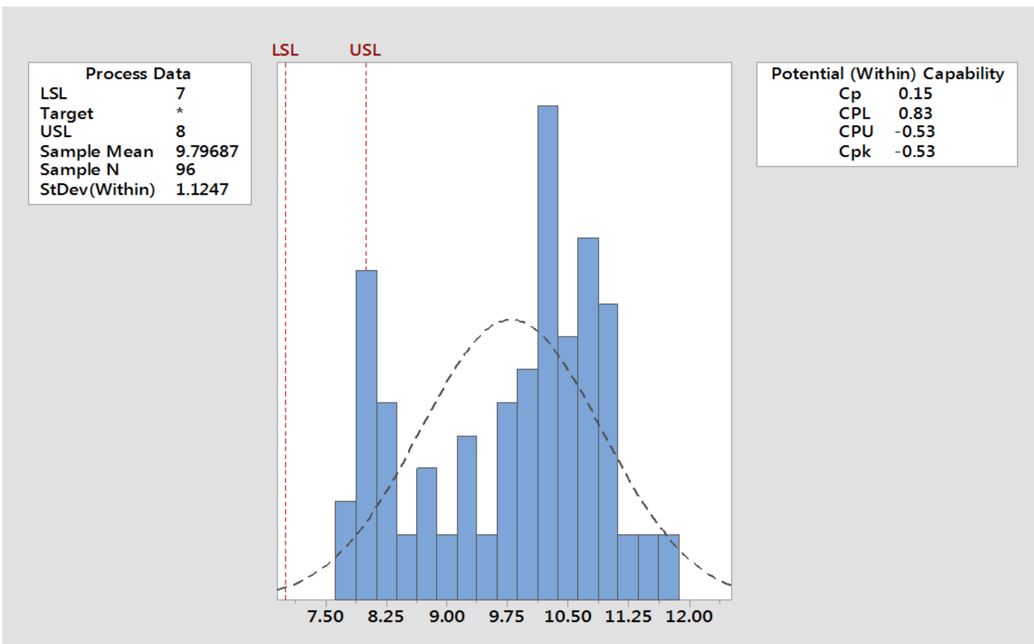

Figure 5.14 Process capability before redesigning the processes

Improve and Control: To further reduce service resolution time, one option was to hire more service executives and invest more resources but it was not monetarily viable option. So it was decided to collect and analyze the data based on the type of service provided. Six type of services i.e. service process 1, 2, 3, 4, 5, 6.namely 1- Modem related problems, 2- Adopter related problems, 3- Splitter related problems,4- Drop wire related problem, 5- Telephone instrument related problems and 6- Cable related problems. Table 5.14 to 5.19 present service resolution time in hours for six processes where as figures 5.16 to 5.21 illustrate X bar and R chart for aforementioned processes. After sub grouping and analyzing the data based on type of service, it was discovered that service process 4 and 6 have average time of 12 hours.

On further investigating service processes 4 and 6, it was discovered that Standard Operating Procedures (SOPs) for these service processes were not clearly defined and documented. After redesigning Standard Operating Procedures (SOPs) for these service processes, mean service resolution time was reduced to 7.7 hours as shown in figure 5.15. It was further recommended to monitor the process performance regularly through process control charts.

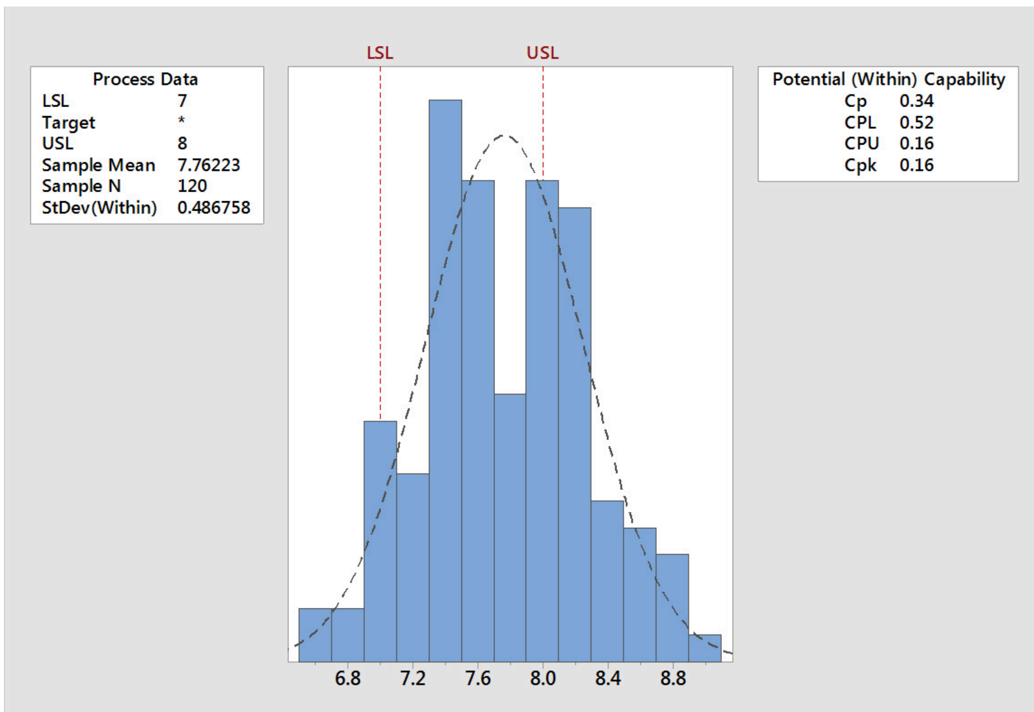

Figure 5.15 Process capability after redesigning the processes

Table 5.14 Service resolution time in hours for process 1

Subgroup number	Day of the week	Modem related problems - process 1			
1.	Tuesday	7.9	7.8	7.7	8.3
2.	Wednesday	7.5	7.4	7.3	7.9
3.	Thursday	8.0	7.9	7.8	8.4
4.	Friday	7.7	7.6	7.5	8.1
5.	Saturday	7.9	7.8	7.7	8.3
6.	Tuesday	7.6	7.5	7.4	8.0
7.	Wednesday	8.1	8.0	7.9	8.5
8.	Thursday	7.9	7.8	7.7	8.3
9.	Friday	8.3	8.2	8.1	8.7
10.	Saturday	8.1	8.0	7.9	8.5
11.	Tuesday	7.5	7.4	7.3	7.9
12.	Wednesday	7.8	7.7	7.6	8.2
13.	Thursday	7.6	7.5	7.4	8.0
14.	Friday	8.3	7.9	8.1	8.7
15.	Saturday	7.8	7.7	7.6	8.2
16.	Tuesday	8.2	8.1	8.0	8.6
17.	Wednesday	8.0	7.9	7.8	8.4
18.	Thursday	7.7	7.6	7.5	8.1
19.	Friday	8.2	8.1	8.0	8.6
20.	Saturday	7.5	7.4	7.3	7.9

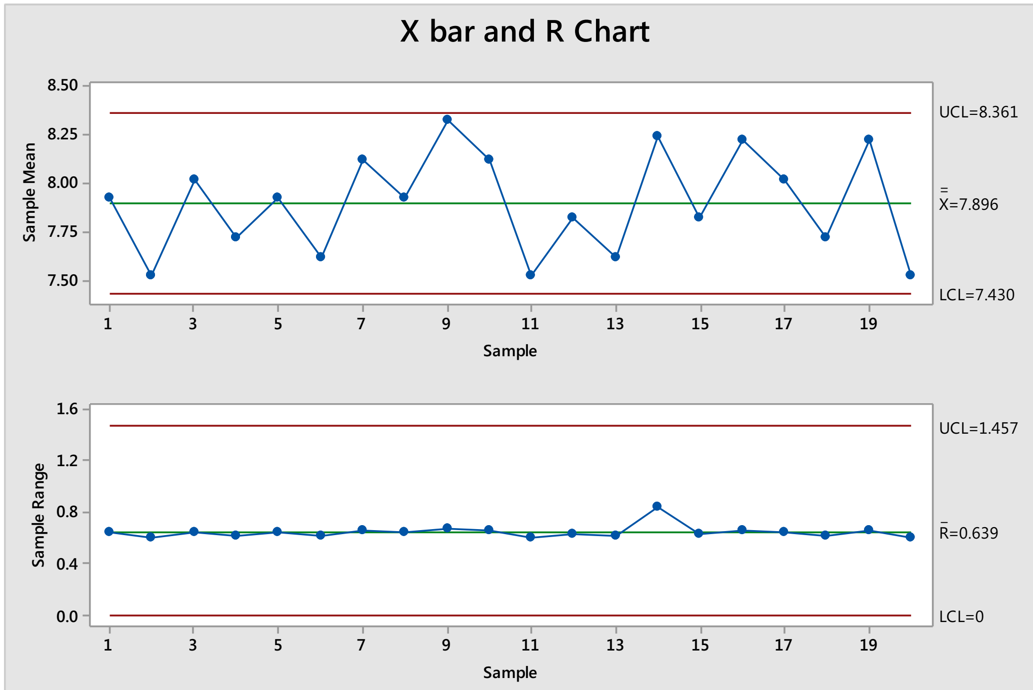

Figure 5.16 X bar and R chart for service process 1

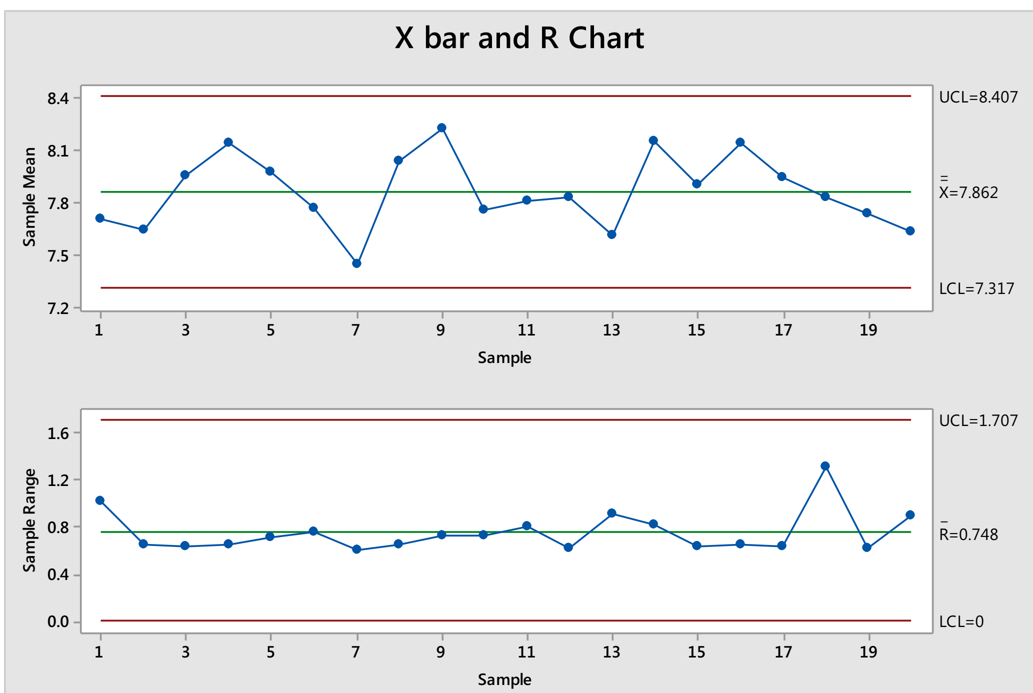

Figure 5. 17 X bar and R chart for service process 2

Table 5.15 Service resolution time in hours for process 2

Subgroup number	Day of the week	Adopter related problems – process 2			
1.	Tuesday	7.8	7.2	7.6	8.2
2.	Wednesday	7.4	7.4	8.0	7.8
3.	Thursday	7.9	7.9	7.7	8.3
4.	Friday	8.1	8.0	7.9	8.5
5.	Saturday	7.8	8.3	7.6	8.2
6.	Tuesday	7.5	7.4	8.2	7.9
7.	Wednesday	7.4	7.4	7.2	7.8
8.	Thursday	8.0	7.9	7.8	8.4
9.	Friday	8.2	8.1	7.9	8.6
10.	Saturday	8.0	7.9	7.8	7.3
11.	Tuesday	7.6	8.2	7.4	8.0
12.	Wednesday	7.7	8.0	7.5	8.1
13.	Thursday	7.5	7.4	7.3	8.2
14.	Friday	8.2	7.8	8.0	8.6
15.	Saturday	7.8	8.0	7.6	8.2
16.	Tuesday	8.1	8.0	7.9	8.5
17.	Wednesday	7.9	7.8	7.7	8.3
18.	Thursday	7.6	7.2	8.5	8.0
19.	Friday	7.7	7.6	7.5	8.1
20.	Saturday	7.4	8.1	7.2	7.8

Table 5.16 Service resolution time in hours for process 3

Subgroup number	Day of the week	Splitter related problems – process 3			
1.	Tuesday	8.0	7.7	8.4	7.3
2.	Wednesday	7.6	8.2	8.5	7.5
3.	Thursday	8.1	7.8	8.5	8.0
4.	Friday	7.8	7.5	8.2	8.4
5.	Saturday	8.0	7.7	8.4	8.5
6.	Tuesday	7.7	8.4	8.1	7.6
7.	Wednesday	8.2	7.9	7.5	8.1
8.	Thursday	8.0	7.7	8.4	8.2
9.	Friday	8.4	8.1	7.6	7.5
10.	Saturday	8.2	7.9	7.4	8.1
11.	Tuesday	7.6	7.3	8.0	7.5
12.	Wednesday	7.9	7.6	8.3	8.3
13.	Thursday	7.7	7.4	8.4	7.6
14.	Friday	8.4	8.1	8.8	8.0
15.	Saturday	7.9	7.6	8.3	7.8
16.	Tuesday	8.3	8.0	8.7	8.2
17.	Wednesday	8.1	7.8	8.5	8.0
18.	Thursday	7.8	8.7	8.2	7.7
19.	Friday	8.3	8.0	8.7	8.2
20.	Saturday	7.6	7.3	8.0	8.3

