A STUDY OF CRITICAL SUCCESS FACTORS FOR SIX SIGMA IMPLEMENTATION IN UK ORGANIZATIONS

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Abstract and Keywords

KEY WORDS

Six Sigma, Critical Success Factors, Process Improvement, Organizational Change

ABSTRACT

Six Sigma is a systematic process improvement methodology, which leads to breakthrough in profitability through quantum gains in product/service quality, customer satisfaction, and productivity. The concept of implementing Six Sigma processes was pioneered at Motorola in the 1980s and the objective was to reduce the number of defects to as low as 3.4 parts per million opportunities. Many organizations have reported significant benefits as a result of six sigma project implementation, though not all are yet success stories. For the effective implementation of Six Sigma projects in organisations, one must understand the critical success factors that will make the application successful. The aim of the research was to study the implementation of Six Sigma in UK organizations and to identify the critical factors which contribute to successful implementation of Six Sigma. It also aimed to highlight the common problems faced in Six Sigma implementation and investigate the significant benefits achieved by implementing Six Sigma. The research methodology included designing a research questionnaire and collecting data by mailing and personal visits. The population of the research consisted of UK organizations, manufacturing and services, which are implementing or have implemented Six Sigma. A total of 75 UK companies were identified which had implemented Six Sigma or were in the process of implementing Six Sigma and 19 responses were received. The research findings indicate that the respondents ranked the top management support and an effective organizational culture as the most critical factors for Six Sigma success. In addition, effective communication, teamwork, and employee education and training were also ranked higher as important factors for Six Sigma. On the other hand, role of IT and use of Six Sigma consultants were ranked lowest. The study indicated that most common problems faced by the organizations included lack of resources, poor data collection and analysis, lack of management commitment, measurement problems, and organizational resistance to change. The results showed that the most significant benefits attained through Six Sigma implementation were cost reduction, reduced defects/errors, cycle time reduction, and minimization of waste and non-value-added activities. Based on the study results, a Six Sigma framework has been proposed incorporating the key elements for effective implementation of Six Sigma. At the core of the framework is the six sigma methodology which is supported by interlinked hard factors and soft factors. The critical hard factors include organizational infrastructure for Six Sigma, project management, process management, and statistical tools. The soft factors supporting the hard factors are top management support and commitment, effective culture of change, education and training, effective communication, and teamwork.

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2005

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PREFACE

Six Sigma is a new addition to the menu of powerful concepts which has gained significant attention through its dramatic results. Motorola, which pioneered Six Sigma, claimed a fivefold growth in sales with cumulative savings of US$ 14 billion as a result of ten years of Six Sigma implementation while General Electric (GE) and AlliedSignal reported savings of US$ 1 billion and US$ 2 billion, respectively, within two to five years of Six Sigma implementation. Whilst it promises a lot, the results so far, do however, indicate that not all the organizations implementing the concept have achieved dramatic results. Rather many of them abandoned their Six Sigma initiative since it was not significantly contributing to the bottom line in any meaningful period of time. These contrasting results of Six Sigma implementation pose some very serious questions: what are the factors which contribute to the successful implementation of Six Sigma? what are the problems faced in implementing a Six Sigma program? what are the tangible and intangible benefits of Six Sigma implementation?

Realizing the importance of this issue, this research project was initiated with the aim to study the Six Sigma implementation in the UK organizations and to identify the critical success factors for Six Sigma, the problems faced in the Six Sigma implementation, and the benefits attained through implementing Six Sigma. The research was unique in the sense that such a broad analysis of Six Sigma implementation was never carried out before in the UK. One Six Sigma research project done earlier focused on the identification of critical success factors for Six Sigma but did not analyze the status of Six Sigma implementation in UK organizations and the problems faced in the Six Sigma implementation.

There were some challenges in conducting this project. First, Six Sigma is still a relatively newer concept from an academic perspective and there is not much depth and width of academic research and articles on Six Sigma as compared to TQM and BPR. Second, Six Sigma has not yet been fully exploited and adopted by UK organizations as compared to American companies where this concept has really taken roots and adopted by hundreds of companies. Hence, it was not an easy task to find companies in UK which are implementing Six Sigma. Third, since the research was a cross-sectional study of Six Sigma implementation in UK organizations, the time span was limited, thus constraining the scope of the research.

Despite these challenges, the research project was successful in achieving its objectives thanks to the positive response by the respondent companies for which I am grateful to them. Their inputs were of immense value and help in testing the research questions, thus leading to some important findings and conclusions. I would like to thank the staff of ECTQM, especially ***Jacqui*** for her useful contribution in the administrative aspects of the research. I would also like to pay my gratitude to all the faculty of M.Sc. Program for sharing their knowledge and wisdom which enabled me to grasp the concepts and broaden my vision on the subject. And my utmost regards and humble thanks to ***Professor Zairi*** for his unending support and continuous guidance during all stages of the research project, without which this project would have not achieved its objectives. Above all, I would like to thank ***Almighty*** for giving me the vision, knowledge, and courage to take up this project and complete it within specified timeframe in a distinguished manner.

STATEMENT OF AUTHENTICITY

I have read the University Regulations relating to the plagiarism and certify that this dissertation is all my own work and does not contain any unacknowledged work from any other sources.

Signed: ______________________________

Date: __________________

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CHAPTER 1. INTRODUCTION

1.1. BACKGROUND OF RESEARCH

The most challenging question confronting business leaders and managers in the new millennium is not "How do we succeed?" It's; "How do we stay successful?" Business today offers the spectacle of a succession of companies, products, and even industries getting their peak for a short period of time and then fading away. It's like riding the wheel of fortune as consumer tastes, technologies, financial conditions and competition change ever more quickly.

Many quality models and frameworks have been proposed to improve the competitiveness of businesses in the modern world. Total Quality Management (TQM), Business Process Reengineering (BPR), Kaizen, Benchmarking, Balanced Scorecards, Business Excellence models, and other improvement programs have been adopted and implemented by various organizations. All these frameworks advocate the concept that everyone in an organization is responsible for the quality of goods and services produced by the organization. All of them focus on process improvement, need for organizational and cultural change, radical improvement in organizational performance in terms of quality and cost, education and training, focus on customer needs, and team-based approach.

However, research studies indicate that organizations implementing these different frameworks have exhibited mixed results. Taking the example of BPR which claims amazing results on performance improvement. Companies like Ford Motor Co., CIGNA, and Wal-Mart are all recognized as having successfully implemented BPR. However, not every BPR project is successful. Hammer and Champy (1993) claim that 70 per cent of organizations failed to achieve any benefit from their own re-engineering efforts. In addition, Price Waterhouse performed a survey of the experience of Fortune 500 companies and large British companies with re-engineering. They found that executives were only partially pleased with their results

(Berman, 1994). A number of critical factors for BPR success have been identified by various researchers (Choi and Chan, 1997; Al-Mashari and Zairi, 1997; O'Neill and Sohal, 1998).

Similarly, TQM has been a popular business strategy in many organizations over the past 15 years. However, research data show that only one-fifth or at best one-third of TQM programs in the USA and Europe have achieved significant or even tangible improvements in quality, productivity, competitiveness or financial returns (Harari, 1993). Brown (1995) found that more than two-thirds of the companies which adopted TQM ended up failing or dropping the system initiative before it could really take hold. This caused many managers to rethink their belief in TQM. A number research studies on the critical success factors of TQM implementation have been carried out by academicians and researchers (Youssef and Zairi, 1995; Lau and Idris, 2001; Sohal and Terziovski, 2000).

Six Sigma is another approach aimed at achieving significant improvements in business performance and popularized by the success stories of Motorola, GE, and Allied Signals. Motorola, where Six Sigma was developed in the 1980s, claims to have made amazing results. From 1987 to 1997, Motorola achieved a fivefold growth in sales with profits climbing nearly 20 percent per year, cumulative savings at $US14 billion and stock price gains compounded to an annual rate of 21.3 percent. Motorola was also cited as the first winner of America's Malcolm Baldrige National Quality Award in 1988. Similarly, GE and Allied Signals achieved savings of US$2 billion and US$1 billion in five and three years, respectively. Looking at the exemplary achievements of these companies, many other leading organizations have embarked upon the implementation of Six Sigma. However, not all companies can claim to have had the same benefits. A study by Deloitte indicates that fewer than 10 per cent of the companies are implementing Six Sigma to the point where it is significantly affecting the balance sheet and the share price in any meaningful period of time.

These mixed and varying results of Six Sigma implementation poses some very serious questions:

- What are the factors which contribute to the successful implementation of Six Sigma?
- What are the problems faced in implementing a Six Sigma program?
- What are the tangible and intangible benefits of Six Sigma implementation?

This research is aimed at answering these questions from the UK's perspective. It investigates the critical success factors for Six Sigma implementation, the problems faced, and the benefits attained through Six Sigma.

1.2. OBJECTIVE OF RESEARCH

The purpose of the research is to study the implementation of Six Sigma in the UK organizations. Based on the results of the study, it then aims to identify the critical factors which contribute to the successful implementation of Six Sigma implementation. In addition, it also attempts to investigate the different problems faced in the Six Sigma implementation, and the benefits attained through implementing Six Sigma. The research findings will then be used to propose a Six Sigma framework which addresses the key factors necessary for Six Sigma implementation.

1.3. SCOPE OF STUDY

The research covers the national and multinational organizations in UK which have implemented or are implementing Six Sigma. They population of study includes both manufacturing and service organizations.

1.4. RESEARCH QUESTIONS

The research aims to answer the following research questions:

1. What is the implementation status of Six Sigma in UK organizations?

2. What are the problems faced or barriers in implementing Six Sigma?
3. What are hard and soft factors which impact on the successful implementation of Six Sigma?
4. What are the key benefits attained through Six Sigma implementation?

1.5. OVERVIEW OF RESEARCH METHODOLOGY

The research methodology is based on quantitative approach which involves collection of research data and interpretation of results using statistical tools.

The primary research data was collected using the questionnaire tool. The scope of research was UK companies which are implementing or have implemented Six Sigma. The list of companies and the corresponding contact information were collected through Six Sigma conferences, published literature references, and internet sources. The questionnaire along with a covering letter and returned envelop was sent to 75 organizations through postal mail. In addition, the covering letter and questionnaire were sent to some companies through e-mails where the mailing address was not available.

Literature search was done using the secondary data in the form of articles published in international journals on Six Sigma, quality and others. Electronic journals in the library resources, such as, Emerald, were intensively used for collecting secondary data for literature review. In addition, books and publications from leading authors on Six Sigma were also used for literature review. Case studies of various organizations implementing Six Sigma published in journals and available on net were also consulted for literature review and analysis of research findings.

1.6. REPORT STRUCTURE

The report has been divided into the following sections:

- **Chapter two** covers the literature review which describes the evolution and history of Six Sigma, Six Sigma concept and definitions, the benefits of Six Sigma, Six Sigma methodologies, Six Sigma and other management concepts, and limitations of Six Sigma.

- **Chapter three** addresses the Theoretical Framework which includes the Critical Success Factors for Six Sigma based on the literature review.

- **Chapter four** covers the Research Design which describes the philosophy, strategy, and approach of research project and the process of data collection.

- **Chapter five** presents the analysis of data and discussion of findings.

- **Chapter six** includes the conclusions based on the analysis of research data and recommendations for effective Six Sigma implementation.

- At the end of chapters are the **Appendices** and **Bibliography**, which include the supporting material for research report.

1.7. SUMMARY

The chapter covered the introduction and background of research, identifying the need for a study to investigate critical factors of Six Sigma implementation owing to the mixed results of Six Sigma implementation in different organizations. The objective of the research is to study the implementation of Six Sigma in UK organizations and identify the critical success factors along with problems faced and the benefits gained. The research employs quantitative approach using cross-sectional survey of UK organizations

CHAPTER 2. LITERATURE REVIEW

2.1. INTRODUCTION

This chapter covers the review of academic and professional literature on various aspects of Six Sigma. It starts with the background of Six Sigma, explaining the evolution of Six Sigma. This is followed by definitions of Six Sigma and the reasons behind its success and popularity . Also, the key methodologies of Six Sigma have been discussed and compared. Finally, the comparison of Six Sigma concept with other process improvement approaches has been discussed.

2.2. HISTORY OF SIX SIGMA

In separate articles by two Motorola veterans, Mikel J. Harry (1998) and Dennis Sester (2001), each author explained how the idea of Six Sigma was first conceived by experts at Motorola in the early 1980s. Bob Galvin, who was chairperson of Motorola at the time, presented an incredibly demanding quality goal to his employees in 1981, which may have been the stimulus for Six Sigma. Engineer Bill Smith's research regarding process capability and defect reduction around 1985 became the basis for Six Sigma innovation. Leadership at Motorola later asked Mikel J. Harry, then part of Motorola's technical staff, to pioneer the strategic methodology that would soon become Six Sigma. Harry and his colleagues refined the Six Sigma strategy by decade's end.

Six Sigma clearly focused resources at Motorola, including human effort, on reducing variation in all processes, that is to say manufacturing processes, administrative processes and all other processes. To set a clear measure on the improvement work, the program called Six Sigma was launched in 1987. Signs of significant success at Motorola quickly became apparent. In fact, from 1987 to 1997 Motorola achieved a fivefold growth in sales with profits climbing nearly 20 percent per year, cumulative savings at $US14 billion and stock price gains compounded to an annual rate of 21.3

percent. Motorola was also cited as the first winner of America's Malcolm Baldrige National Quality Award in 1988.

Soon other companies became interested in the program and successively more companies were able to demonstrate good results. As examples, AlliedSignal attained savings of $US2 billion during a five-year period while General Electric saved $US1 billion over a two year window. Since then Six Sigma has been touted in numerous articles for having improved countless business processes as well as the overall vitality of several major organizations. Motorola, GE, Allied Signal [now Honeywell], Ford, Johnson Controls, TRW, Delphi, Raytheon, Lockheed-Martin, Texas Instruments, Sony, Bombardier, Polaroid, 3M, and American Express are some of the organizations that have implemented Six Sigma (Hahn et al., 1999; Harry, 1998; Lanyon, 2003; Miller, 2001; Snee, 1999; Williams, 2003).

Six Sigma activities and achievements, seen mainly in large manufacturing operations, are also becoming more prevalent in small businesses, transactional business processes (e.g., HR and purchasing), and in the service sector (Gnibus & Krull, 2003; Goh, 2002; Hammer & Goding, 2001; Harry, 1998; Smith, 2003). Smaller companies have had similar financial success compared to larger companies but on a smaller scale (Brue, 2002; Gnibus & Krull, 2003; Harry, 1998). One example of six sigma application in small and medium-sized enterprises can be found at the Solectron factory in O¨ stersund, Sweden, where AXE switchboards are manufactured. In this company of approximately 1,000 employees, the year 2000 saw 14 people attending a seven month Black Belt (deep knowledge in Six Sigma philosophy and methods) education program on a half-time basis, 20 more people attending a two-day course on Six Sigma, and ten people in the top management group attending a one-day course on Six Sigma. Six Sigma applications at this factory saved about $US0.5 million during the first ten months of 2000 – about $500 per employee over the entire employee base, but closer to $10,000 per employee trained in Six Sigma methods (Kelfsjo et al, 2001).

From at least a financial perspective, it appears that Six Sigma has had a considerable impact on numerous organizations across a variety of industries.

2.3. WHAT IS SIX SIGMA?

Some scholars and practitioners have attempted to describe Six Sigma in one or two definitions (e.g., Breyfogle, Cupello, & Meadows, 2001; Dambolena & Rao, 1994). However, many have concluded that there are at least three definitions (e.g., Adams, Gupta, & Wilson, 2003; Brue, 2002; Eckes, 2001; Pande & Holpp, 2002): Six Sigma can be viewed as a metric, a mindset, and a methodology.

The first logical and commonly heard definition for Six Sigma is that it is a statistical expression – a metric (Breyfogle et al., 2001; Brue, 2002; Dambolena & Rao, 1994; Hahn et al., 1999; Harry, 1998; Pande & Holpp, 2002). The lowercase Greek symbol σ (sigma) is the metric or fundamental statistical concept that denotes a population's standard deviation and is a measure of variation or dispersion about a mean. Mikel J. Harry (1998) and Forrest W. Breyfogle et al. (2001) among others explained how Six Sigma can be defined as a term for process performance that produces a mere 3.4 defects per million opportunities (DPMO). According to Paul (1999),

> Six Sigma is a statistical term that refers to 3.4 defects per million opportunities (or 99.99966 percent accuracy), which is as close as anyone is likely to get to perfect. A defect can be anything from a faulty part to an incorrect customer bill (Paul, 1999).

In simple terms, Six Sigma is a metric representing a process that is performing virtually free of all defects.

In fact, there is a difference in the true value of Six Sigma and Motorola's value of Six Sigma (Billups, 1993). To understand the definition of Six Sigma, it is important to differentiate between these. The sigma value of a process describes the quality level of that process. A quality level of K sigma exists in a process when the half tolerance of the measured product characteristic is equal to K times the standard deviation of the process:

$$K * \text{process standard deviation} = \text{half tolerance of specification}$$

However, this definition alone does not account for the centering of a process. A process is centered when X = T, where X is the process average or mean and T is the target value, which is typically the midpoint between the customer's upper specification limit (USL) and the lower specification limit (LSL). A process is off-centered when the process average, X, does not equal the target value T. The off-centering of a process is measured in standard deviations or sigma.