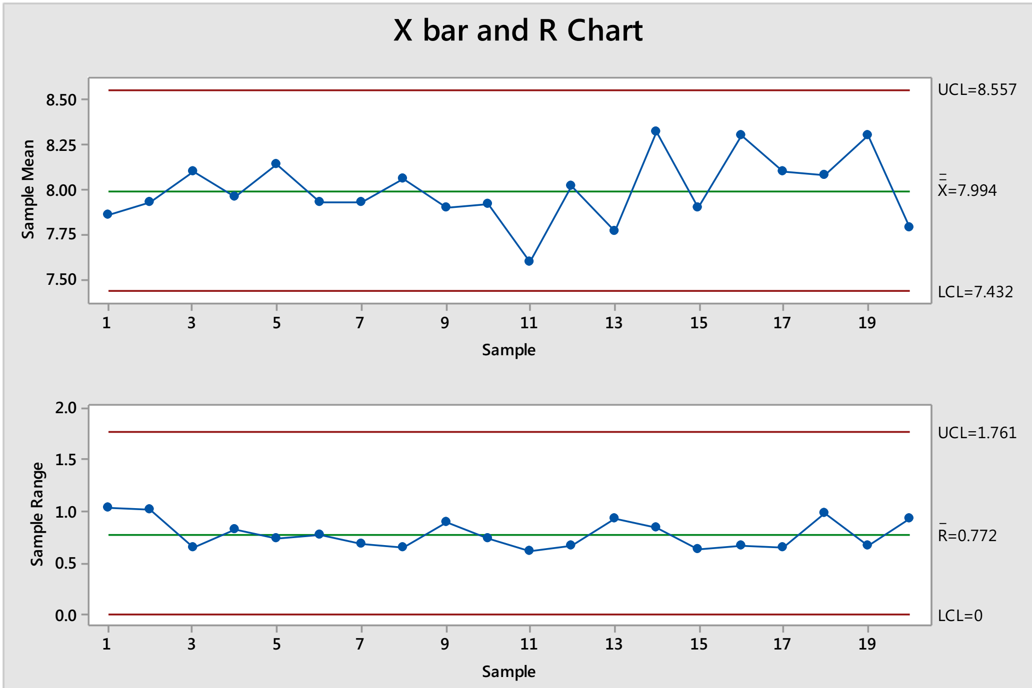

Figure 5.18 X bar and R chart for service process 3 `

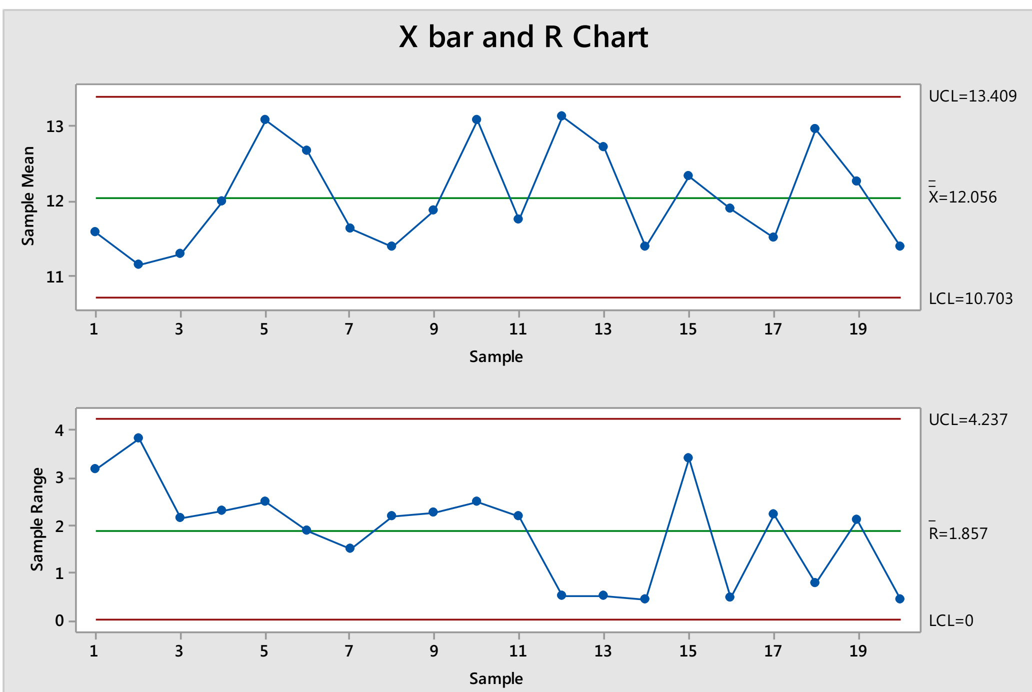

Figure 5.19 X bar and R chart for service process 4

Table 5.17 Service resolution time in hours for process 4

Subgroup number	Day of the week	Drop wire related problems – process 4			
1.	Tuesday	11.0	10.0	12.1	13.2
2.	Wednesday	9.3	13.1	10.2	12.0
3.	Thursday	11.4	10.4	12.5	10.8
4.	Friday	12.1	11.0	13.3	11.5
5.	Saturday	13.2	12.0	14.5	12.5
6.	Tuesday	12.4	12.9	13.6	11.8
7.	Wednesday	10.7	12.2	11.8	11.9
8.	Thursday	11.5	10.5	12.7	10.9
9.	Friday	12.0	10.9	13.2	11.4
10.	Saturday	13.2	12.0	14.5	12.5
11.	Tuesday	13.1	12.0	10.9	11.0
12.	Wednesday	12.9	13.4	13.2	13.0
13.	Thursday	12.5	13.0	12.8	12.6
14.	Friday	11.2	11.6	11.4	11.3
15.	Saturday	13.9	12.7	10.5	12.2
16.	Tuesday	11.7	12.2	11.9	11.8
17.	Wednesday	10.5	10.9	12.7	11.9
18.	Thursday	13.0	12.5	13.3	13.1
19.	Friday	12.2	11.2	13.3	12.3
20.	Saturday	11.2	11.6	11.4	11.3

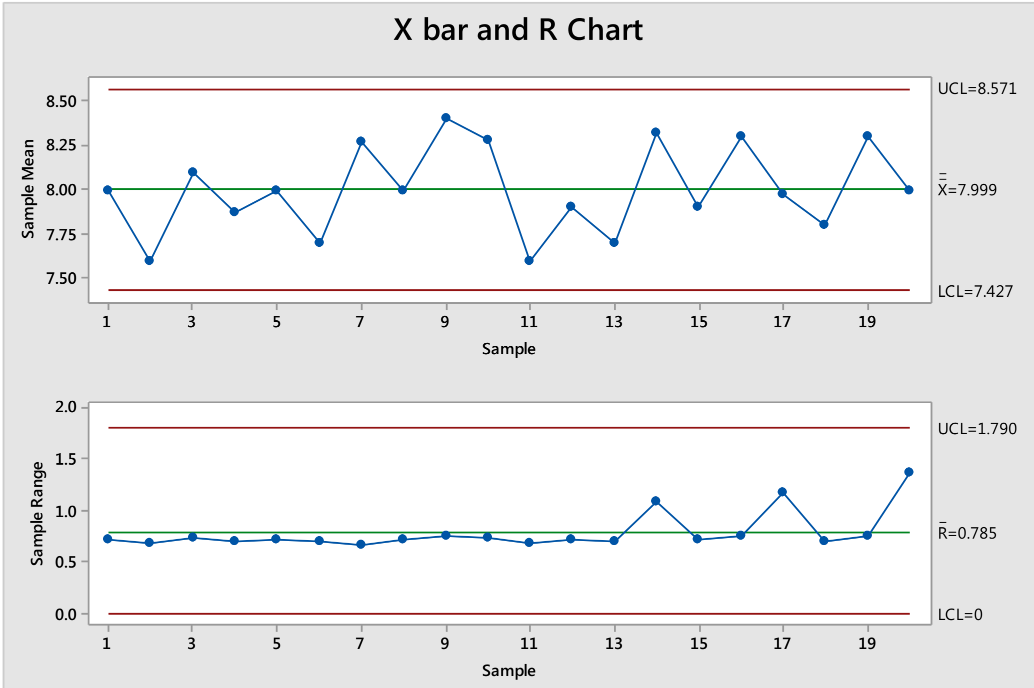

Figure 5.20 X bar and R chart for service process 5

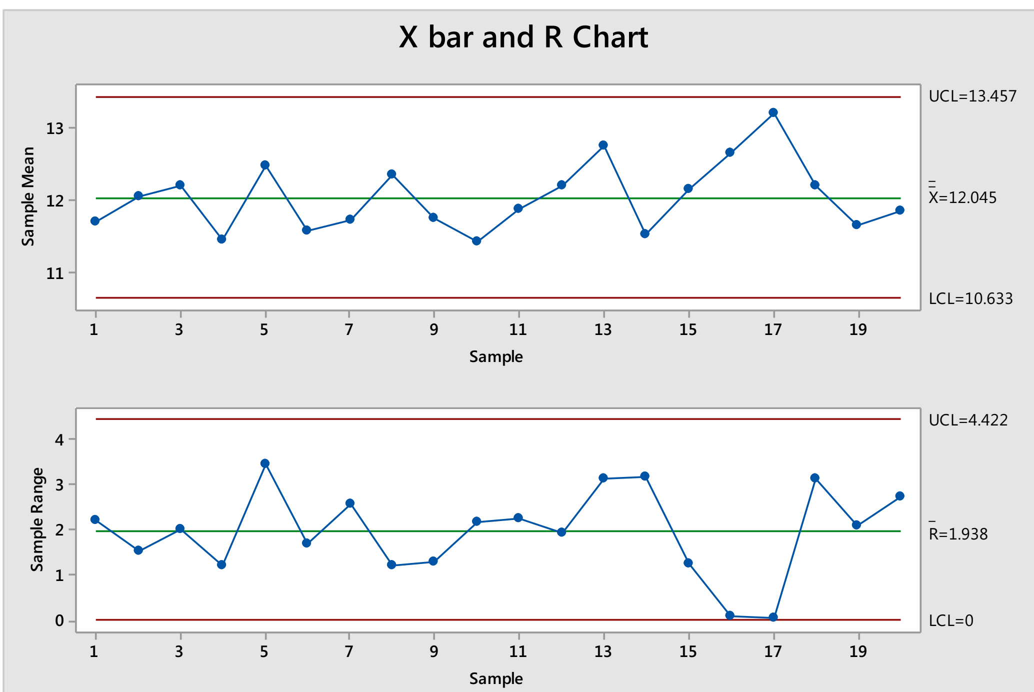

Figure 5.21 X bar and R chart for service process 6

Table 5.18 Service resolution time in hours for service process 5

Subgroup number	Day of the week	Instrument related problems – process 5			
1.	Tuesday	8.5	8.0	7.8	7.7
2.	Wednesday	8.0	7.6	7.4	7.4
3.	Thursday	8.6	8.1	7.9	7.8
4.	Friday	8.2	7.8	7.9	7.5
5.	Saturday	8.5	8.0	7.8	7.7
6.	Tuesday	8.1	7.7	7.5	7.4
7.	Wednesday	8.7	8.2	8.0	8.2
8.	Thursday	8.5	8.0	7.8	7.7
9.	Friday	8.9	8.4	8.2	8.1
10.	Saturday	8.7	8.5	8.0	7.9
11.	Tuesday	8.0	7.6	7.4	7.4
12.	Wednesday	8.4	7.9	7.7	7.6
13.	Thursday	8.1	7.7	7.5	7.4
14.	Friday	8.9	8.4	8.2	7.8
15.	Saturday	8.4	7.9	7.7	7.6
16.	Tuesday	8.8	8.3	8.1	8.0
17.	Wednesday	8.6	8.1	7.4	7.8
18.	Thursday	8.2	7.8	7.6	7.5
19.	Friday	8.8	8.3	8.1	8.0
20.	Saturday	8.0	8.7	7.9	7.4

Table 5.19 Service resolution time in hours for service process 6

Subgroup number	Day of the week	Cable related problems			
1.	Tuesday	13.1	10.9	11.0	11.8
2.	Wednesday	12.9	11.4	12.0	11.9
3.	Thursday	12.5	12.5	12.9	10.9
4.	Friday	11.2	11.0	12.2	11.4
5.	Saturday	13.9	13.0	10.5	12.5
6.	Tuesday	11.7	12.6	10.9	11.0
7.	Wednesday	10.5	11.3	12.0	13.0
8.	Thursday	13.0	11.8	12.0	12.6
9.	Friday	12.2	10.9	11.8	12.1
10.	Saturday	11.2	12.4	11.9	10.2
11.	Tuesday	13.2	10.9	10.9	12.5
12.	Wednesday	12.8	11.4	11.4	13.3
13.	Thursday	11.4	12.5	12.5	14.5
14.	Friday	10.5	11.0	11.0	13.6
15.	Saturday	11.9	13.0	11.9	11.8
16.	Tuesday	12.7	12.6	12.7	12.7
17.	Wednesday	13.3	13.2	13.3	13.2
18.	Thursday	13.3	12.0	13.3	10.2
19.	Friday	11.4	10.8	11.4	12.9
20.	Saturday	10.5	11.5	12.2	13.2

5.3.2 Research Outcome of Six Sigma in a Telecommunication Organization

- Average Service Resolution time was reduced to 7.7 hours from 10.3 hours.
- It was decided to effectively supervise and provide hands on training sessions to all the trainees in organization.
- It was recommended to categorize the problems based on the severity and time taken to resolve the problem.
- It was decided that standard operating procedures for cable related problems should be clearly defined and documented.

5.4 SIX SIGMA IN MANUFACTURING

DMAIC - define-measure-analyze-improve-control methodology is widely talked about approach in Six sigma. DMAIC methodology is widely used for existing problems. Six Sigma methodologies are justified when root cause of defect is not traceable The present work deals with elimination of casting defects in an automobile supplier company. The application of DMAIC methodology in casting process is chosen because casting is a very versatile process, which has many steps right from pattern making to fettling. Being a multistage process it is characterized by variations in each stage and has a wide scope of improvement in each stage. In even casting processes the sand casting is the process in which large numbers of variables are to be controlled and optimized at every stage. Following is the few papers relating to Application of Six Sigma in casting process. Syrcos (2003) has studied significant process parameters affecting aluminium alloy die casting. He has worked for achieving optimal parameters of die casting process in order to yield optimum casting density of aluminium alloy. Kumar, S. et al. (2011) have studied casting defects of cast iron differential housing cover casting. The authors have used orthogonal array to analyze various criterion effecting process parameters and their levels. Surekha et al. (2012) have optimized process parameters including green compression strength, permeability, hardness and bulk density using evolutionary genetic algorithm and particle swarm optimization. The authors have developed a multi objective optimization of green sand mold system. Singh and Khanduja (2011) have identified various problems of industries which act as bottlenecks for optimizing a process in foundry. The authors have further recommended a integrated approach of Design of

Experiments for implementation in product or process type industrial environment. Shen et al. (2007) have proposed a model to combine artificial neural network and genetic algorithm to optimize injection molding process. A large number of experimental investigations linking green sand casting parameters have been carried out by researchers and foundry engineers over past few decades and it is established fact that green sand plays one of key factors in quality of sand castings. Some of the factors are controllable where as other are noise factors (Haq et al., 2009; Guharaja et al., 2006). Muzzammil et al. (2003) have conducted work for optimizing gear blank using taguchi robust design technique.