Table 2-1: Sigma Quality Level

	Sigma Quality Level						
Off-centering	**3 sigma**	**3.5 sigma**	**4 sigma**	**4.5 sigma**	**5 sigma**	**5.5 sigma**	**6 sigma**
0	2,700	465	63	6.8	0.57	0.034	0.003
0.25 sigma	3,577	666	99	12.	1.02	0.1056	0.0063
0.5 sigma	6,440	1,382	236	32	3.4	0.71	0.019
0.75 sigma	12,288	3,011	665	88.5	11	1.02	0.1
1.0 sigma	22,832	6,433	1,350	233	32	3.4	0.39
1.25 sigma	40,111	12,201	3,000	577	88.5	10.7	1
1.5 sigma	66,803	22,000	6,200	1,350	233	32	3.4
1.75 sigma	105,601	40,100	12,200	3,000	577	88.4	11
2.0 sigma	158,700	66,00	22,800	6,200	1,300	233	32

Source: Tadikamala (1994)

As Table 2-1 (Tadikamala, 1994) shows, the value or number of defects of a process is a function of the sigma value (quality level) of the process (e.g. 6 sigma) and the off-centering value of the process (e.g. 0 or 1.5 sigma). The true value of the quality level of a process is the number of defects that occur when the process is centered, when the off-centering value is 0 sigma. In the case of six sigma, there are 0.002 defects per million or 2 defects per billion. On the other hand, "Motorola's concept of 6 sigma allows a shift in the mean of 1.5 sigma" (Evans, 1993). Therefore Motorola's value of six sigma assumes an allowable shift of 1.5 sigma and thus also shows a defect rate not exceeding 3.4 per million (see Table 2-2). The value of 3.4 defects per million in a centered process implies a process quality level between 4 and 5 sigma. This is the concept that was introduced and popularized by Motorola and became known as Six Sigma (Anonymous, 1998a).

Table 2-2: Six Sigma and DPMO

Sigma level	DPMO[a]
2	308,537
3	66,080
4	6,210
5[b]	233
6	3.4

Notes: [a] Defects per million opportunities. [b] Most US businesses operate at the 3 sigma level

Source: Hendersen and Evans (2000)

As a second definition, Six Sigma is considered an organizational mindset that emphasizes customer focus and creative process improvement (Brue, 2002; Dambolena & Rao, 1994; Hahn et al., 1999; Harry, 1998; Pande & Holpp, 2002). As Mikel J. Harry (1998) aptly stated,

> "The philosophy of Six Sigma recognizes that there is a direct correlation between the number of product defects, wasted operating costs, and the level of customer satisfaction" (p. 60).

With this mindset, individuals are prepared to work in teams in order to achieve Six Sigma and its ultimate goal of reducing process variation to no more than 3.4 defects per million opportunities (Harry, 1998). In their book, Six Sigma Deployment, Cary Adams, Praveen Gupta, and Charles Wilson, Jr. (2003) maintained that,

> "Five sigma will not meet customer requirements, and seven will not add significant value. Six Sigma's 3.4 parts per million is close to perfection, and that makes it a more attainable and realistic goal to achieve" (p. 8).

Interestingly, the vast majority of processes found in U.S. companies are said to linger near four sigma or less (Breyfogle et al., 2001; Harry, 1998).

As a third definition, Six Sigma is viewed as a strategic improvement methodology termed DMAIC (Breyfogle et al., 2001; Brue, 2002; Eckes, 2001; Hahn et al., 1999; Harry, 1998; Pande & Holpp, 2002; Pande et al., 2002). DMAIC is an abbreviation of the five systematic steps in the Six Sigma methodology. The steps used for breakthrough thinking and improvements are: define, measure, analyze, improve, and control. This methodology is used to carry out the structured philosophy of Six Sigma in places that include but are not limited to manufacturing, design, engineering, human resources, purchasing, and customer service. APPENDIX 3 illustrates the steps and various tools used in Six Sigma DMAIC approach.

2.3.1. Definitions

Pande et al (2000) defines Six Sigma as:

> "a comprehensive and flexible system for achieving, sustaining, and maximizing business success. Six Sigma is uniquely driven by close understanding of customer needs, disciplined use of facts, data, and statistical analysis, and diligent attention to managing, improving, and reinventing business processes."

According to Antony and Banuelas (2001), Six Sigma is:

> ". . . a business improvement strategy used to improve business profitability, to drive out waste, to reduce costs of poor quality and to improve the effectiveness and efficiency of all operations so as to meet or even exceed customers' needs and expectations"

2.4. WHY SIX SIGMA?

A **''big dollar impact''** is one of key reasons cited by Hoerl (1998) for the success of Six Sigma. Six Sigma pioneer Motorola began the program in 1987, and it took a full five years to see significant results. Motorola attributes $15 billion in savings to Six Sigma from 1987 to 1998 (Paul, 1999). AlliedSignal, which operates within the slightly wider band of 3.5 to 4 sigma, has shown an incredible upturn since it introduced Six Sigma. In 1992, annual sales were about US$13 billion from a workforce of 102,00. Sales (in February 1998) were estimated around US$14 billion with a workforce of 77,000. Productivity in 2Q1998 rose above the long-term target of 6 percent a year (Murdoch, 1998). When GE decided to go with Six Sigma, it set stretch goals and in 1997 alone invested US$380 million in Six Sigma – mostly for training. However, the payback in the same year was about US$700 million in documented benefits from increased productivity (Paul, 1999). In 1997 GE Company raised its company-wide savings estimates twice: from between US$400 million to US$500 million up to between US$600 million and US$650 million and finally up to US$700 million. In 1998, GE expects to see benefits of US$1.2 billion.

Some of the other reasons for implementing Six Sigma (Henderson and Evans, 2000) are:

- **to be responsive to and focused on the customer base –** Sales and marketing VP at GE Aircraft Engines directly attributes the success of the division to the Six Sigma initiative: "it has helped our salespeople focus on building relationships with our customers [whose demands] for increased value have forced us to place a greater emphasis on speed, quality, and productivity" (Cohen, 1997).

- **to improve product and service performance –** the goal of Six Sigma is to improve product and service performance by reducing defects inherent in the processes and materials used to produce them (Torode, 1998) (GE Capital ITS).

- **to improve financial performance and profitability of business –** most manufacturers in the USA operate at about three sigma, churning out 66,000 bad parts for every million produced. These companies lose up to 25 percent of their total revenue due to defects (Murphy. 1998).

- **to be able to quantify quality programs –** the Six Sigma process strives to eliminate those defects by forcing a company to quantify its quality. A database is installed to collect information about every process within a facility. Improvement can then be charted on a factual basis. Implementation of Six Sigma within a business's processes eliminates "I think" and "I feel" from conversations about plant operations (Murphy, 1998).

- **to be considered as a supplier for a business –** Electronics suppliers, especially semiconductor manufacturers, commonly have defect levels of less than 100ppm (parts per million) and some even reach SS level quality. Building a part with a low part per million defect rate allows a supplier to be considered for business, but it has become a dying differentiator (Carbone, 1996).

Antony (2004) highlights the following differentiating aspects of Six Sigma from other quality improvement methodologies:

- Six sigma strategy places **a clear focus on achieving measurable and quantifiable financial returns** to the bottom-line of an organisation. No six sigma project is approved unless the bottom-line impact has been clearly identified and defined.

- Six sigma strategy places an unprecedented importance on **strong and passionate leadership and the support** required for its successful deployment.

- Six sigma methodology of problem solving **integrates the human elements** (culture change, customer focus, belt system infrastructure, etc.) and **process elements** (process management, statistical analysis of process data, measurement system analysis, etc.) of improvement.

- Six sigma methodology **utilises the tools and techniques** for fixing problems in business processes in a sequential and disciplined fashion. Each tool and technique within the six sigma methodology has a role to play and when, where, why and how these tools or techniques should be applied is the difference between success and failure of a six sigma project.

- Six sigma creates an **infrastructure of champions, master black belts (MBBs), black belts (BBs) and green belts (GBs)** that lead, deploy and implement the approach.

- Six sigma emphasises the **importance of data and decision making based on facts and data** rather than assumptions and hunches! Six sigma forces people to put measurements in place. Measurement must be considered as a part of the culture change.

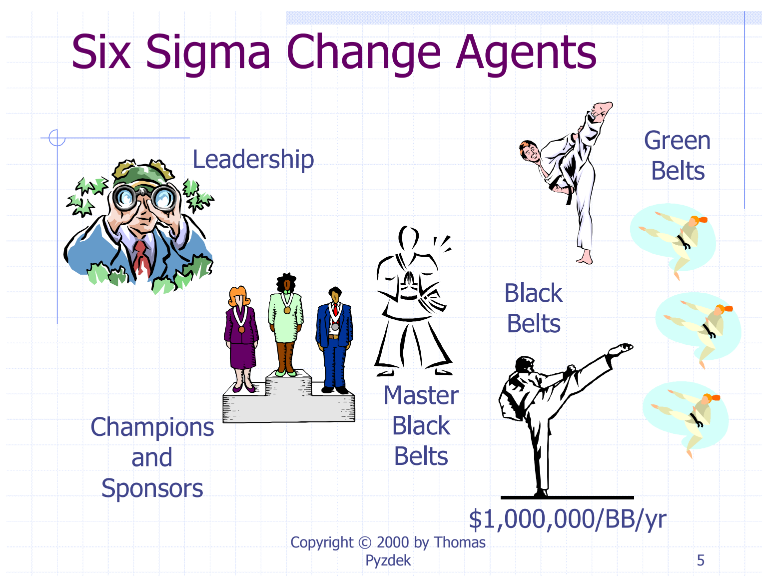
- Six sigma utilises the concept of statistical thinking and encourages the **application of well-proven statistical tools and techniques** for defect reduction through process variability reduction methods (e.g. statistical process control and design of experiments).

2.5. SIX SIGMA ORGANIZATIONAL INFRASTRUCTURE

The organizational infrastructure for Six Sigma program consists of a hierarchy of roles of management and employees depending on the different levels of expertise (Adams et al., 2003; Breyfogle et al., 2001; Brue, 2002; Eckes, 2001; Hahn, Doganaksoy, & Hoerl, 2000; Hoerl, 2001; Pande et al., 2002; Pyzdek, 2000b). These roles are classified as:

- Champion
- Master Black Belt
- Black Belt
- Green Belt, as shown in Figure 2-1

Figure 2-1: Six Sigma Organizational Infrastructure



Source: www.pyzdek.com

2.5.1. Champion

Six Sigma champions are high-level individuals who understand Six Sigma and are committed to its success. In larger organizations Six Sigma will be lead by a full time, high level champion, such as an Executive Vice-President. In all organizations, champions also include informal leaders who use Six Sigma in their day-to-day work and communicate the Six Sigma message at every opportunity. Sponsors are owners of processes and systems who help initiate and coordinate Six Sigma improvement activities in their areas of responsibilities.

2.5.2. Master Black belt

This is the highest level of technical and organizational proficiency. Master Black Belts provide technical leadership of the Six Sigma program. Thus, they must know everything the Black Belts know, as well as understand the mathematical theory on which the statistical methods are based. Master Black Belts must be able to assist Black Belts in applying the methods correctly in unusual situations. Whenever possible, statistical training should be conducted only by Master Black Belts. Otherwise the familiar "propagation of error" phenomenon will occur, i.e., Black Belts pass on errors to green belts, who pass on greater errors to team members. If it becomes necessary for Black Belts and Green Belts to provide training, they should do only so under the guidance of Master Black Belts. For example, Black Belts may be asked to provide assistance to the Master during class discussions and exercises. Because of the nature of the Master's duties, communications and teaching skills are as important as technical competence.

2.5.3. Black belt

The front line leaders of Six Sigma are called black belts. These individuals are full-time project leaders with all the same responsibilities as green belts. However, black belts receive significantly more training than green belts (e.g., 4 weeks vs. 1 week) and are expected to generate more results from larger scope projects (Hoerl, 2001). Black belt candidates are described as disciplined problem solvers who possess a fair amount of technical ability, are comfortable with basic statistics, and are not afraid to question conventional wisdom (Hoerl, 2001; Adams et al., 2003). A black belt has also been described as an open-mined change agent and project manager who must be able to communicate effectively at all levels (Brue, 2002). Many experts have insisted that black belts be able to use a broad set of soft skills, such as meeting management and presentation methods (Breyfogle et al., 2001; Eckes, 2001; Hoerl, 2001; Pyzdek, 2000b). As a chosen leader, the black belt will guide a team through DMAIC.

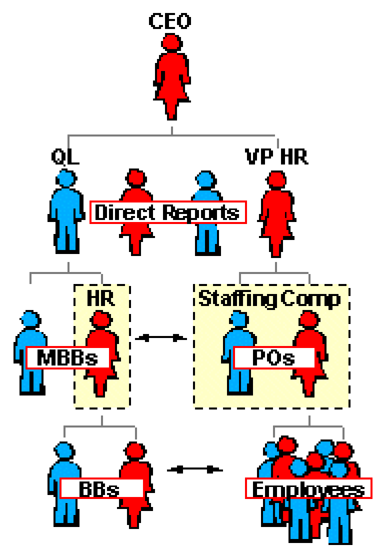
Black belts are "future business leaders" (Eckes, 2001, p. 43) and "the backbone of Six Sigma culture" (Brue, 2002, p. 86). Cary W. Adams et al. (2003) insisted that black belts are in strong demand and should be selected based on management potential. They make up on average roughly two percent of an organization's workforce. Their voluntary assignment is usually temporary lasting anywhere from two to three years. These trained individuals are expected to focus their efforts fulltime in the black belt role over this two to three year period and are not to be distracted with tasks from the role he or she temporarily left. Under these conditions, a black belt can complete approximately four to six projects in a twelve month period. There is generally an estimated annual savings of one million dollars in total for all projects completed in this timeframe (Adams et al., 2003; Harry, 1998; Hoerl, 1998). A prolific first year in Six Sigma can result in certification or reward and recognition by the company.

2.5.4. Green belt

Green Belts are employees trained in Six Sigma who spend a portion of their time completing projects, but maintain their regular work role and responsibilities. Depending on their workload, they can spend anywhere from 10% to 50% of their time on their project(s). As your Six Sigma quality program evolves, employees will begin to include the Six Sigma methodology in their daily activities and it will no longer become a percentage of their time -- it will be the way their work is accomplished 100% of the time.

The hierarchy of the roles mentioned above is shown in the Figure 2-2.

Figure 2-2: Six Sigma Roles Hierarchy



Source: www.isixsigma.com

At 3M, Six Sigma is driven by our executive management teams, who are fully engaged in critical business processes and actively deploying Six Sigma methodologies throughout the organization. Specific Six Sigma roles within 3M include:

- ***Six Sigma Directors***—Full-time leaders who report to executive leadership. They are responsible for Six Sigma deployment and results in their organizations.
- ***Champions***—Business leaders who support Six Sigma projects by identifying improvement opportunities and ensuring adequate resources and support for Six Sigma teams.
- ***Master Black Belts***—Full-time leaders are responsible for Six Sigma strategy, training, mentoring, deployment and results in a business, country, or organization. They lead and support Black Belts.
- ***Black Belts***—Full-time Six Sigma experts, who, during their two-year assignment, lead process-improvement teams and report to Maser Black Belts. They are trained in leadership, statistical measurement and problem solving.

- ***Green Belts***—All salaried employees are trained as Green Belts. Green Belts use Six Sigma skills to complete projects in their job areas.

- ***Six Sigma Coaches***—Six Sigma Tool Experts who coach and support Master Black Belts and Black Belts on projects and deployment within 3M.

Within the GE realms, the organizational infrastructure for Six Sigma consists of a diverse population of technical and non-technical people, managers, and people from key business areas (Hendersen and Evans, 2000), which are classified as:

- ***Champions*** are fully trained business leaders who promote and lead the deployment of Six Sigma in a significant area of the business;

- ***Master Black Belts*** are fully-trained quality leaders responsible for Six Sigma strategy, training, mentoring, deployment, and results;

- ***Back Belts*** are fully-trained Six Sigma experts who lead improvement teams, who work projects across the business and mentor green belts;

- ***Green Belts*** are full-time teachers with quantitative skills as well as teaching and leadership ability; they are fully-trained quality leaders responsible for Six Sigma strategy, training, mentoring, deployment, and results; and

- ***Team Members*** are individuals who support specific projects in their area.

2.6. SIX SIGMA'S IMPLEMENTATION METHODOLOGIES

A **methodology** is an organized set of methods, techniques and tools, developed to guide the whole cycle of a process to achieve its objectives (Saracelli and Bandat, 1993). According to Preece and Peppard (1996), a methodology is simply theory put into practice aiming at dealing with real world situations. Valiris and Glykas (1999) define a methodology as a structured set of guide-lines (or principles) which enable an analyst to derive ways of alleviating a problem.