5.4.1 Application of Six Sigma DMAIC Methodology in a Foundry Shop

The sand casting process in the present study has been divided in three stages; first stage include sand preparation, mold making and core making, second stage includes melting and pouring of the metal and maintaining accurate chemical composition and third stage includes fettling, cleaning and machining operations of the castings. The existing casting defects revealed from previous data were metal penetration, sand fusion and blow holes. The factors which have been found to be affecting these defects are:

1. Increased metal penetration occurs with increased grain size or poor ramming of the sand.
2. Increased penetration occurs with increased carbon contents.
3. Inadequate use of mold washes and mold-facing materials causes penetration.
4. Large metal mass compared with small sand mass causes metal penetration.
5. Moisture or other gases in the sand may react with the sand or metal to open channels for metal penetration.
6. Cores not properly vented may cause blowholes.
7. When molding sand or core sand is not sufficiently strong it may cause sand fusion.
8. The longer molten metal is held in contact with sand the greater the chance for metal penetration.
9. High pouring temperature leads to penetration and sand fusion

10. Increased metal pressure increases the metal penetration. Normally metal does not penetrate sand because of surface tension effects, the effect of pressure overcome the normal resistance offered by surface tension. High metal pressures are directly related to the differential metal head that exists in molten metal.

Factors from serial number one to seven affect the first stage of process and factors eight, nine and ten affect second stage of the process. Defects declared at serial number eight and nine can be eliminated or reduced by automation of pouring process or by employing highly skilled workers so that pouring time could be minimized. Defect arising because of factor at serial number ten may be eliminated by modifying the gating design and by changing the taper of the sprue. It is evident from above discussion that defects in first phase such as sand preparation, mold making and core making is Critical to Quality characteristics (CTQs) for producing a superior quality casting. The Six Sigma team for the present study includes a black belt, two green belts and two process owners.

Define: In Six Sigma DMAIC methodology, problem is defined with the basic equation Y = f (X) which defines the relationship between the dependent variable Y (and the outcome of the process) and a set of independent variable or possible causes that effect the problem. In the present case study dependent variable Y is porous core where as X is the set of independent variables, which may affect all the three phases of casting process. The process mapping of sand casting process is shown in figure 5.22.

Measure: Measurement is the first step that leads to control and eventually to improvement. If we can't, measure something, you cannot understand it. Further if we cannot understand it, we cannot control it and if we cannot control, it cannot be improved. The measurement phase is concerned with selecting one or more product characteristics, mapping the process, making the necessary measurements, recording the results on control charts and establishing a base line of process capability.

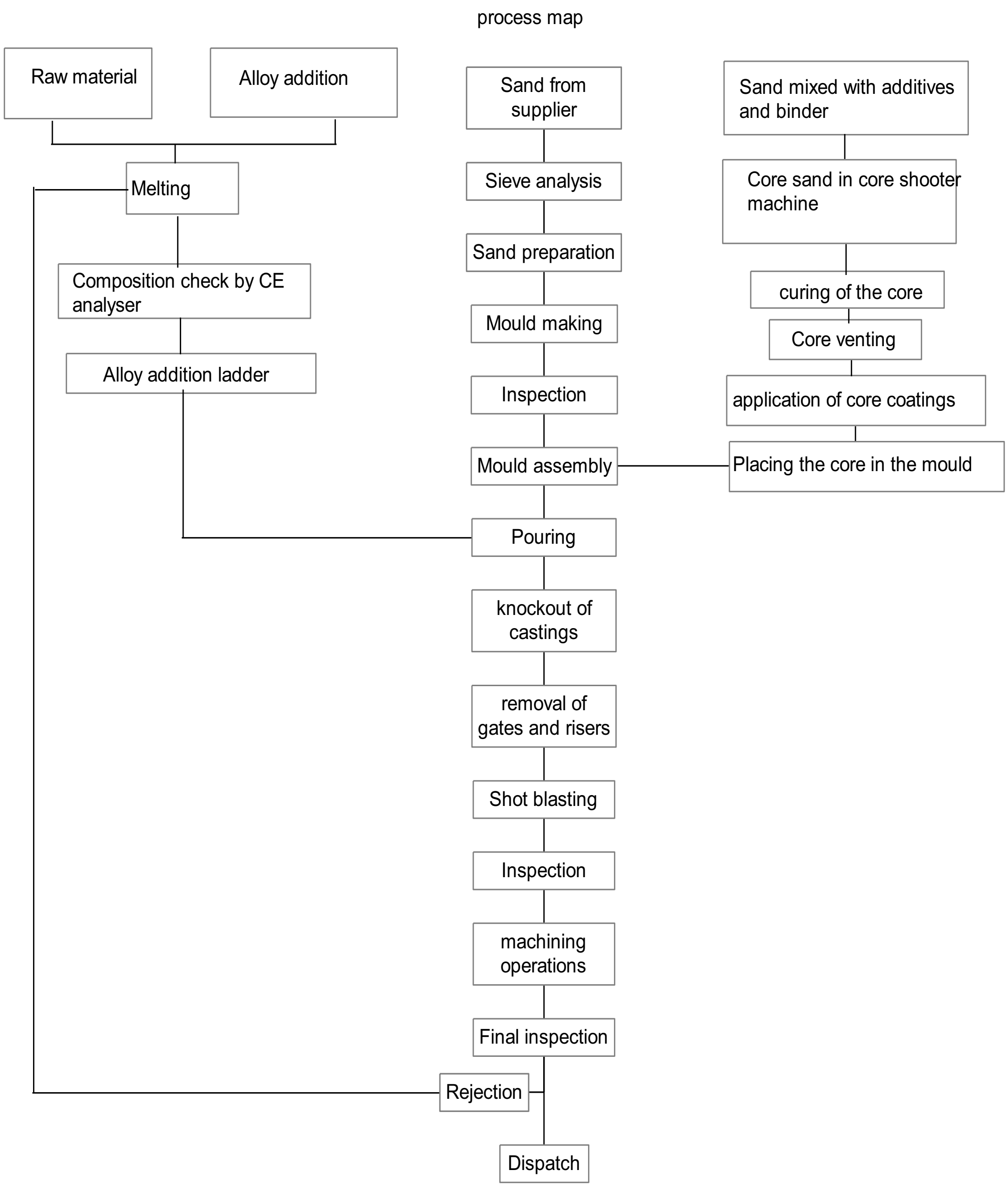

Figure 5.22 Process mapping of sand casting process

In the present work American Society men's Society (AFS) number of sand is found out by performing sieve analysis. AFS grain fineness number is number of average grain size and convenient means of describing relative fineness of sand. In AFS sieve analysis size and distribution of sand grains in sand is determined. A dried 50 grams sand sample is used. The sample is placed on the top of sieve and shaken for 15 minutes. After shaking period, the sand retained on each sieve and the bottom pan is weighed, and its percentage of the total sample determined. The results of AFS Sieve analysis are presented in table 5.20

Table 5.20 A F S Sieve analysis

Sieve Number	Amount of 50 grams retrieved on sieve		Multiplier	Product
	Sand (in grams) in sieve	percentage		
6			3	
12			5	
20			10	
30			20	
40	0.7	1.4	30	42
50	7.8	15.6	40	624
70	16.62	33.24	50	1662
100	12.94	25.88	70	1811.6
140	9.28	18.56	100	1856
200	2.16	4.32	145	626.4
270		0	200	0
Pan	0.5	1	300	300
Total	50	100		6922

AFS No = Total product/total percentage of sample = 6922/100 = 69.22. Hence AFS number of sand is 69.22.

In addition to determination of AFS Number, following four significant tests are conducted namely moisture content, compatibility, green compression strength and Permeability.Following tests were conducted to check whether the sand characteristics are as per specifications:

Moisture Test: For testing moisture contents moisture teller is often used to quickly assess the moisture contents. During the test, weighed amount of sand sample and calcium carbide are placed in two containers and then allowed to mix by shaking the container. The resulting pressure of gas generated is indicated on scale, which is calibrated directly in the percentage of moisture.

Compact ability Test: This test measures the percent decrease in height from original constant level of loose sand, under the influence of a fixed compacting force. The test directly stimulates the behavior of sand used on molding machine. In the test, a specimen tube filled with loose riddled sand is rammed with three drops of sand rammer, or squeezed at a chosen pressure e.g. 10 kg/cm^2. The percent decrease in height is read from a scale as percentage Compact ability. A Compatibility test accessory is available with standard sand rammer. Compact ability is a direct measure of degree of tamper water of sand. As the composition of sand changes the moisture must change to maintain the desired molding characteristics, indicated by the Compact ability level. In practice the Compact ability level is selected on the basis of molding performance and casting quality. High Compact ability would indicate voids on the vertical faces of the mold. Low Compact ability would render the sand friable and subjects to cuts and washes.

Permeability Test: For permeability test firstly the sand is poured in to the same apparatus which is used for testing the Compact ability. After ramming three times, the sand container is kept on permeability testing equipment and reading dial shows a value of permeability. Permeability is expressed in terms of permeability number which is defined as the volume of air in c.c. that will pass per minute through a sand sample of 1 cm^2 in cross section and 1 cm in high, at a pressure of 1 gm per cm^2. Thus Permeability number is = V * h / p*A*t. Where V is volume of air in c.c., his the height of sample in cm; p is the pressure of air in gm/cm^2, A is cross sectional area of sample in cm^2, t is the and the time in minutes.

Green Compression Test: Strength testers are used to estimate the compressive, tensile and shear strengths of the sand. In this test, sand sample prepared by standard rammer is placed in a holder and squeezed mechanically until it breaks. The force applied during squeezing is shown with the help of an indicator. The force registered at the breaking point is the compressive strength of the sand. By changing the holder, the same tester may be used for testing tensile and shear strengths.

The parameters found out from above tests were found as per standard specification limits and are presented in table 5.21. Cause and effect diagram is drawn to find out the potential causes of the casting defects. In this case, main problem is the porosity of the core which is written on the right side. The cause and effects diagram has been categorized in six categories which are: Measurements, Methods, Machines, Environment, Material and People.

Table 5.21 Specifications of the parameters for hand molding and machine molding.

S.No	Parameters	Hand molding	Machine molding
1	Moisture	3.5 – 4.6 %	3.5 – 4.6 %
2	Compatibility	36-46%	36-46%
3	Green Compression strength (Kg/cm^2)	0.7 – 1.1	0.7 – 1.1
4	Permeability (cc/min)	140 – 220	140 – 220
5	Volatile matter	3.0 – 4.0 %	3.0 – 4.0 %
6	Loss in ignition	4.0 – 5.0 %	4.0 – 5.0 %
7	Active clay	6.5 – 9.0 %	6.5 – 9.0 %
8	AFS clay	10.5 – 4.0 %	10.5 – 4.0 %
9	Dead clay	5%	5%

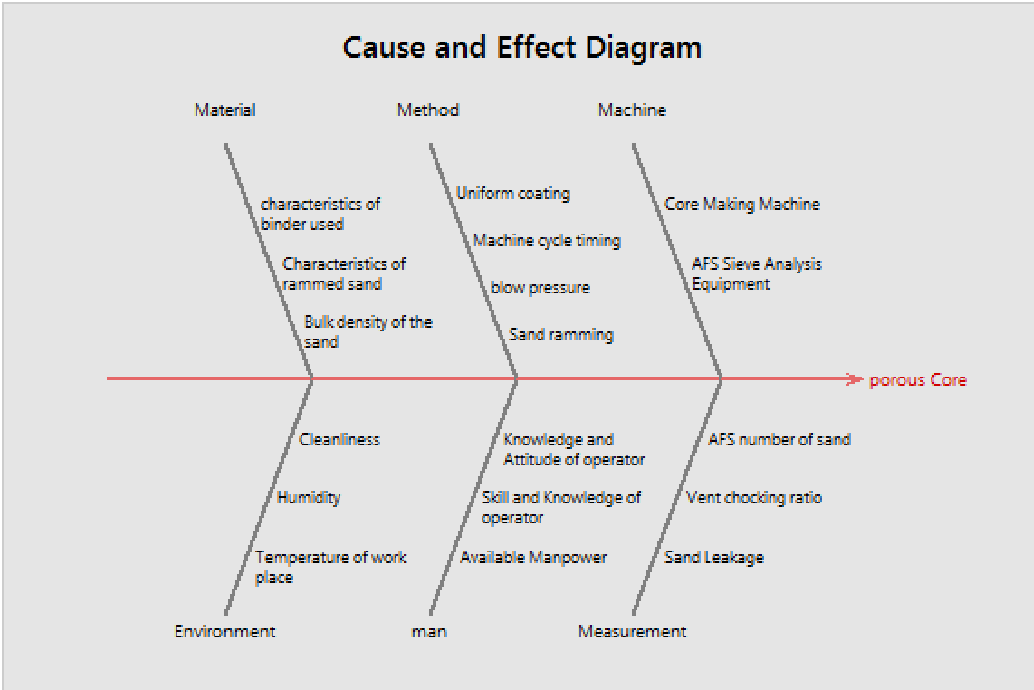

Figure 5.23 Cause and effect diagram for porous core

Analyze: The data and process tools used in measure phase help focusing on process factors that are most likely contributing to the problem at hand. But that belief is just a theory until it is tested with additional data. In present work two factors factorial design is performed on three process variables identified from the measure phase. The response variable is depth of porosity and variables affecting response variable are sand leakage, and bulk density of sand. As there are two factors and two levels two level factorial design is chosen so that it may be studied that how these factors are affecting response variables and what is the affect of these variables on each other.

Table 5.22 Two factor factorial design data for factors affecting depth of porous core

Bulk density (gm/cc)	Sand leakage (gm/blow)	Depth of Porous core (mm)		
		Replication 1	Replication 2	Replication 3
1.72	32	1.85	1.7	1.75
1.97	12	1.25	1.35	1.35
1.97	32	1.4	1.6	1.55
1.72	12	1.7	1.6	1.55

Table 5.23 Two factor factorial design results for depth of porous core

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	3	0.320625	0.106875	16.55	0.001
Linear	2	0.318750	0.159375	24.68	0.000
Bulk density	1	0.226875	0.226875	35.13	0.000
Sand leakage	1	0.091875	0.091875	14.23	0.005
2-Way Interactions	1	0.001875	0.001875	0.29	0.605
Bulk density*Sand leakage	1	0.001875	0.001875	0.29	0.605
Error	8	0.051667	0.006458		
Total	11	0.372292			

From results of experimental design, it is observed that bulk density and sand leakage significantly affect depth of porous core. As the sand leakage increases depth of porous core increases and increase in bulk density of sand is accompanied by reduced depth of porous core. The sand leakage was because of misalignment of two halves of core box. The two halves were properly aligned and packing was provided to seal any opening from which sand may come out. The bulk density of sand may be improved by adding iron oxide.

Improve: In improvement phase concept of design for manufacturing and design for quality has been implemented. Design for manufacturing means that how can a product be designed to make it easier to produce. Design for quality is the term that refer to the principles and procedures employed to ensure that highest possible is designed in to the product. The general objectives of DFQ are to design the product to meet or exceed customer requirements, to design the product so that its function and performance are relatively insensitive to variation in manufacturing and subsequent application and to continuously improve the performance and functionality and other quality aspects of product. In foundry, two major factors affecting quality of casting are gating design and design of part. In present work the problem of blow holes was minimized by changing the sprue shape. Blow holes are caused by limitations of molding procedure such as molding sand characteristics, gating design etc. In a sand mold care should be taken to ensure that pressure anywhere in the liquid metal stream does not fall below atmospheric pressure. Otherwise the gases originating from baking of organic compounds in the mold will enter the molten metal stream, producing porous casting. This is known as aspiration effect.