The use of a methodology is essential for a number of reasons. First, a methodology provides a means of codifying experience, knowledge and ideas, in a form that not only can be easily applied, but also can be evaluated and tested. Second, a methodology offers a certain level of organization, and facilitates planning and monitoring. Third, a methodology enables those who are involved to understand their tasks and clarify their roles. Finally, adoption of a methodology allows a standard set of required skills to be identified and developed.

The main focus of six sigma is to reduce potential variability from processes and products by using either a continuous improvement methodology, abbreviated as **DMAIC**, or a design/redesign approach known as design for six sigma (**DFSS**). Let us discuss these two methodologies one by one:

2.6.1. DMAIC

DMAIC methodology is used for improving the existing processes. It consists of five stages which are abbreviated as DMAIC: Define, Measure, Analyze, Improve, and Control.

Define (D) is the first step of the Six Sigma methodology where leaders are expected to select projects, set initial goals or targets, and develop a project charter or statement of work (SOW). Costs of poor quality associated with the new or existing process being analyzed are estimated. Improvement targets are set often in terms of sigma and cost (Pande et al., 2002). Leadership selects the appropriate team members. The team then determines more precisely the criteria that are critical to the customer. Run charts, interviews, or surveys, for example, are utilized to obtain leads and useable figures (Eckes, 2001). A high-level process map of the existing process is to be developed with start and end-points clearly illustrated. Strategic deliverables are a process map, a working project charter, a team roster, and the costs of poor quality. A progress report to leadership normally concludes each step (Eckes, 2001; Pande et al., 2002).

Measure is the second step of the Six Sigma methodology and is denoted by the capital letter **M**. This is where a baseline measure is taken using actual data (Eckes, 2001; Pande et al., 2002; Snee, 2003). The measure then becomes the origin from which the team can gauge improvement. The team develops measures or utilizes existing ones, such as SPC data or database information, and pairs them accordingly with critical customer criteria. Pareto diagrams and controls charts as well as methods mentioned above in the define step are possible data sources for baseline measures. Testing repeatability and reproducibility (R&R) of a measurement system is recommended throughout a Six Sigma project wherever critical measures are taken. A data gathering plan or sampling plan can be followed for greater accuracy (Eckes, 2001; Pande et al., 2002). The project charter or SOW should be refined based on the data gathered in the measure step. The process map can be revised based on new discoveries of value added or non-value added steps in the existing process. Strategic deliverables for the measure step are baseline figures, R&R results, process capability, an improvement goal, a refined process map, and a refined project charter (Eckes, 2001; Pande et al., 2002).

The third step, **A**, is **Analyze**. Here teams identify several possible causes (X's) of variation or defects that are affecting the outputs (Y's) of the process. One of the most frequently used tools in the analyze step is the cause and effect diagram (Eckes, 2001; Snee, 2003). A Six Sigma team explores possible causes that might originate from sources, such as people, machinery and equipment, environment, materials, and methods. Another highly effective technique to expose root cause is asking "why" to a possible cause at least five times (Eckes, 2001). Team member suggestions may need clarified before proceeding further, so each and every team member has a clear understanding of the cause being presented. The resulting list should be reduced to the most probable root causes. Causes can be validated using new or existing data and applicable statistical tools, such as scatter plots, hypothesis testing, ANOVA, regression, or design of experiments (DOE). Experts warn not to assume causation or causal relationships unless there is clear proof. Furthermore, validating root causes can help teams avoid implementing ineffective improvements and wasting valuable resources (Eckes, 2001).

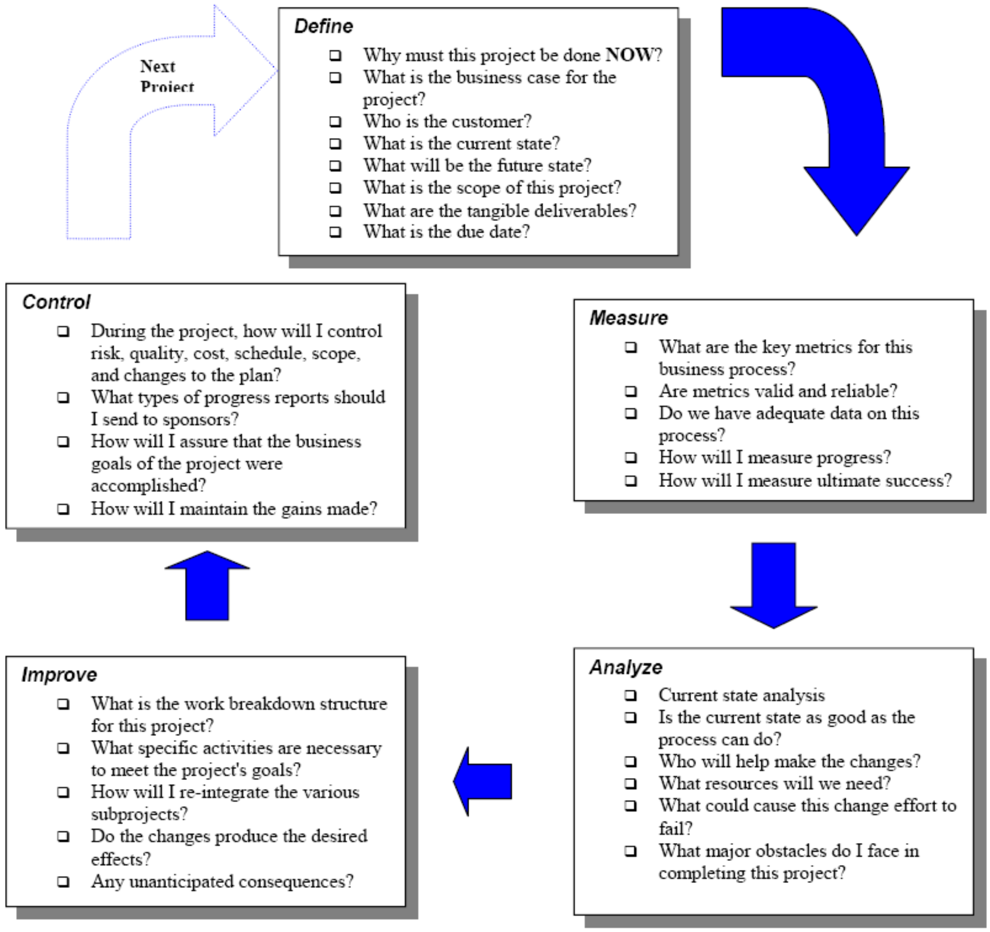
The team then enters the **Improve (I)** step. Here a team would brainstorm to come up with countermeasures and lasting process improvements that address validated root causes. The tool most preferred for this process is the affinity diagram, which is a brainstorming technique where a topic or issue is presented to a small team who then quickly list ideas or solutions (Eckes, 2001). The team should narrow the list to one or two potential improvements that are step deliverables for small-scale implementation. Improvements should be selected based on probability of success, time to execute, impact on resources, and cost (Eckes, 2001; Pande et al., 2002). If newly gathered data indicates the small-scale implementation is a legitimate success, teams should proceed to full-scale implementation (Pande et al., 2002).

The final step for at least the black belt and many of the team members is **Control**, which is signified by the capital letter **C**. At this point devices should be put in place to give early signals when a process is heading out of control. Teams may develop poka-yokes or mistake proof devices that utilize light, sound, logic programming, or no-go design to help control a process (Breyfogle et al., 2001). The ultimate goal for this step is to reduce variation by controlling X's (i.e., the inputs) and monitoring the Y or Y's (i.e., the outputs) (Pande et al., 2002).

In approximately three to six months, the sigma levels or process capability figures, that should be routinely measured and documented by workers, are then checked by the process owner to make certain that the installed improvements are lasting. Any documentation and project reports should be finalized. With a control plan in place, the project is delivered to the rightful owner who is usually the project champion or a sponsor from leadership. It is the owner's duty to then manage the new or improved process (Eckes, 2001; Pande et al., 2002).

The DMAIC project cycle is shown in Figure 2-3.