It can be easily visualized that sprue profile should be tapered with some curve when pressure throughout the stream is atmospheric. However, it is easier to construct a straight taper sprue. Another situation where aspiration effect comes into picture is associated with a sudden change in the flow direction such as sudden change in flow direction from sprue to runner. It was recommended that use of straight sprue should be discontinued and taper sprue should be used as per the material complexity, and size of casting & size, it was established by practice that increasing taper angle of sprue by one degree effective reduces air aspiration as well as increases the flow rate.

The relationship was not theoretically obtained but established by practice by the experimenters for casting material, shape & size.

Control: In control phase efforts are made to maintain the improvements which have been brought from the analysis of process and modification of product in previous phases. It is assured that process is carried as per standard operating procedures (SOPs). In case of foundry shop simply drawing control charts will not help much because control chart for attributes are inferior as compare to control chart for variables (as far as haunting for assignable cause is concerned). Moreover number of defectives in the casting process is usually high as compared to other manufacturing processes because rejected castings can be again melted. In the present study the defects were reduced by 25%. It was recommended that proper monitoring of process parameters will help to detect and correct the process to be within specifications limits before it shows some assignable causes and customer dissatisfaction. It was suggested that sampling inspection should be done in daily routine and whenever sampling inspection shows more number of defectives there is definitely an assignable cause in the process. Frequency and size of the sample should be increased and if required 100% inspection should be done. It was recommended that process should be standardized specifically the procurement of molding sand and core sand should be standardized to eliminate the variations in mold making. Standardized core sand has proper proportions of sand and binder which minimizes the blocking of vents during curing process. The molding sand of AFS number 60-70 was recommended to achieve better results. Zircon mixed with magnesium should be used to the refractoriness of the core coatings and bulk density of sand may be increased by adding iron oxide. The vendor should be selected after vendor evaluation and vendor rating. This aspect should be analyzed as sand is critical to quality characteristics. Standardization provides us with reduced cost and prices which of course increases productivity and increased demand and sales.

5.4.2 Research Outcomes of Six Sigma in a Foundry Shop

- The Casting defects were reduced by 25%. It was recommended that proper monitoring of process parameters will help to detect and correct the process to be within specifications limits before it shows some assignable causes and customer dissatisfaction.

- It was suggested that sampling inspection should be done in daily routine and whenever sampling inspection shows more number of defectives there is definitely an assignable cause in the process. Frequency and size of the sample should be increased and if required 100% inspection should be done
- It was recommended to inspect the alignment of two halves of core boxes and to provide packing to seal any opening from which sand may come out.
- The molding sand of AFS number 50-60 was recommended to achieve better results. Zircon mixed with magnesium should be used to the refractoriness of the core coatings and bulk density of sand may be increased by adding iron oxide.

5.5 SIX SIGMA IN HEALTH CARE

Six Sigma methodology measures the process failure rate as 3.4 in a million. All these processes are meant for raising the standard of human beings. Health care is prime importance as it deals directly with life of human beings. The measurement matrices in health care are needed to be reformed. We should start measuring our healthcare failures in deaths per million. Even failures per million is not a high-quality matrix. The required measurement scale should be failures per billion. Studies indicate that service industries have average sigma level of 2.0 to 2.5 sigma. It is sarcastic that process sigma level of many health care activities is less than 2.0 sigma or around 308,538 defects per million opportunities. Hence it is highly significant to implement Six Sigma in health care

5.5.1 Application of Six Sigma DMAIC Methodology in Health Care

As health care is part of service industry, methodology behind Six Sigma is more significant than specific measurement of failure rate. The Six Sigma methodology helps health care organization to identify, define and measure CTQS like patient satisfaction and employee satisfaction. When some hospitals claims that it is patient cantered than they must ask themselves that what does it means to them. It is of paramount significance that how does they measure patient satisfaction. If hospital measure patient satisfaction by tradition accounting ways such as revenue generation by patients and expenses incurred on patients and other health care activities but clinical mistakes are typically not measured then Six Sigma methodologies may contribute a large to find ways to measure what is important to them. Following are the application of Six Sigma tools during various phases of Six Sigma DMAIC Methodology

In define phase Cause and effect diagram may be drawn to understand the various causes of Low Customer Satisfaction. The cause and effect diagram as shown in figure 5.24 was drawn after having a brainstorming session with a core team in a hospital to understand the main causes of low customer satisfaction. The main causes came out of cause and effect diagram were categorized under the category of people and equipment. On further investigation, it was revealed that the doctors and supporting staff were not motivated because of shortage of staff and wrong policies for the staff leave. During measure phase gage repeatability and reproducibility analysis may performed to check proportion of the measurement variation. In analysis phase, Failure Modes and Effects Analysis may be performed to analyse the risk priority number of various process. THE FMEA for visit to a doctor for Consultation is presented in table 5.24. In above mentioned FMEA case, the Risk Priority Number (RPN) at serial number four and five in table 5.24 is highest which is 210 and therefore is a factor for improvement.

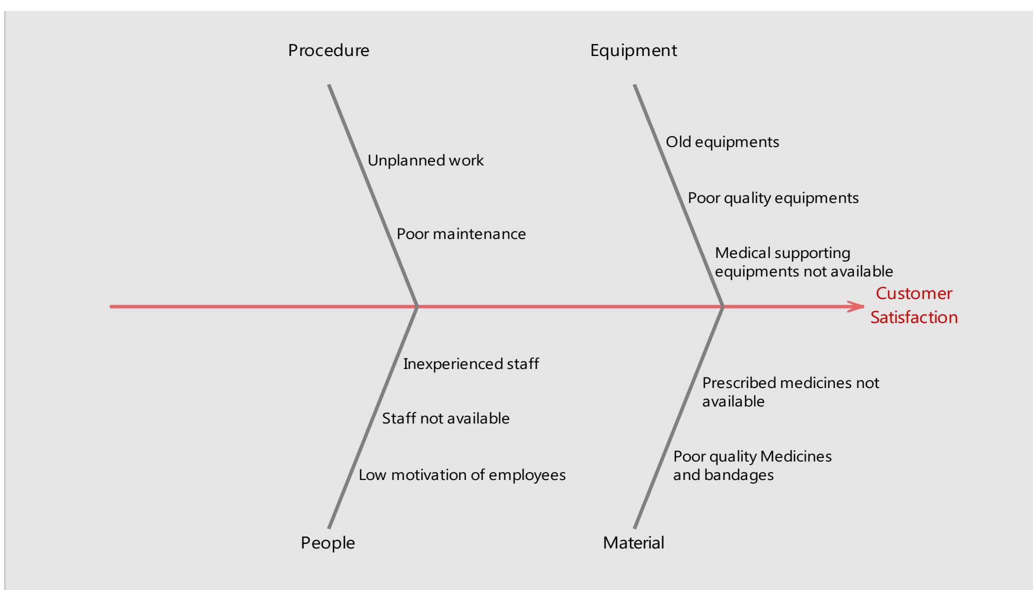

Figure 5.24 Cause and effects diagram for low customer satisfaction

Table 5.24 FMEA analysis for a patient consultation to doctor

S.No.	Failure Mode	Severity (S)	Occurrence (O)	Detection (D)	Risk Priority Number (RPN)= S x O x D
1.	Patent Missing appointment	3	2	8	48
2.	Patient unable to provide clear information regarding the symptoms of the ailment	6	2	7	84
3.	Patient unable to understand the Precautions provided by doctor	6	3	7	126
4.	Improper diagnoses by doctor	10	3	7	210
5.	Wrong medicines given to patient	11	3	7	210

5.5.2 Research Outcomes of Six Sigma in Health Care

In health care when we are talking about quality of service processes, it is quite significant as quality of service means we are talking about the patients' lives. There are immense opportunities in health care environment. The opportunities may come from administrative processes as well as clinical procedures. The opportunities may include billing, emergency services and room services. If the billing process is as good as a six sigma process, the account department might be resolving claims at very efficient rate. Six Sigma process in emergency services enables a patient to be transferred at appropriate venues at the earliest so that proper treatment could be given to a patient with in no time. The room service of the patients brings their psychological healing which in turn lead to faster recovery and increased patient satisfaction. It is to be noted that that healthcare processes are usually highly repetitive in nature. The patient reaction to a drug might vary but the method of administration and documentation is usually same for a incidence. The doctors supporting staff, floor layout, pharmacy, room service and other administrative and clinical procedures remains same. After implementing Six Sigma Define Measure and Analyze methodology health care professionals can take hold of processes needing attention and accordingly they can improve and control the errors in the health care processes.

5.6 CONCLUDING REMARKS

The application of Six Sigma in service processes including the various processes of a Technical Institution, Telecommunication Organization, Health Care Organization, and Foundry shop have been illustrated with the help of case studies. There is enormous potential for Six Sigma in service organizations because there are many non productive processes in service organizations which add to the customer cost but contribute no value in the customer eye. It is essential to identify, analyze and optimize these processes so that bottom line gains could be achieved.

CHAPTER 6

GENERALIZED MODEL OF SIX SIGMA

Six Sigma is a popular approach to drive out variability from the processes using powerful statistical and engineering analysis tools. The chapter presents key elements in a Six Sigma system and includes Six Sigma philosophy, Six Sigma improvement and management strategies, Six Sigma Methodologies and Organizational structure.

6.1 INTRODUCTION TO KEY ELEMENTS IN A SIX SIGMA SYSTEM

The introduction of Six Sigma into manufacturing industry in 1980 was a step in revolutionizing the scope and use of quality system. Since then, Six Sigma has been gaining momentum in industry. The Six Sigma encompasses the methodology of problem solving and focuses on optimization and cultural change. Six Sigma makes use of collection of quality management and statistical tools to construct a frame work for process improvement. The objective is to enhance the sigma level of the performance measures that reflect the voice of customer (Goh and Xie, 2004). Like all other systems, Six Sigma system is made of some essential components which combine to drive improved business performance. These components include Six Sigma philosophy, Six Sigma improvement & management strategies, Six Sigma methodologies, and organizational structure of Six Sigma Company. The key elements of a Six Sigma System as illustrated in figure 6.1 play vital role for successful deployment of a Six Sigma project. The quantum gains achieved in process improvement after successful deployment of Six Sigma project are further quantified in terms of defect reduction, cost reduction of cycle time reduction.

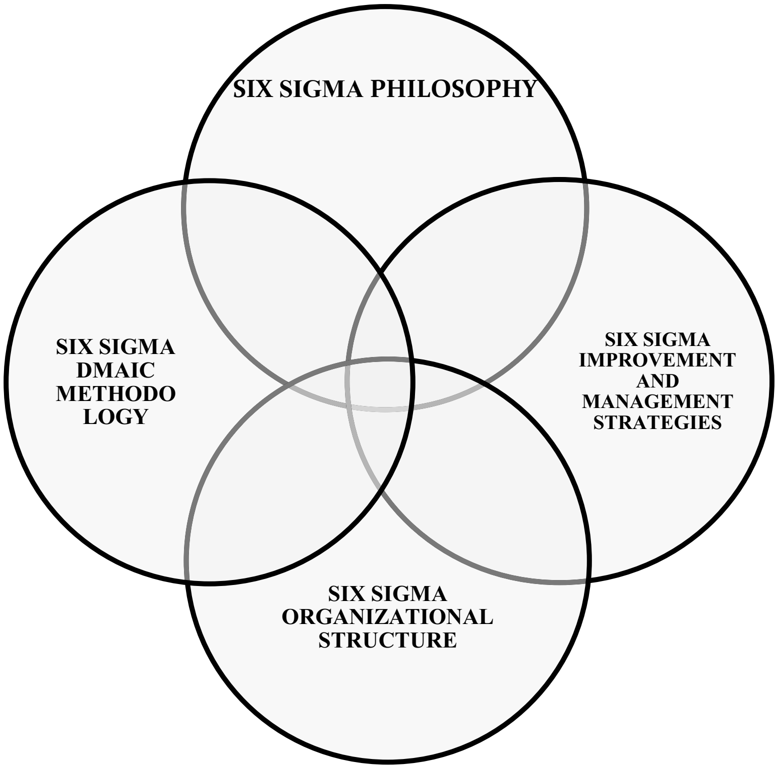

Figure 6.1 Key elements of a Six Sigma system

6.2 SIX SIGMA PHILOSOPHY

The Six Sigma definitions reflect its basic philosophy. The basic philosophy of Six Sigma is that variations are biggest enemies of a process. Understanding, analyzing and reducing the variations are keys to success for a Six Sigma project. In a Six Sigma project, variations are systematically reduced in critical processes. As the variations are reduced, sigma rating of process is increased which leads to excellent quality, higher productivity and reduced cost. For reducing variations, it is necessary to understand the dynamic behavior and variation in a process. The variations can be divided in two types (i) random variations or chance variations & (ii) assignable variations.

Random variations are due to inherent characteristics of a process and they are sure to happen in any process and cannot be avoided. They are caused by factors such as inherent human variability from one operation cycle to other, minor variations in raw materials & machine vibrations. Individually these factors may not amount too much but collectively they can be significant enough to cause trouble unless they are in specified limits of tolerance. It has been observed that if variations are due to random causes only then they form normal distribution curve. When only chance variations are there process is said to be under statistical control. This type of variability will continue as long as process is operating normally.

Assignable variations occur when process deviates from normal working conditions. Something that has occurred in process that is not accounted by random variations is assignable variation. These are of greater magnitude as compared to those due to chance causes. Assignable causes include: operator mistake, defective raw material, equipment mall function, and tool failure, difference among workers, difference among machines, and difference among material. Assignable variations cause the deviation in output from normal distribution and process is said to be out of control. Figure 6.2 illustrates chance variations and figure b, c & d present assignable variations. Figure 6.2 a Presents Normal distribution with mean μ_0 and Process spread σ_0 , in figure b process mean μ_0 is shifted to μ ($\mu > \mu_0$), whereas in figure c process spread σ_1 has increased ($\sigma_1 > \sigma_0$), and in figure d both process mean μ ($\mu > \mu_0$), and process spread σ_1 ($\sigma_1 > \sigma_0$) has increased.

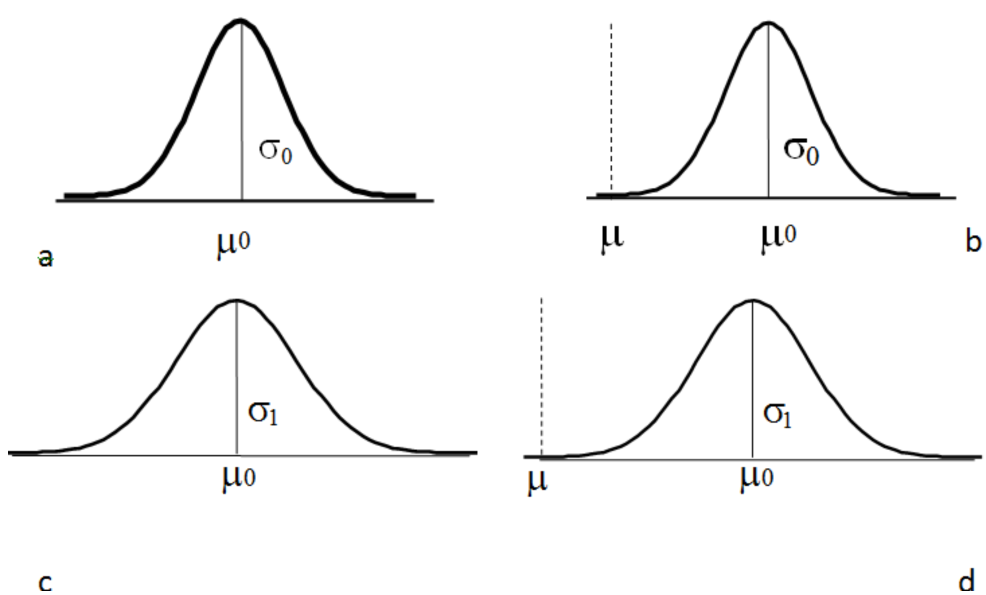

Figure 6.2 Chance and Assignable Variation

6.2.1 Short Term and Long Term Variation

In organizations, often-short term & long term variation are considered. The short-term variation involve reproducibility of process output with in a very short time frame - a few hours or a few days at the most. Short time variation include only a chance cause variation (standard deviation) since in a short period there may not be any change in process level so we avoid inclusion of any variation due to assignable causes. We can estimate short-term variation by taking 25-30 consecutive observations over short duration say half an hour, two hours, or a shift of eight hours. Based upon data we can estimate standard deviation by following formula:$\sigma = \sqrt{\Sigma(x_i - \text{x bar})^2 /(n-1)}$. To justify the use of this method stability of the process must be maintained either by normal distribution curve or by histogram. For a stable process about 99.7 % of the observations are expected to contain around $\pm 3\sigma$ around the mean. Long-term variation involve the capability of process to produce consistent output over a longer period of time - several days or weeks. For estimating long-term variation 200-300 observations may be taken & then standard deviation of this variation is computed. This variation is often known as overall variation as it is the combined variation due to short term as well as long-term disturbances. An estimate of standard deviations for short-term variation (when data is in sub groups) is computed using the formula Sigma = R/D2 Where R is the average range & D2 is constant depending upon sample size (n).short term and long term variations are illustrated in figure 6.3.

The sub grouping refers to the way observations are grouped in the subgroups. Sub grouping should be done in such a manner that it leads to discover assignable causes when process is not under control. In subgroups same data can be used to estimate the long-term variation or overall variationσ. The short-term variation (σ_0) is computed as R/D2.The estimate of component of overall variation due to long-term disturbances alone $\sigma 1$ can be computed as $\sigma 1 = \sqrt{(\sigma^2 - \sigma^2_0)}$

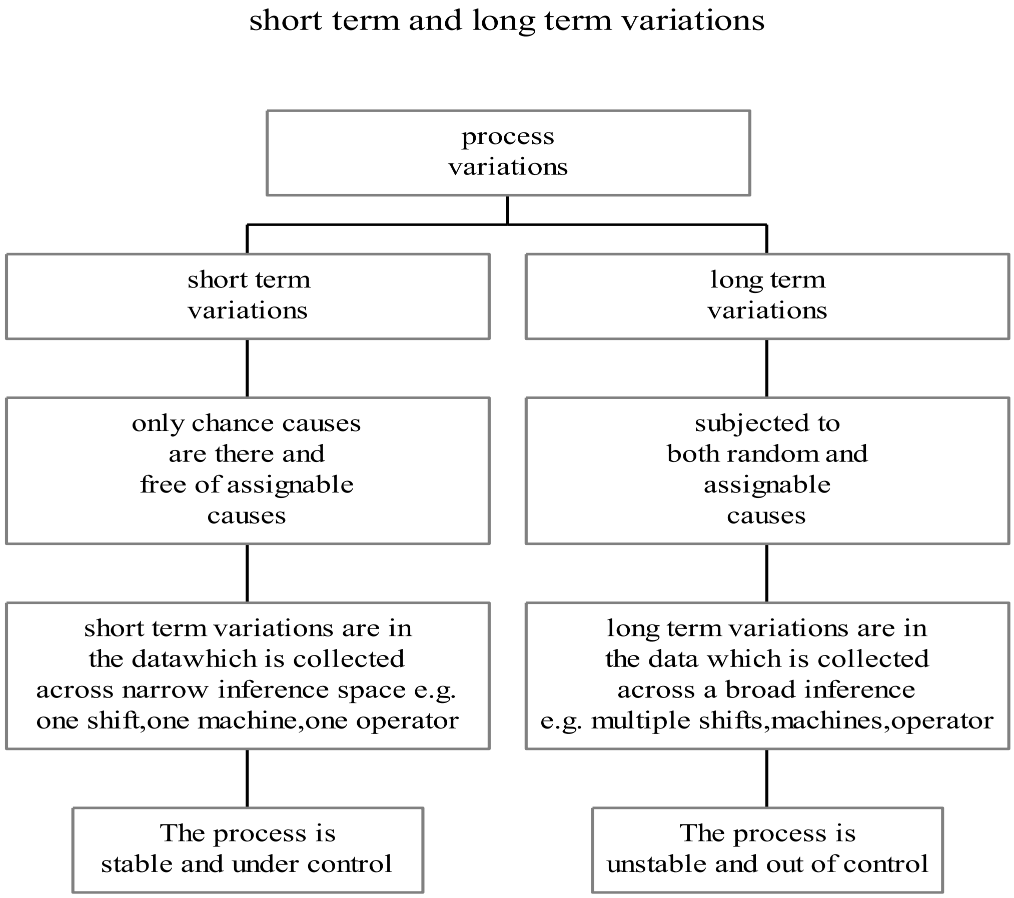

Figure 6.3 Short term and long term variation

6.2.2 Actual Process Variation and Measurement System Variation

In any process the input is transferred into output and any information we gather about the process behavior first pass through a sensory system. To analyze and reduce actual process variability including all sources of variation, the variation due to the measurement system must be identified and separated from that of process. Measurement system is used as base of decision-making and if measurement system goes wrong then we cannot control the process. Measurement is the first step that leads to control and eventually to improvement. If we can't, measure something, you cannot understand it. Further if we cannot understand it, we cannot control it and if we cannot control, it cannot be improved. In any process overall observed variation are sum of actual process variation and measurement system variation. Measurement variation includes equipment error, human error, and human-equipment interaction and may be reduced through conducting Measurement System Analysis (MSA).

Overall process variation are presented in figure 6.4. whereas figure 6.5 presents possible sources of variation in a process. The sources of variation include

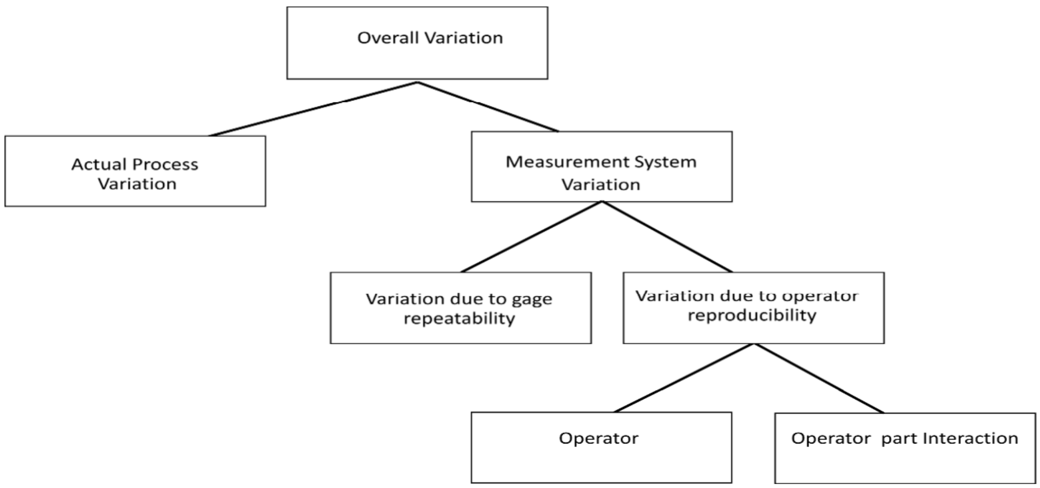

Figure 6.4 Overall Process Variation

Lot to lot variation: For a part produced in lots, this variation can be due to the difference between the process average and possibly process spread from lot to lot. In order to reduce this variation, lot to lot data of a product must be distinguished and then analyzed through plotting control charts.

Steam to stream variation: For a part produced from several parallel streams include stream to stream variation. In order to reduce this variation, it may be necessary to analyze each stream by plotted separate control charts for each stream.

Time to time variation: it is necessary to study and analyze time to time variation in order to minimize the variation caused to factors discussed above. The main objective of plotting control charts is to analyze and reduce time to time variation.

Piece positional variability: physical measurement taken at many different points on a part may cause piece positional variability e.g. diameter of a shaft measured at several different points need not lead to consistent results. Significant positional variation in part may necessitate change in tooling, material or machinery.

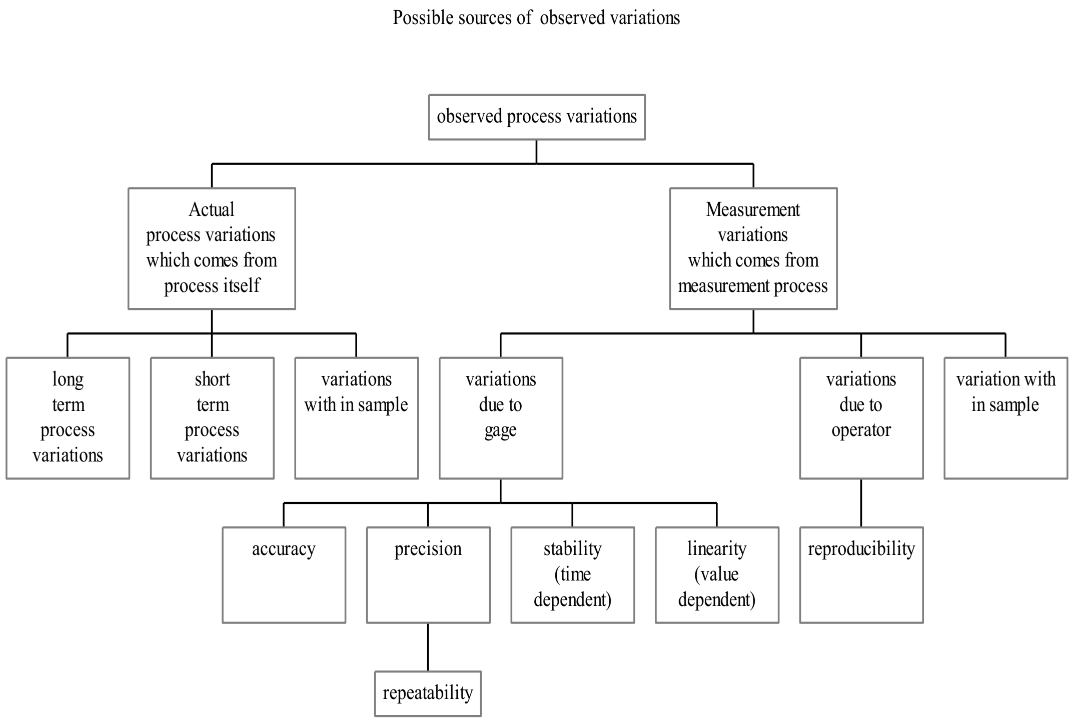

Figure 6.5 Possible sources of variation

6.2.3 Strategies for Reducing Variation

The two significant characteristics in a process include location of process mean (μ) and spread of the process spread (σ). These characteristic have major contribution towards process improvement and are important to decision makers. The process may exhibit the behavior of off centering from mean and higher spread due to special cause(s) and/or common cause(s) variation. As a result process may go out of statistical limit and does not meet desired specifications. Table 6.1 illustrates that as the process off centering from mean increases, the Defects Per Million Opportunities (DPMO) for particular process sigma level increases. In the same manner, increase in process spread leads to higher DPMO. The process control charts helps us in providing an opportunity to monitor the process online and diagnose the problems related with process. The other strategies for reducing variation include documentation of process control to ensure process standardization. The standard operating procedures must be developed and documented. In the physical world, law of entropy explains the gradual loss of order. In the business processes, documents and ongoing process control works as energy. The process tends to degrade over the time losing the gains achieved by design and improvement activities. The documentation, and control plans are the structure through which we may add energy to business processes. In addition, mistake proofing and warning mechanisms contribute significantly toward reducing process variation. These mechanisms warn the operator before process goes outside the specification limit so that preventive action can be taken. Process control chats have proved to be very helpful strategy when process cannot be mistake proofed or easily controlled with in required tolerance range

Table 6.1 Increase in DPMO due to process off-centring from mean as well as increase in process spread from three sigma to six sigma process

Process sigma level	process capability (Cp) of a centered process	DPMO of a centered process	DPMO with 0.5 σ off centering	DPMO with 1 σ off centering	DPMO with 1.5 σ off centering	DPMO with 2 σ off centering	Improvement over previous σ level
3σ process	1	2700	6440	22832	66803	158700	4.6 times
4σ process	1.33	63	236	1350	6200	22800	10.7 times
5σ process	1.66	0.57	3.4	32	233	1300	26.6 times
6σ process	2	0.002	0.019	0.39	3.4	32	68.5 times

6.2.4 Process Capability and Six Sigma

For any process to be stable 99.7 % of the observations are expected to remain within spread of six times standard deviation. The process capability is ratio of allowable process spread to actual Process spread. Cp =Allowable Process spread / Actual Process spread i.e. Cp = USL – LSL /6 σ.Cp cannot indicate whether the process is centered or not .It would be possible to have considerable percentage of parts outside specification limits with high Cp just by locating the mean significantly close to specification limit. Cpk is process capability index or achieved process capability .Cpk index relates scaled distance between mean and the closest specification limits. Cpk = Minimum {CPU, CPL}, CPU (Upper capability index) = (USL – Mean)/3 σ, CPL (Lower capability Index) = (Mean-LSL)/3σ. For calculating process capability of attribute data DPMO (defects per million opportunities) to process sigma conversion tables may be used. To calculate any given value following formulae can be used in MS excel. Process sigma = NORMSINV {1- (DPMO/1000 000)} +1.5.The equation for converting process sigma to DPMO. The DPMO = 1000 000 * {1- NORMSDIST (process sigma – 1.5)}. Henderson and Evans (2000) have described that when half tolerance of the measured product is equal to 'H' times standard deviation of the process then H * process standard deviation = Half tolerance specification. Table 6.1 represents increase in DPMO due to process off-centring from mean as well as increase in process spread for three sigma to six sigma process. Table 6.2 illustrate Numbers of defective pieces per million for specified off centring of the process at various sigma ratings (quality levels). In horizontal direction sigma represents quality level & in vertical direction sigma represents off centring of the process from mean. Defective parts for any quality level is minimum when the off centring of the process is zero sigma and goes on increasing as off- centring of the process from mean increases.. Switching over from three to Six Sigma means 19600 time improvements.