Figure 2-3: DMAIC Project Cycle



Source: www.pyzdek.com

2.6.2. Design for Six Sigma (DFSS)

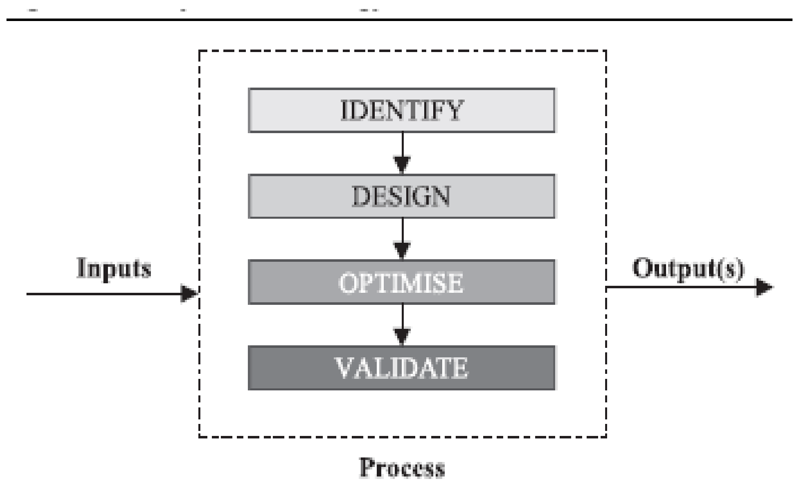
DFSS is defined as:

> A systematic methodology using tools, training, and measurements to enable the design of products, services, and processes that meet customer expectations at Six Sigma quality levels. DFSS optimizes the design process to achieve six sigma performance and integrates characteristics of Six Sigma at the outset of new product development with a disciplined set of tools (Brue and Launsby, 2002)

DFSS is based on the notion that Six Sigma quality should be built in right at the outset of new product development. By incorporating DFSS, it is assured that the product or service being launched will perform dependably in the marketplace, thus setting it up for very positive acceptance.

Unlike DMAIC, a number of methodologies have been proposed for DFSS (UGS, 2005). A well-known methodology for DFSS is **IDOV** as shown in the Figure 2-4.

Figure 2-4: IDOV Methodology



Source: Antony (2002)

Stage 1: Identify

This stage essentially ensures that the organization understands the criteria for success. It achieves this by:

- Identification of customers and their requirements
- Clear definition of the design requirements for the product
- Identification of customer critical-to-quality (CTQ) characteristics using quality function deployment (QFD)
- Planning of functional and engineering requirements
- Determination of relationship between customer requirements and technical requirements
- Determination of target for each CTQ

Stage 2: Design

Once the organization understands the parameters of design, these must be translated into actual, effective design. This stage involves:

- Analysis of the design requirements and key design parameters and their relationship with CTQs
- Identification of design alternatives
- Utilization of concurrent engineering practice
- Study of the relationship of design parameters to CTQ at sub-levels in complex processes or systems
- Identification of the risks involved and typical failures, using, for example, design failure mode and effect analysis (DFMEA)

Stage 3: Optimize

The third stages involves the further consideration of design to ensure effective "marketability" – so that the organization is confident that the product can be manufactured within design parameters, and with the agreed budget. This stage involves:

- Identification of sources of variability (manufacturing, environmental, etc.)
- Minimizing product performance sensitivity to all sources of variation using robust design
- Application of tolerance design for critical design parameters obtained from robust design
- Optimizing the design for manufacturability (DfM)
- Optimizing the design for product reliability

Stage 4: Validate

The final stage checks that the process is complete, valid and will meet requirements in practice. It involves:

- Verification of the design to ensure that it meets the set requirements
- Assessment of performance, reliability, capability, etc.

- Development of process control plan for the mean and variance of CTQs in production
- Development of a DFSS scoring card

Another popular DFSS methodology is called **DMADV**, which includes the following stages:

- **Define—**determine the project goals and the requirements of customers (external and internal)
- **Measure—**assess customer needs and specifications
- **Analyze**—examine process options to meet customer requirements
- **Design—**develop the process to meet the customer requirements
- **Verify—**check the design to ensure that it's meeting customer requirements

DCCDI is another DFSS popularized by Geoff Tennant and is defined as Define, Customer Concept, Design and Implement. It includes:

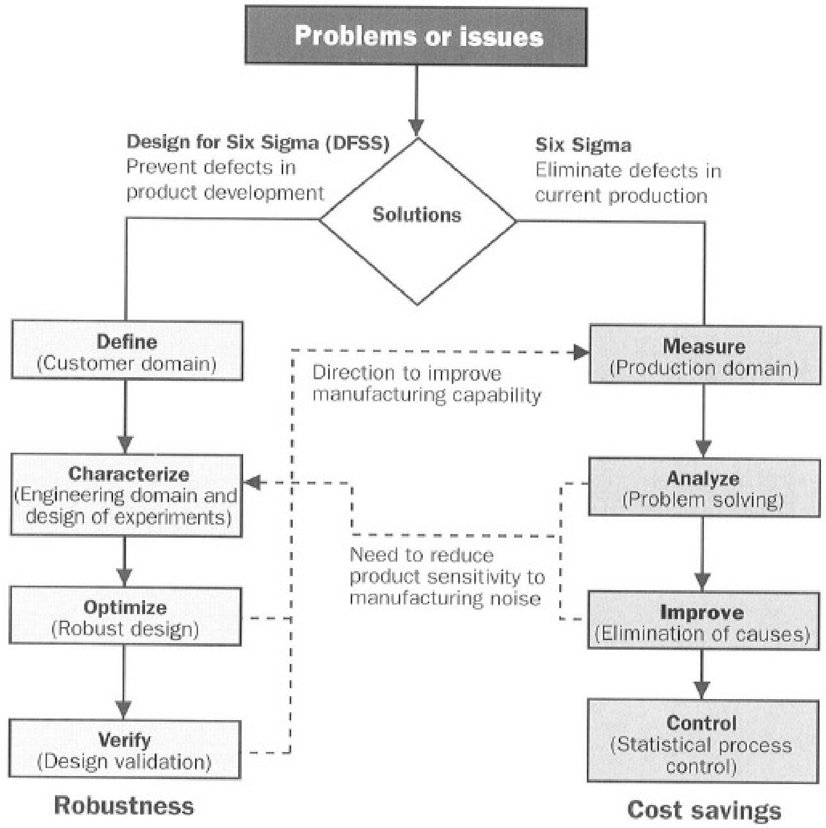
- **Define—**the project goals are defined
- **Customer Concept—** customer analysis is done; concept ideas are developed, reviewed and selected.
- **Design—** product is developed to meet the customer and business specifications.
- **Implementation—** design implementation is done to develop and commercialize the product/service.

Antoher DFSS methodology is **DMEDI**, developed by PricewaterhouseCoopers and stands for Define, Measure, Explore, Develop and Implement.

2.6.3. Difference between DMAIC and DFSS

Because of the similarities between Six Sigma and DFSS, DFSS is often confused as the logical extension of DMAIC for design and development. Figure 2-5 shows DFSS and DMAIC work on issues in two different domains. While DFSS is a methodology to solve issues coming from the end customer, DMAIC solves operational issues.

Figure 2-5: DMAIC vs. DFSS



Source: Ferryanto (2005)

The basic differences between the Six Sigma DMAIC and DFSS (Brue and Launsby, 2002) are summarized as:

- DMAIC is more focused on reacting, on detecting and resolving problems, while DFSS tends to be more proactive, a means of preventing problems.
- DMAIC is for products or services that the organization offers currently; DFSS is for the design of new products or services and processes.
- DMAIC is based on manufacturing or transactional processes and DFSS is focused on marketing, R&D, and design.
- Dollar benefits obtained from DMAIC can be quantified rather quickly, while the benefits from DFSS are more difficult to quantify and tend to be much more

long-term. It can take six to 12 months after the launch of the new product before you will obtain proper accounting on the impact of a DFSS initiative.

- DFSS involves greater cultural change than DMAIC, because for many organizations DFSS represents a huge change in roles. The DFSS team is cross-functional: it's key for the entire team to be involved in all aspects of the design process, from market research to product launch.

The differences of DMAIC and DFSS are summarized in the Table 2-3:

Table 2-3: DMAIC vs. DFSS

DMAIC	DFSS
1. A universal DMAIC methodology used by all companies	No standard methodology for DFSS. The different methodologies include IDOV, DMADV, DCCDI, and DMEDI.
2. Focuses on improving the existing processes	Focuses on designing and developing new products or processes incorporating six sigma quality level
3. Reactive approach	Proactive approach
4. More focused on manufacturing or transactional processes	More focused on marketing and R&D
5. Dollar benefits can be quantified easily	Benefits are more difficult to quantify and tend to be more long-term. It can take six to 12 months after the launch of the new product before proper accounting on the impact can be obtained.

Source: Brue and Launsby (2002)

2.7. SIX SIGMA AND OTHER MANAGEMENT FRAMEWORKS

2.7.1. Six Sigma and Total Quality Management (TQM)

TQM can be defined as:

> … an approach to improving the effectiveness and flexibility of a businesses as a whole. It is essentially a way of organizing and involving the whole organization; every department, every activity, every single person at every level (Oakland, 1989)

TQM can be seen as a continuously evolving management system consisting of values, methodologies and tools, the aim of which is to increase external and internal customer satisfaction with a reduced amount of resources. TQM starts in most descriptions from values which contribute to creation of organizational culture. To attain this, the values have to be supported, systematically and continuously, by suitable methodologies and tools.