Table 6.2 Numbers of defective pieces per million for specified off centring of the process at various quality levels.

	Sigma Ratings (Quality Levels)							
Process off centering		3σ	3.5σ	4σ	4.5σ	5σ	5.5σ	6σ
	0 σ	2700	465	63	6.8	0.57	0.034	0.002
	0.25 σ	3577	666	99	12.8	1.02	0.1056	0.0063
	0.5 σ	6440	1382	236	32	3.4	0.71	0.019
	0.75 σ	12288	3011	665	88.5	11	1.02	0.1
	1 σ	22832	6433	1350	233	32	3.4	0.39
	1.25 σ	40111	12201	3000	577	88.5	10.7	1
	1.5σ	66803	22800	6200	13500	233	32	3.4
	1.75 σ	105601	40100	12200	3000	577	88.4	11
	2.0σ	158700	66800	22800	6200	1300	233	32

6.3 SIX SIGMA IMPROVEMENT AND MANAGEMENT STRATEGIES

The Term process improvement and management refers to strategies of developing scientific solution so as to reduce variation by eliminating root causes of business performance problems. The essence of business improvement process seeks to fix a problem while leaving the basic structure of work process harder. The emphasis is to address the vital few (the Xs) that causes the problem (the Y). The majority of Six Sigma projects are process improvement efforts. The process improvement has been used synonymously as continuous improvement or kaizen. Figure 6.6 illustrate Six Sigma Improvement and Management Strategies

The process improvement strategy can bring about only small incremental improvements in the process. At times, business leader lose patience due to slow pace of improvement. This frustration opens avenues to re engineering of the process. In addition, incremental improvements do not allow organization to keep up with rapid pace of change in areas of technology, customer demand and competition. That is why Six Sigma brings together both process improvement and design/redesign in cooperating them as essential strategies for sustained success

In process design/ redesign strategy, objective is not to fix the problem but rather to replace a process with new one. There should be a rule of thumb to redesign major processes after say after five years. The performance of process enhances over the time and process achieves a stage where there is no slackness in it, it is the time to make a major investment in time, money and creativity to reengineer and upgrade the process. Through careful design planning and testing you may reach to whole new level of performance. After redesigning the process, the cycle of continuous improvement starts again.

However, the reengineering in some organizations has ended up producing its own disappointments. In spite of all these worries and considerations, sometimes you have no choice. Without reengineering/designing/ redesigning the processes quantum gains in business are not achieved. As a result you lose your edge in market and this is the high time to invest your money, time and efforts to survive in market as well as to achieve quantum gains in business.

The third key strategy of Six Sigma is most evolutionary. It involves a change in focus from oversight & directions of functions to understanding and facilitation of the process. In a mature process management approach, processes are documented and responsibilities are assigned in such a way to ensure cross functional management of critical processes. . Process management is an approach in which organizations tend to learn and develop slowly. Customer requirements are clearly defined and updated. Process owner use the measures and process knowledge to assess performance in real time and take action to address problems and opportunities. Each manager keeps track of critical processes. In a Six Sigma based process management approach, the people are trained in a D M A I C model (define, measure, analyze, improve, control), that guides process improvement / redesign. The DMAIC process management model provides organization people a consistent way to manage change and improvement in a growing organization

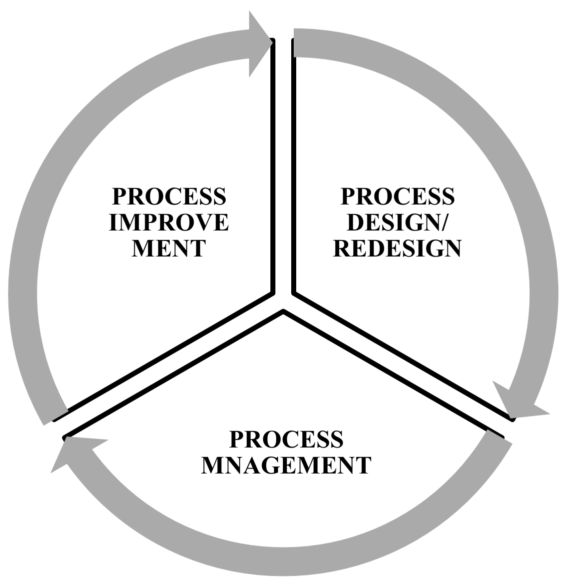

Figure 6.6 Six Sigma Improvement and Management Strategies

6.4 SIX SIGMA DMAIC METHODOLOGY

Six Sigma approach has been predominantly used by manufacturing organization. Currently the popularity of Six Sigma in service organizations is growing exponentially in developed countries especially in banking services, health care, Airline industries, telecommunications, and utility services. The reason behind this is that service organizations are catering for 80 % of economy in developed countries. Developing countries are also following the trend. Six Sigma DMAIC methodology is a efficient frame work to feel existing process improvement and for achieving the defined performance levels to achieve quantum benefits.(kwak and Anbari, 2006; Gupta, Jain and Tyagi, 2005; Raisinghani, 2005).Six Sigma DMAIC methodology improves any existing process by constantly reviewing & re-tuning the process. To achieve this, Six Sigma DMAIC methodology is implemented. Figure 6.7 represents various phases of Six Sigma DMAIC methodology and table 6.3 illustrates various tools and deliverables of each phase.

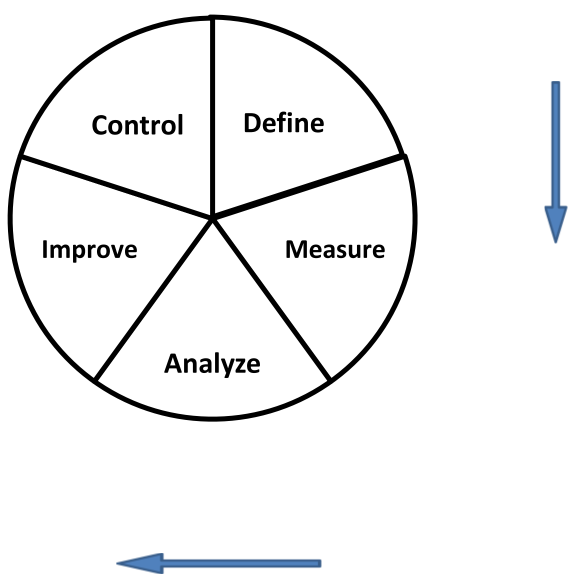

Figure 6.7 Six Sigma DMAIC model

Table 6.3 Use of DMAIC (Define Measure Analyze Improve Control) for a Six Sigma project

Steps	Description	Tools	Deliverables
DEFINE	Identify CTQs, identify customers, develop team charter, draw as is (current) process map and draw should be (future) process map.	Voice of customer, pareto analysis, cause & effect diagram, process mapping, supplier-input - process – output - customer (SIPOC) diagram.	Project CTQs will be identified, problem and goal statement are developed, project scope is determined and high level process map connecting the customer to the process are developed.
MEASURE	select CTQs, define performance standards, identify key matrices for business processes, establish data collection techniques and perform measurement system analysis.	Quality function deployment (QFD), FMEA, process capability analysis, variable gauge repeatability & reproducibility analysis, variable gauge repeatability & reproducibility analysis.	Measurable CTQs that is to be improved will be identified and selected, performance parameters are established and Measurement system is validated.
ANALYZE	Analyze current state of processes, establish current process capability, define performance objectives and identify sources of variation.	Test of normality, FMEA, cause and effects matrix, pareto analysis, hypothesis testing and regression analysis.	Current baseline of the process is established, process goal is statistically defined and relationship with process input and output variables is established.
IMPROVE	Explore and screen potential causes, discover optimal relationship between variables, implement new processes and validate should be process map.	Design of experiments, factorial design, hypothesis testing and regression analysis.	Key process input variables affecting the output are identified, optimal settings of key process input variables is achieved and confirmation run of processes are performed.

Steps	Description	Tools	Deliverables
CONTROL	Verify process improvement, validate measurement system for input variables, establish control plans and monitor the process using control charts.	Control charts, FMEA, control plans and poka yoke.	Improved process capability is established, improvement goal are confirmed, control plans are established and process is effectively monitored.

6.5 SIX SIGMA ORGANIZATIONAL STRUCTURE

In a Six Sigma Organization, adequate efforts and resources are dedicated to educate and train staff members. Responsibilities and authorities are distributed in a structured way using a belt system namely champion, master black belt, black belt, green belts, similar to that used in karate. Depending upon the Six Sigma project management decides that how many black belts and green belts are required for a project. The black belts which are the primary drivers of improvement take three weeks of training with follow up exams and continued learning through conferences and other forums. Green belts take two weeks of training.

6.5.1 Key Players for Six Sigma Organizational Structure

Six Sigma projects are executed through belt based organizational structure. The methodology categorizes the organizational people based on their profile at different levels namely Green Belt, Black Belt, Master Black Belt, and Champion (Gnanraj et al., 2010).

Champion is responsible for overall deployment. He facilitates in careful selection of high impact projects. He identifies the business and facilitates for removing the roadblocks in achieving high performance with Six Sigma. In addition, he focuses on development of black belt and ensures that the process owner's support is there during all phases. He plays a vital role in transferring project ownership from black belt to line managers who own the process upon completion of the corrective actions.

Black Belt implements the Six Sigma methodologies with his Team. He identifies, and leads projects to achieve significant results, which impact the bottom line. He uses statistical tools to effective design process and to solve the technical problem faced during DMAIC phase. Black belt receives training and guidance from Six Sigma master black belt.

Green Belt works as a member in black belt Projects. He may also work on small projects independently. Green belts are employees throughout the organization, who execute Six Sigma as a part of their overall job. While working with the black belts, they gain experience in the practical application of the Six Sigma methodology and tools.

6.6 CONCLUDING REMARKS

Six Sigma has been considered as revolutionary approach to product and process quality through the effective use of statistical methods. The chapter has presented critical factors in a Six Sigma system derived from thorough analysis of various research papers, and case studies. All aforementioned key elements should be taken in account for optimizing the financial returns from a Six Sigma project. The concept of analyzing and reducing variation to improve process performance can be applied to services as well as manufacturing organizations. In a Six Sigma project responsibilities and authorities should distributed in a structured way using a belt system similar to that used in karate. The belt system must be aligned with requirements of the projects otherwise resulted savings may be in thousands of dollars which may be otherwise millions of dollars. It may disappoint the company to implement six sigma projects for other problems. Another critical factor affecting the successful implementation of Six Sigma is the exact definition of problem and its customization. Problem should not be generalized as every problem has its own parameters and specific solution.

CHAPTER 7

SIX SIGMA IN SERVICES - CRITICAL TO QUALITY CHARACTERISTICS AND CHALLENGES

The chapter presents a comprehensive comparison of quality enablers, Critical to Quality Characteristics and performance matrices in service organizations. Common challenges, benefits, limitation and myths regarding Six Sigma for service organizations have also been stated.

7.1 INTRODUCTION

Six Sigma methodologies have been successfully implemented in many manufacturing organizations. However, service organizations have lagged behind. As per Bob Galvin, former CEO of Motorola ‘the lack of Initial Six Sigma emphasis in non manufacturing areas was a mistake that cost Motorola at least five billion dollars over a period of four years. Service operations comprise a major share of GDP in developed countries and still rapidly growing. Even in manufacturing organization the major factor governing product cost are from support and design functions including finance, human resources, product development and purchasing. The major categories among wide spectrum of service organizations include Transportation, telecommunication, public utilities, finance, information technology, real estate, healthcare services, hotels, professional services such as doctors, charted accountants, & lawyers. personal services such as amusement, barber & beauty parlour., repair services and news media. The variety of services gives rise to distinguished characteristics but there are also similarities among some service industries. The service is provided when customer demands it, the service output is created and delivered and usually it cannot be stored in an inventory. The wide range of service industries makes it difficult to generalize the way to approach quality.

7.2 CRITICAL TO QUALITY CHARACTERISTICS (CTQs) FOR SIX SIGMA SERVICE ORGANIZATIONS

Critical to quality characteristics (CTQs) are the transformation of customer explicit requirements to key measurable indicator of the process or product. CTQs are translation of customer needs into measurable terms from design perspective. These translated needs become CTQs and must be satisfied by design solution (Chua et al., 2007) CTQs are spoken needs of customer. Establishment of CTQs is first fundamental step in Six Sigma processes. The next step is to find the current status of process by defining the performance matrices. CTQs may be classified as follows:

Time: Time is the significant factor in services especially when customer is involved in the process itself (e.g. banking services). Time can be classified as follows

- Service time: It is the time required to serve a particular customer
- Waiting time (Idle time): It is the time customer has to wait to get the work completed Process cycle time: It is the total time of particular process. It include both service time and waiting time
- Extended time slots: Time slots of service organizations have also become significant in the process where customer is involved in the process itself. Extended service time slots help in getting more number of customers.

Cost: Cost is also a significant factor from customer point of view. At times customer is willing to pay more for a service which can be completed in shorter time. The balance between price of service and serving time is important in services.

Service: service is a broader term & involves many factors mainly employee's behaviour and attitude towards customer. Getting right information in easy way at right time is also an important aspect from customer point of view.

7.3 QUALITY ENABLERS AND PERFORMANCE MATRICES

Six–sigma performance matrices (CTQs) vary from process to process and Organization to Organization. Nevertheless there are commonly used performance matrices across the number of service organizations. The Quality Enablers and performance matrices of some of the service Organization is presented in Table 7.1.

Table 7.1 Quality enablers and performance matrices of some service organizations.

S. No	Service organization	Quality Enablers	Performance Matrices
1.	Universities and institutes	Faculty Qualification, Experience and motivation, Infrastructure, Faculty and staff salary, Curriculum design, Industry institute interaction.	Number of students placed, ranking of the University, ranking of institute, qualifying marks of incoming students, overall faculty academic qualifications, paper publish by faculty members, students and faculty satisfaction.
2.	Health care	Infrastructure, availability of the experienced and skilled doctors, basic and super specialty facilities in the hospital, Time to respond for the emergency services, basic and life saving medicines, hygienic and sterilization facilities in Operation theaters.	Time taken to admit a patient in emergency room, number of successful surgeries per week (or month), number of wrong diagnoses by doctors, number of wrong reports generated by hospital labs, time taken to register a patient at OPD, time taken to visit a doctor, quality of canteen, parking and other facilities provided by a hospital.
3.	Tele communications	Infrastructure, facilities, Innovative and attractive schemes to attract customers, personalized attention to customers.	Service resolution time, Number of dropped in a particular traffic region, number of complaints per month, behavior and attitude of employees towards customers.

S. No	Service organization	Quality Enablers	Performance Matrices
4.	Banking	Customer friendly atmosphere, facilities, time taken for services provided to the customers, changes for the services.	Cycle time for receiving and processing a request or complaints, no of customer complaints received per week or month, number of ATM breakdowns per month, duration of ATM breakdown, idle time (waiting time) of customer in the processes where customer is part of process itself.
5.	Aviation industry	Number of flights taking off on time, salary of Pilots and ground staff, numbers of strike days in a year.	Emergency landings per year, baggage misplaced per month, total time taken from airport to boarding a plane, number of mistakes in reservation.

7.4 COMMON CHALLENGES FOR SERVICE ORGANIZATIONS

Six Sigma methodologies have yielded proven results in manufacturing sector but in service organizations it has yet to yield such results. The various challenges in service organizations include data collection related issues, process performance measurement related issues, dynamic market demands, noise factors, non normality of data etc.

7.4.1 Data collection

In data collection process sample of data may not represent the correct picture of whole universe.

- Method of collection of data: Data collection technique like interviewing, survey, and distribution of questionnaire

- Source of data: source of data collection is challenging in service processes customer itself is source of data. Moreover when data is collected in face to face interaction, the nature and mood of the customer, time available to customer may affect the trueness of the data.
- Type of data: In service sectors data obtained usually don't have both lower specification limit and upper specification limits. Moreover data may be non normal. Data may not be divided in subgroups always and we may have to work on individual data.

7.4.2 Effect of process off centring on Performance of process

Six-sigma approach asserts that it is too difficult to hold mean at target value because of inherent variability in materials or processes. Therefore, it allows a 1.5 σ shift of mean from target value. Off centring increases the defect level from 0.002 DPMO to 3.4 DPMO, i.e. quality adulteration of 1700:1, yet it will be termed as six-sigma process. Figure 7.1 illustrate effect of process off centring on Six Sigma process. In actual practice, it is relatively easy to correct shift of mean value (X) from target through a minor adjustment. It is more difficult to correct process spread of a parameter that requires application of higher level of statistical tools and techniques like DOE, ANOVA and hypothesis testing. 80% of companies are not even aware for aforementioned techniques and still these boast of Six Sigma companies. In service organization process off centring badly affects the process sigma rating because process sigma rating calculations involve number of potential opportunities.

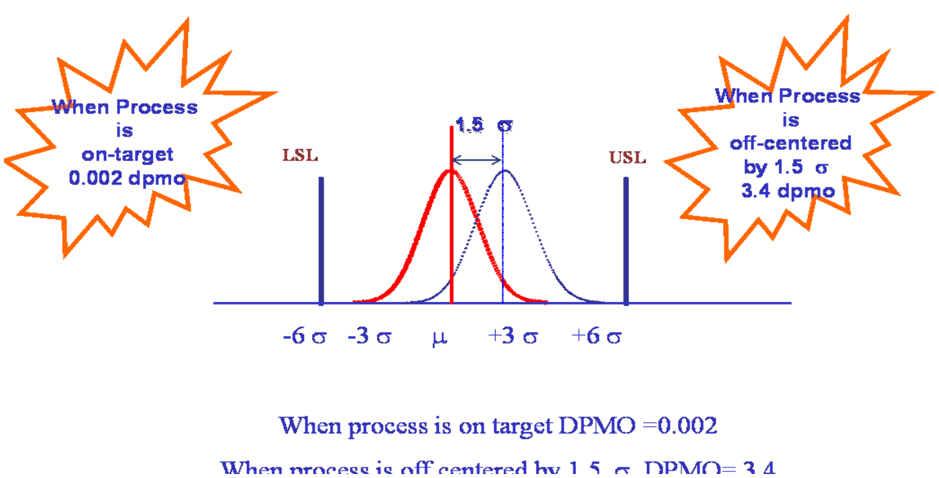

Figure 7.1 Effect of process off-centring on Six Sigma process

7.4.3 Calculation of Process Sigma Rating

In manufacturing sector it is quite common to have some sort of quantitative measurement which provides information about sigma rating of the process. Process capability (Cp) and Process capability index (Cpk) of process having upper and lower specification limit is calculated as

$$Cp = \frac{USL - LSL}{6\,\sigma}, \quad Cpu = \frac{USL - x\text{ double bar}}{6\,\sigma}, \quad Cpl = \frac{x\text{ double bar} - LSL}{6\,\sigma}$$

Cpk= minimum of Cpu and Cpl

In service organizations attribute data in involved and both upper and lower specifications are rarely specified. In addition, process sigma rating calculation involves number of potential opportunities, therefore it is challenging to identify and scrutinize service processes. The process sigma rating is calculated based upon defects per opportunity (DPO) or defects per million opportunities (DPMO) which is calculated as DPMO = Number of defects x 10,00,000 /{number of units x number of opportunities}. As we increase number of potential opportunities, the DPMO decreases which further translates in to improved process sigma rating. However, it is not a good practice to increase potential opportunities just to boost sigma rating. Moreover, in a six-sigma project, painting an over positive picture by selecting more potential opportunities would make it harder to show improvements later. The DPMO can be further translated into sigma rating with help of normal table. Table 3 shows the conversion of DPMO in to process sigma rating. The following factors should be considered for establishing opportunities for products or services.

- Standardization: Standard problems area should be considered. The effects, which are rare, should not be considered as opportunities.
- Grouping of opportunities: The closely related defects should be grouped together in to single opportunity to avoid the inflation of opportunities.
- Critical to quality characteristics: It should be ensured that the opportunities considered are CTQs are those customer considers to have the critical impact on quality

The process sigma rating calculation of a service organization may be understood by considering the study of a small hospital. In a hospital 100 patients were asked about the potential problem and following data was recorded as presented in Table 7.2.

Table 7.2 Conversion of DPMO to process sigma rating

Process is perfectly centered			Process is off centered by 1.5 σ	
DPMO	Process sigma rating		DPMO	Process sigma rating
2700	3 σ		66803	3 σ
465	3.5 σ		22800	3.5 σ
63	4 σ		6200	4 σ
6.8	4.5 σ		13500	4.5 σ
0.57	5 σ		233	5 σ
0.034	5.5 σ		32	5.5 σ
0.002	6 σ		3.4	6 σ

In the following case study, there are 12 potential opportunities. These opportunities are grouped in three broad categories namely Emergency services, OPD services, and support services respectively. As the numbers of complaints are 70 and opportunities are 3 the DPO can be calculated as follows: DPO = 70/(100*3) = 0.233.The DPO value of 0.117 may be further translated in to process sigma rating is 1.9. In the above study process sigma rating may be apparently improved by classifying the potential opportunities in more than three categories.

Table 7.3 Potential opportunities in a small hospital

S.No.	Broad potential opportunities for services	Number of Patient complaints	Potential opportunities
1	Emergency Services	4	Doctors are not available in emergency room.
2		6	In accidental cases, time taken from entrance in hospital and to be attended by doctor in emergency is too long.
3		2	Unsuccessful surgery operations performed.
4		2	Surgical supplies are not available.
5	Out Patient Department	8	Doctors on Out Patient Department (OPD) duty not available.
6		14	Waiting time is too long during visit to doctor.
7		4	Wrong report generation by hospital lab for routine test.
8		2	Wrong diagnoses by doctors.
9	Support Services	10	Front desk staff not providing relevant and proper information to patients and their attendants.
10		6	Vehicle parking facility is not adequate.
11		8	Canteen services are not good.
12		4	Patient attendant’s waiting rooms are not proper.

7.4.4 Measurement System Analysis

Measurement system analysis (repeatability and reproducibility analysis) identifies the different sources of variation that affects measurement system. A measurement system includes both the measurement instrument and the item being measured. In service organizations, the data being measured is usually attribute. The gauge Repeatability and reproducibility analysis for attribute data actually provides only checking for inconsistency of appraiser (i.e. agreement with in appraiser). There is no protection from a gauge, which is consistently inaccurate. More over the agreement of appraiser with reference is subjected to capabilities and personal style of domain expert.

7.5 BENEFITS AND LIMITATIONS OF SIX SIGMA IN SERVICE ORGANIZATIONS

- In service organizations, achieving quantum and measurable gains is a challenging affair. The challenges faced by service organizations are that processes are intangibles and people working at key positions drive the processes. Following are the benefits and limitations of implementing Six Sigma methodologies.
- Six Sigma is a data driven methodology and decision are based on facts and figures instead of perceptions and feelings.
- It explores concepts of statistical science and encourages the application of statistical tools through every stage (Define – Measure – Analyze – Improve – Control) of the project.
- In Six Sigma projects responsibilities and authorities are distributed in structured way using a belt system similar to that used in karate.
- Six Sigma creates a infrastructure of professionally qualified people like champions, master black belts (MBBs), black belts (BBs), Green belts (GBs) that lead train and deploy the process improvements
- It is scientific focused and disciplined approach which provides out of the box ideas & solutions to solve chronic problems
- In Six Sigma processes analyzing and inferring conclusion based on data is challenging when quality data is not available. Moreover in many processes when

customer itself is source of data nature and mood of customer may affect the trueness of data.

- The number of opportunities is calculated based on the assumption of normality of data. But in service organizations non normal data is there many times.
- The assumption of 1.5 sigma process shift for all the service processes is not sensible. It may lead to wrong calculation of process DPMO and sigma rating.
- The opportunities in Six Sigma are sometimes not calculated by importance to the customer. Sometimes ten minor defects might improve but five important defects may get worse. In this case Six Sigma process rating will improve
- Many companies such as Clarke American have chosen not to implement Six Sigma because they feel Six Sigma focus in not on reducing or managing inventory but rather on processes that involves those inventories.

7.6 CONCLUDING REMARKS

Six Sigma is misunderstood as statistical science jargon. In addition, commitment of top management is underestimated. It is misunderstood that there is some magic in Six Sigma methodology. Companies implementing Six Sigma methodologies sometimes impatiently look for increase in sales without contributing the required efforts and attitude to achieve success. It is recommended to work on the principles of design for quality i.e. quality needs to integrated in design itself rather than just creating mechanism to monitor the process. This Argument is in line with Genichi Taguchi who is best known for design for quality & optimizing the processes. He invented robust design that focuses on eliminating defects by implementing scientific methods instead of trial and error methods. Six Sigma should be truly understood with its strong data driven base rather than using is as 'market ploy'. The immediate goal of this technique should be to reduce process defects which further leads to process improvement and Customer satisfaction. But the ultimate aim of Six Sigma projects should be to enhance financial gains. Six Sigma will be prevailing in both service and manufacturing organizations as long as it delivers measureable bottom line results in monetary terms.

CHAPTER 8

CONCLUSION AND SCOPE FOR FUTURE RESEARCH

The chapter presents Six Sigma system perspectives for successful execution of Six Sigma projects. In addition, chapter provides major contribution of work done in the study. and highlights the outcomes of the study and scope of future work in this area.

8.1 INTRODUCTION

Global competitiveness has forced the organizations to take up innovative initiatives like Six Sigma to sustain in the market. Six Sigma has been a proven method to solve any problem of a service as well as a manufacturing organization. . It uses the statistical analysis of data and much focused approach to find the CTQ's and to reduce defects in any process. Has Six Sigma produced new tools? In reality the tools used in Six Sigma were available and in use before six sigma movement was started. Nevertheless, Six Sigma is a very disciplined and focused approach which has made the best use of statistical tools, quality tools and engineering analysis to solve a problem. It is the same dish with somewhat change in recipe and the manner of presentation.

The basic philosophy of Six Sigma is that variation is biggest enemies of a process. Understanding, analyzing and reducing variation are keys to success for a Six Sigma project. The concept of reducing variation and using statistical signals is to improve process performance can be applied to any area. The real understanding of the process involves insight contact with actual process control situations. There is no substitute for hands on experience. The study of variation should be considered as a step towards use of statistical methods. However, it is improper to blindly use this approach. It is recommended to consult experts who have proper knowledge and practice in statistical theory as to appropriateness of other techniques. In any case, processes and procedures followed must satisfy the customer requirements and the overall aim is customer delight.

Another critical factor affecting the successful implementation of Six Sigma is the exact definition of problem and its customization. Problem should not be generalized as every problem has its own parameters and specific solution. Generalized six sigma approach lacks some quite desirable characteristics. For example there is an end point to the benefits that can be attained in the process and then is no loose point or slackness in the process and therefore no productivity is possible. Now should we try to squeeze yet more efficiency out of our past methods? It would be tragic to devote efforts and invest to improve a process that is about to become obsolete. To achieve quantum gains rather than incremental improvements in any process we should see that whether DMAIC approach should be followed or any other methodology like DFSS should be implemented.

With reference to implantation of Six Sigma methodology a significant question may arise why the different companies have drastically different results even when it is stated that it is quite efficient approach. The answer is that it is in the management commitment and customization of problem. After all it is a tool used by team and the commitment of top management plays a very crucial role in the success of six sigma approach.

In six sigma project substantial efforts and resources are dedicated to educate and train staff members. Responsibilities and authorities are distributed in a structured way using a belt system similar to that used in karate. Depending upon the six sigma project management should decide how many black belts and green belts are required for a project. If a problem requires say ten black belts exclusively for some black belt project and only four to five are trained and allowed to work part time in their projects then resulted savings may be in millions of dollar which may be otherwise thousands of dollar. It may disappoint the company to implement six sigma projects for other problems. We should also establish criteria for minimum process improvement speed and direct attention should be given to waste due to waiting, over processing, motion etc. Moreover focus should be there on attacking the work in process inventory.

8.2 MAJOR CONTRIBUTION OF RESEARCH

Although there are few examples of Six Sigma implementation in academia, it is possible to use this methodology for improvement in academic institution. In present study application of Six Sigma in technical institution revealed many areas of improvements such as teaching learning process, evaluation strategies, student passing ratio and student placement ratio. It was recommended to standardize evaluation process by establishing standard operating procedures. Evaluators should be provided with answers of all the questions by concerned subject coordinator. The subject lesson plan and study material should be prepared by subject coordinator. The commitment of top management enables a institution to overcome the challenges for implementing Six Sigma. The challenges in technical institution include definition of customer, quality of measurement, evaluation policies, and difficulties in establishing CTQs..

The levels of implementation of Six Sigma in academia may be categorized as implementation of Six Sigma project at university level, institution level or at department level. Depending upon the CTQs, the level of the implementation may be chosen. Implementation of Six Sigma project at University level provides university administrators with data for decision making regarding administrative and policies related issues. Concerted efforts are required to bridge the gap between Institutes of national importance and other institutions. The Institutes of national importance are required to work as a catalyst in the growth of quality Engineering Education the country, and play a major role in training faculty from other institutions of the country in both teaching and research. The quality of self financed technical institution can be improved by replicating the best practices of leading technical institutions. Top management of the institution should dedicate substantial efforts and resources to educate and train faculty members and staff for the Six Sigma project.