Figure 2-6: Total Quality Management

Source: Klefsjo et al (2001)

The roots of Six Sigma can be traced to TQM. From TQM, Six Sigma preserved the concept that everyone in an organization is responsible for the quality of goods and services produced by the organization. Other components of Six Sigma that can be traced to TQM include the focus on customer satisfaction when making management decisions, a significant investment in education and training in statistics, root cause analysis, and other problem solving methodologies. However, Six Sigma differentiates from TQM in the sense that TQM is a holistic approach encompassing a number of tools and methodologies while Six Sigma is a focused, systematic approach based on two standard methodologies of DMAIC and DMADV. Six Sigma focuses on impacting the bottom line through breakthrough improvements while TQM advocates incremental improvements based on Kaizen. Six Sigma defines a formal, clearly defined organizational infrastructure consisting of Champions, Master Black Belt, Black Belt, and Green Belt, not found in the case of TQM. Six Sigma utilizes project management approach for identifying and implementing improvement projects while TQM does not specify a formal approach for implementation.

2.7.2. Six Sigma and ISO 9000

ISO 9000 family of standards were released in 1987, which specify the requirements for implementing a Quality Management System in an organization. The standard was later revised in 1994 and the latest revision was released in 2000. The standard is based on eight quality management principles, which include: customer focus; leadership; people involvement; process approach; system approach to management; continual improvement; factual approach to decision making; and mutually beneficial supplier relationship (ISO 9000:2000). ISO 9000 is a generic standard applicable to any organization regardless of its type or size. It does not specify the product or service standards to be followed but requires organizations to identify the customer and regulatory requirements and monitor and measure the products, services, processes, and customer satisfaction.

The comparison of ISO 9000 and Six Sigma is given in the Table 2-4:

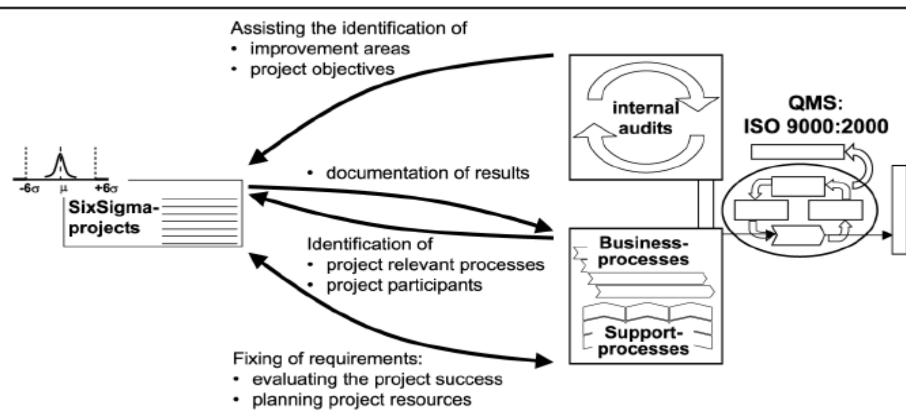
Table 2-4: Six Sigma vs. Quality Management

	Six Sigma	Quality Management
Objective	Monetary benefit through customer satisfaction	Customer satisfaction through high quality products
Strategy	High quality level/low failure rates in all business processes	Arranging business processes according to the requirements of standards
Management	Commitment and clear objectives for projects, creating an organizational structure which pursues the objective	Listing of management responsibilities
Required resources	Required resources for projects (basically human resources)	Human resources, infrastructure and work environment
Training	In all areas of an organization, different levels of qualification dependant on the function in processes	Required but not specified
Project Management	DMAIC/DMADV (continuous improvement approach)	PDCA (model for continuous improvement)
Process Approach	SIPOC (approach for describing single processes)	Model of a process-based QMS
Methods	Specified toolbox	No specification
Documentation	No specification	Listing of requirements

Source: Pfeifer et al (2004)

According to Pfeifer (2004), Six Sigma and QMS can be integrated to attain maximum benefits from the two systems. The integrated model is shown in the Figure 2-7.

Figure 2-7: Integration of Six Sigma and QMS



Source: Pfeifer et al (2004)

All relevant processes have first to be determined and their interactions have to be analysed. Six sigma demands therefore the SIPOC-model as described before (Hammer, 2002). In this context, previously documented business processes in QMS often provide the required input. The process maps offer an analytic framework in order to show the interactions of processes.

Six sigma offers an objective-oriented approach for the identification of projects, which promise a high financial success. On the other side, the application of QMS process audits permits a continuous and systematic search for all existing improvement potentials in the organisation. Thus, it makes sense to apply these two different approaches simultaneously: the search for the most profitable projects carried by the project officers (black belts) and the continuous and systematic determination of improvement potentials by the process owners (green belts).

After identifying the involved processes using process maps, the process objectives described in QMS can be compared with the planned six sigma project objectives. Thus the impact of modifications in interrelated processes, i.e. between production and logistic processes can be clearly identified.

The participants required for a six sigma project have to be chosen by examining the related processes. Departments involved, as well as their functions and responsibilities in the processes, are already specified in the QMS documentation. The required knowledge, which individual participants need to fulfill the demands of the project, can be estimated by regarding the definitions in the system as well as specific project tasks.

The project results have to be systematically documented in order to assure their availability in the whole organisation for further projects. QMS offer well-structured facilities for the documentation of process-related results. These can be documented and visualised, i.e. as process flowcharts, system procedures, working instructions, systems of precepts or lessons learned listings. This encourages also the acceptance of QMS and its continuous updates because of its rising importance for the operative work (Douglas et al., 2003)

Advantages of the systematic integration of both approaches are:

- an effective proceeding to identify the most relevant improvement areas;
- the assurance of conform project and process objectives and thus the sustainability of six sigma projects;
- choice of the most capable project participants and minimization of the qualification effort;
- the fulfilment of all organizational requirements for running projects using standard procedures and measures; and
- increased availability of project experiences through well-structured documentation facilities.

2.7.3. Six Sigma and Business Process Reengineering (BPR)

BPR is defined as:

> "… the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical, contemporary measures of performance, such as cost, quality, service, and speed" (Hammer and Champy, 1993)

The essential components within BPR are: focus on process, notion of radicalness, use of Information Technology (IT) and need for organizational change (Al-Mashari and Zairi, 2000). BPR focuses on the core concept of **business process** rather than on function, product or service. BPR involves **radical and fundamental changes** and drives organizations to reengineer old businesses by introducing new structures and procedures. **Information Technology (IT)** is considered to be a major tool and fundamental enabler of BPR efforts. BPR results in change and successful BPR implementation requires fundamental **organizational change** in terms of organizational structure, culture and management processes (Davenport, 1993a).

Six Sigma and BPR share some common features, such as: focus on process improvement, need for organizational and cultural change; radical improvement in organizational performance in terms of quality and cost; focus on customer needs; and team-based approach. However, they differ in that six sigma is a highly data-based approach involving the use of advanced statistical tools while BPR uses modern IT to achieve dramatic results in business performance. On the other side, lean manufacturing does not seem to be strongly related to BPR though both focus on process improvement and aim for customer satisfaction. However, lean manufacturing is more manufacturing biased and utilizes the Japanese quality improvement tools for waste elimination.

2.7.4. Six Sigma and Lean Manufacturing

Lean production is defined as:

> "Lean production is lean because it uses less of everything compared with mass production –half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half the time. Also it requires keeping far less than half the needed inventory on site, results in many fewer defects, and produces a greater and ever-growing variety of products." (Womack et al, 1990)

Lean manufacturing aims to produce high quality products and services at the lowest possible cost through systematic identification and elimination of waste, with an emphasis on continuous improvement and employee involvement. The manufacturing waste (Muda) includes inventory, defects, overproduction, waiting, movement, complexity, and unused employee creativity.

There are five essential steps in the lean manufacturing (Nave, 2002):

1. **Identify value** – value is expressed in terms of how the specific product meets the customer's needs, at a specific price, at a specific time. The value determination can be from the perspective of the ultimate customer or a subsequent process.

2. **Identify the value stream** – once value is identified, the activities that contribute value are identified. The entire sequence of activities is called value stream. All non-valued added activities are transitioned out of the process.

3. **Improve flow** – once value-added activities are identified, improvement efforts are directed towards making the activities flow. Flow is the uninterrupted movement of product or service through the system to the customer.

4. **Allow customer pull** – After waste is removed and flow established, efforts turn to letting the customer to pull product or service through the process. The company must make the process responsive to providing the product or service only when the customer needs it – not before, not after.

5. **Work toward perfection** – this effort is the repeated and constant attempt to remove non-value added activity, improve flow and satisfy customer delivery needs.

The core principles of lean manufacturing (Karlsson and Ahlstrom, 1996) include elimination of waste, continuous improvement, zero defects, Just-in-Time deliveries, pull of materials, multifunctional teams, and integration of functions.