The full utilization of the Six Sigma can be realized only when we focus on process insight rather than process output. In the present study on telecommunication organization it was recommended that management should delegate process ownership to people who are working on the process so that remedial action on the process can be taken without much relying on the management. In addition, it was found that training for both management & process owners is important factor for quantum gain in process improvement. It was recommended to categorize the problems based on the severity and time taken to resolve the problem. It was decided that standard operating procedures such as cable related problems in present work should be clearly defined and documented.

There are limitless opportunities of Six Sigma in health care. When we are talking about quality of service processes, it is quite significant as quality of service means we are talking about the patients' lives. The opportunities may come from administrative processes as well as clinical procedures. The opportunities may include processes such as billing, emergency services and room services. The measurement matrices in health care are needed to be reformed. We should start measuring our healthcare failures in deaths per million. Even failures per million is not a high-quality matrix. The required measurement scale should be failures per billion. It is sarcastic that process sigma level of many health care activities is less than 2.0 sigma or around 308,538 defects per million opportunities. Hence it is highly significant to implement Six Sigma in health care. The Six Sigma methodology helps health care organization to identify, define and measure CTQS like patient satisfaction and employee satisfaction. If a hospital measures patient satisfaction by tradition accounting ways such as revenue generation by patients and expenses incurred on patients and other health care activities but clinical mistakes are typically not measured then Six Sigma methodologies may contribute a large to find ways to measure what is important to them. Six Sigma Define Measure and Analyze methodology health care professionals can take hold of processes needing attention and accordingly they can improve and control the errors in the health care processes.

8.3 SCOPE FOR FUTURE RESEARCH

Six Sigma has achieved a reasonable maturity and there has been substantial contribution made in Six Sigma framework to extend application from manufacturing to services context. Although the review does on claim to be exhaustive, it does provide reasonable insight in to state of art Six Sigma research. Based on the literature review presented in the paper, we identify following directions of future research:

- There has been a considerable research on Six Sigma fundamentals in last decade. Instead of discussing much about the Six Sigma basics and comparison of Six Sigma with other quality initiatives, more focus should be on how to integrate other quality efforts in to Six Sigma to achieve quantum gains.
- There is a need to have more case studies clearly presenting the application of Six Sigma within each domain in a proposed framework.
- More research is to be conducted on user experiences reflecting pros and cons of Six Sigma in such context.
- The domain including Six Sigma and its linkages with other initiatives, Six Sigma and Statistical thinking, Six Sigma in Supply Chain have great potential for research.
- Six Sigma deployment in Health Care and Education is either not visible or is at very nascent stage. Six Sigma implementation strategies and critical success factors for successful deployment of Six Sigma project are other areas for future research. Applications of Six Sigma projects in Indian states and central government run organizations and administration have also not been explored.
- The areas for further research can be summarized as Applications of Six Sigma in manufacturing & service sectors areas which are not explored yet with full potential, areas of Six Sigma enhancement and integration of Six Sigma with other quality initiatives, critical success factors for successful deployment of Six Sigma& Six Sigma implementation strategies,

In Six Sigma projects true and quantum gains can be achieved by customizing the problem and paying attention to each and every variable which is responsible for manufacturing the desired product/services at minimum possible cost. The integration of Six Sigma with lean manufacturing and supply chain management and other innovative management techniques will be ideal solution for achieving maximum productivity. Six Sigma will be prevailing in industries as long as Six Sigma projects yield measurable or quantifiable bottom line results in financial or monetary terms.

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Appendix Table 1 Constants and Farmulas for Variable Control Charts

Table Of Constants and Formulas for Control Charts

	$\overline{X}$ and R Charts*				$\overline{X}$ and s Charts*			
	Chart for Averages (X)	Chart for Ranges (R)			Chart for Averages (X)	Charts for Standard Deviations (s)		
Subgroup Size	Factors for Control Limits	Divisors for Estimate of Standard Deviation	Factors for Control Limits		Factors for Control Limits	Divisors for Estimate of Standard Deviation	Factors for Control Limits	
n	A2	d_2	D_3	D_4	A_3	c_4	B_3	B_4
2	1.880	1.128	–	3.267	2.659	0.7979	-	3.267
3	1.023	1.693	–	2.574	1.954	0.8862	–	2.568
4	0.729	2.059	–	2.282	1.628	0.9213	–	2.266
5	0.577	2.326	–	2.114	1.427	0.9400	–	2.089
6	0.483	2.534	–	2.004	1.287	0.9515	0.030	1.970
7	0.419	2.704	0.076	1.924	1.182	0.9594	0.118	1.882
8	0.373	2.847	0.136	1.864	1.099	0.9650	0.185	1.815
9	0.337	2.970	0.184	1.816	1.032	0.9693	0.239	1.761
10	0.308	3.078	0.223	1.777	0.975	0.9727	0.284	1.716
11	0.285	3.173	0.256	1.744	0.927	0.9754	0.321	1.679
12	0.266	3.258	0.283	1.717	0.886	0.9776	0.354	1.646
13	0.249	3.336	0.307	1.693	0.850	0.9794	0.382	1.618
14	0.235	3.407	0.328	1.672	0.817	0.9810	0.406	1.594
15	0.223	3.472	0.347	1.653	0.789	0.9823	0.428	1.572
16	0.212	3.532	0.363	1.637	0.763	0.9835	0.448	1.552
17	0.203	3.588	0.378	1.622	0.739	0.9845	0.466	1.534
18	0.194	3.640	0.391	1.608	0.718	0.9854	0.482	1.518
19	0.187	3.689	0.403	1.597	0.698	0.9862	0.497	1.503
20	0.180	3.735	0.415	1.585	0.680	0.9869	0.510	1.490
21	0.173	3.778	0.425	1.575	0.663	0.9876	0.523	1.477
22	0.167	3.819	0.434	1.556	0.647	0.9882	0.534	1.466
23	0.162	3.858	0.443	1.557	0.633	0.9887	0.545	1.455
24	0.157	3.895	0.451	1.548	0.619	0.9892	0.555	1.445
25	0.153	3.931	0.459	1.541	0.606	0.9896	0.565	1.435

$UCL_{\overline{X}}, LCL_{\overline{X}} = \overline{\overline{X}} \pm A_2\overline{R}$

$UCL_R = D_4\overline{R}$

$LCL_R = D_3\overline{R}$

$\hat{\sigma} = \overline{R}/d_2$

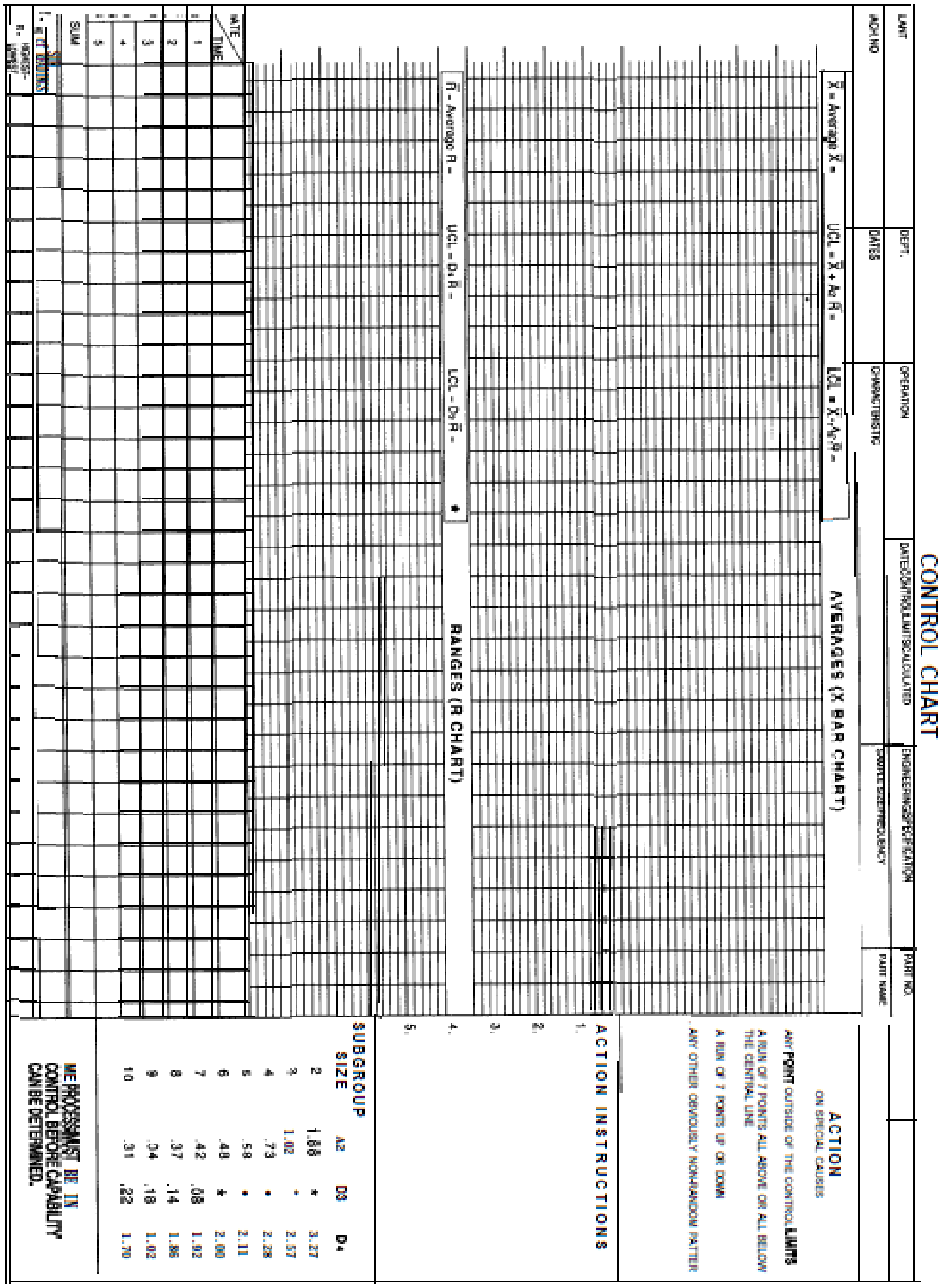
$UCL_{\overline{X}}, LCL_{\overline{X}} = \overline{\overline{X}} \pm A_3\overline{s}$

$UCL_s = B_4\overline{s}$

$LCL_s = B_3\overline{s}$

$\hat{\sigma} = \overline{s}/c_4$

Appendix Table 2 X bar and R Chart Format



Appendix Table 3 Gage R&R Data Collection Sheet

Gage Repeatability and Reproducibility Data Collection Sheet											
Appraiser /Trial #	PART										AVERAGE
	1	2	3	4	5	6	7	8	9	10	
A 1											
2											
3											
Average											$\bar{X}_a$ =
Range											$\bar{R}_a$ =
B 1											
2											
3											
Average											$\bar{X}_b$ =
Range											$\bar{R}_b$ =
C 1											
2											
3											
Average											$\bar{X}_c$ =
Range											$\bar{R}_c$ =
Part Average											$\bar{\bar{X}}$ = R_p =
([$\bar{R}_a$ =] + [$\bar{R}_b$ =] + [$\bar{R}_c$ =]) / [# OF APPRAISERS =] =											$\bar{\bar{R}}$ =
$\bar{X}_{DIFF}$ = [Max $\bar{X}$ =] - [Min $\bar{X}$ =] =											$\bar{X}_{DIFF}$ =
* UCL_R = [$\bar{\bar{R}}$ =] × [D_4 =] =											

*D_4 = 3.27 for 2 trials and 2.58 for 3 trials. UCL_R represents the limit of individual R's. Circle those that are beyond this limit. Identify the cause and correct. Repeat these readings using the same appraiser and unit as originally used or discard values and re-average and recompute $\bar{\bar{R}}$ and the limiting value from the remaining observations.

Notes:____

Appendix Table 4 Gage R&R Report

Gage Repeatability and Reproducibility Report

Part No. & Name:
Characteristics:
Specifications:

Gage Name:
Gage No:
Gage Type:

Date:
Performed by:

From data sheet: $\bar{\bar{R}}$ = $\bar{X}_{DIFF}$ = R_p =

Measurement Unit Analysis | **% Total Variation (TV)**

Repeatability – Equipment Variation (EV)

$EV = \bar{\bar{R}} \times K_1$

= ______ × ______

= ______

Trials	K_1
2	0.8862
3	0.5908

$\%EV = 100\,[EV/TV]$

= 100 [______/______]

= ______%

Reproducibility – Appraiser Variation (AV)

$AV = \sqrt{(\bar{X}_{DIFF} \times K_2)^2 - (EV^2/(nr))}$

$= \sqrt{(\_\_\_\_ \times \_\_\_\_)^2 - (\_\_\_\_^2/(\_\_ \times \_\_))}$

= ______

n = parts r = trials

Appraisers	2	3
K_2	0.7071	0.5231

$\%AV = 100\,[AV/TV]$

= 100 [______/______]

= ______%

Repeatability & Reproducibility (GRR)

$GRR = \sqrt{EV^2 + AV^2}$

$= \sqrt{(\_\_\_\_^2 + \_\_\_\_^2)}$

= ______

$\%GRR = 100\,[GRR/TV]$

= 100 [______/______]

= ______%

Part Variation (PV)

$PV = R_p \times K_3$

= ______ × ______

= ______

$\%PV = 100\,[PV/TV]$

= 100 [______/______]

= ______%

Parts	K_3
2	0.7071
3	0.5231
4	0.4467
5	0.4030
6	0.3742
7	0.3534
8	0.3375
9	0.3249
10	0.3146

Total Variation (TV)

$TV = \sqrt{GRR^2 + PV^2}$

$= \sqrt{(\_\_\_\_^2 + \_\_\_\_^2)}$

= ______

$ndc = 1.41\left(PV/GRR\right)$

= 1.41(______/______)

= ______

BRIEF PROFILE OF RESEARCH SCHOLAR

Virender Narula is presently working as Associate Professor with Mechanical Engineering Department, Faculty of Engineering and Technology Manav Rachna International University Faridabad. He has obtained bachelor's degree in Mechanical Engineering from Marathwada University and Master's degree in Manufacturing and Automation from Y M C A Institute of Engineering with Honours. He is pursuing PhD from Y M C A University of Science and Technology Faridabad, India. He is Certified Six Sigma Black Belt from Indian Statistical Institute Delhi and Certified Lead Auditor in Quality Management Systems ISO 9001: 2008. He has published 16 papers in International Journals & Conferences and authored three books on manufacturing processes.

Earlier he was working as Senior Consultant - Academic with National Project Implementation Unit (NPIU) under Ministry of Human Resource Development, Govt. of India. He is also working as Freelancer Six Sigma Trainer and Consultant with various Industries, Technical Expert for educational scope on panel of TUV-Sud for QMS Audits and Faculty with Sona Skill Development Centre Gurgaon. He has total experience of 19 years.