Six Sigma and Lean Manufacturing share common features and differences. Both Six Sigma and lean management have evolved into comprehensive management systems. In each case, their effective implementation involves cultural changes in organizations, new approaches to production and to servicing customers, and a high degree of training and education of employees, from upper management to the shop floor. Both systems emphasize on customer satisfaction, high quality, and comprehensive employee training. Both involve multifunctional teams and employee empowerment for their implementation. Both systems aim for zero defect level and focus on elimination of waste and non-value added activities.

However, if we explore, in details, the structure and approach of the two systems, we find certain aspects where they differ from each other. Six Sigma has a US-origin, developed based on the Crosby's philosophy of "Zero Defect". Lean Manufacturing, on the other hand, has Japanese-origin, which can be traced to the Toyota Production System (TPS), developed by the Japanese engineers Taiichi Ohno and Shigeo Shingo. While Six Sigma aims for quality improvement by eliminating variations in processes, lean manufacturing focuses on effective use of resources and elimination of waste. Six Sigma uses a systematic DMAIC methodology for improvement in processes while Lean Manufacturing makes use of Japanese manufacturing practices, such as Just-in-Time, Pull System, etc. Six Sigma is a data-based approach and makes extensive use of basic and advanced statistical tools and techniques whereas Lean Manufacturing employs Japanese quality tools, such as Kaizen, Poka Yoke, 5S, etc. The organizational architecture for Six Sigma includes Champion, Master Black Belt, Black Belt, and Green Belts, each having a specific role to play in the six sigma projects. Lean manufacturing architecture, on the other hand, comprises multifunctional teams. Six sigma is being implemented by both manufacturing and services organizations while lean manufacturing is more applicable on the manufacturing organizations.

2.8. SIX SIGMA PROJECT MANAGEMENT

Six Sigma is a project-based improvement approach where project teams headed by Black Belts are used to identify and implement improvements in products, services or processes. The success or failure of any Six Sigma Business Process Improvement Initiative hinges on selecting projects that can be completed in a reasonable amount of time (4-6 months) and will deliver tangible (quantifiable) business benefit in financial impact or customer satisfaction. The best Six Sigma teams make project selection an art form. They are inclusive, and reflective, and involve the entire organization.

2.8.1. Criteria for Six Sigma Projects

On any scale, picking the right projects to work on will ensure that the organization leverages its limited resources wisely while making sure it solves business problems that are most critical to the bottom line. There are three broad areas where an executive can look for opportunities to apply Six Sigma tools (Jackenthal, 2004):

- **Strategy** - Each year organizations of every shape and size, in every industry and discipline, work feverishly to develop a strategic plan for their performance cycle. From the top level down, organizations use these documents to define goals and objectives. By understanding where the gaps in our current performance exist related to our goals we can begin to identify potential project ideas. The larger the gap, the greater the opportunity for improvement. Successful Six Sigma projects must be aligned with the overall business strategy.

- **Budget** – Since our objective is to reduce the cost associated with poor quality, a logical place to look would be the budget. The majority of our expenditures are tied into people, technology and transaction processing. Line item examination of the departmental budget will provide obvious insight into where one can reduce costs and improve business process. Successful projects can leverage existing resources to dramatically improve service levels and/or increase capacity. Successful Six Sigma projects are tied directly to our current cost of doing business.

- **Customer** – Is there an existing loop for customers or employees to provide feedback on their current level of satisfaction? Is this feedback viewed as "complaints" or "opportunities"? Central to Six Sigma concept is the "Voice of the Customer" or VOC. The first step in VOC is knowing who our customers are. The second step is understanding what they specifically value from our business process. We need to understand the root cause of customer dissatisfaction in order to eliminate it permanently. This requires quantitative measurement and analysis. Successful Six Sigma projects are aligned with critical to quality (CTQ) Customer requirements.

Knowing where to look will help us generate a framework of opportunities to focus our project work on. Not all projects are Six Sigma projects, nor should they be. Focusing on these project selection categories will keep the team working on the critical few (Jackenthal, 2004).

- **Recurring events** – We usually dedicate the most resources (both financial and human) to the tasks we perform most frequently. We must think about the services provided and break them down into common threads. Within these threads are the repetitive tasks our teams perform over and over again. Recurring events offer the best insight into process performance.

- **Narrow scope –** For Six Sigma projects to be successful and completed within a reasonable timeframe, they must be narrow in scope. During training, Black and Green Belts are continually reminded that the best Six Sigma projects are scoped "an inch wide and a mile deep" to enable the rigorous data collection and analysis required for the permanent solution we seek. It would be better to do several smaller projects aligned along a common problem than to try to solve them all at once.

- **Available metrics or measurements developed quickly –** In order to apply the discipline of Six Sigma we need data on current process performance (process Inputs or 'X' variables) and not just what we produce (process Outputs or 'Y' variables). When selecting potential projects, we should think about the availability of data for both Inputs and Outputs. What is currently measured and how is it related to the overall process? When there are gaps in the current data, we should think about how easily we might collect data on each step in the process.

- **Direct link to Customer Satisfaction –** By first defining who the customers of the process are we can identify and quantify direct links to their satisfaction drivers. We should think about the customers in the broadest possible terms and should not begin a project unless one can make this connection.

There are some broad categories one might want to consider, as they have proven to dovetail nicely into Six Sigma methodology. Most successful Six Sigma projects tend to fall into one of the following categories (Jackenthal, 2004):

- **Defect Reduction –** "Opportunities" are the things that must go right in order to satisfy the customer. Any undesired result would be considered a "defect". Projects should be selected where one can clearly measure the rate of defects as a function of opportunities. Examples might be found by looking at customer complaints, one-call resolution, training enrollment or attendance, recruiting yield and reducing duplicity, to name a few.

- **Cycle Time Reduction** - If the process is measured as a function of time, reducing the cycle-time by which one completes the process will often have significant impact. Approval time, time to fill/hire, new hire onboarding and relocation, are some relevant examples.

- **Cost per Unit** - This is a great metric to consider for many processes where Executive Management is the primary customer. By reducing the overall cost per unit, we can almost always impact bottom line cost and your budget.

- **Customer Satisfaction (External or Internal) –** This is another reference to Customer Satisfaction. Successful Six Sigma projects are tied to improving a primary metric that links directly to the customer. Employee turnover or retention, applicant tracking and recruiter market share have direct links to customer satisfaction.

2.8.2. Project Selection Matrix

By applying the guidelines discussed above, we can develop a list of potential Six Sigma projects that will have the greatest potential for success. This list will help to prioritize projects based on their significance and potential impact to the business. The 'Project Selection Matrix', shown in APPENDIX 6, can be an invaluable brainstorming tool to assist Six Sigma teams with aligning limited resources to the projects that will give the best return on investment.

One begins by listing the projects along the far left column (or 'Y' axis). Next, evaluation criteria is determined and listed in the column headings along the top row (or 'X' axis). Then the 'Significance Rating' is determined, using a 1 (low) to 10 (high) scale, for each column heading based on business or executive management priorities. This adds some power to the matrix and enables more weight to be places on selection criteria viewed as most important by the business. Now that the framework for the Project Selection Matrix is complete, the team can begin the exercise of filling in the individual boxes by scoring each project selection criteria as they relate to each project idea. Using a 1 (low) to 10 (high) scale for each selection criteria, we can create definitions for the team to use as reference. Once each project has been scored for the selection criteria (multiplied by the significance rating) we will have an overall score for each project. Sorting the table by this column creates a rank order of projects based on the individual cumulative scores.

Knowing where to start looking, using the right selection criteria and thinking about broad categories of project type will allow focusing on projects with the greatest potential for success and measurable business impact. Putting these project ideas through a selection matrix tool enables management team to rank them against business or executive management priorities. The process for project selection should involve the same rigor as project execution. Not doing so will result in projects that consistently fall short of the mark.

2.9. LIMITATIONS OF SIX SIGMA

Six Sigma is described as a philosophy, methodology, and a breakthrough strategy to solve problems. However, it comes at a price, as deploying Six Sigma is both time and money consuming. Moreover, and while it promises massive savings and benefits, not all organizations that pursued it have achieved their goals (Jarrar and Neely, 2005). There are various reasons for this lack of success, and a fair number of these have to do with the way Six Sigma is being hyped as the ‘silver bullet’ for cost savings and high quality output.

One of the major issues facing Six Sigma stems from prevailing corporate cultures where most organisations are not designed nor led to allow such scientific management to be applied. The key to sustainable Six Sigma is the development of a supportive work environment, a culture that welcomes Six Sigma Black Belts into operational teams and encourages the active participation of all employees in business process improvement using the scientific methods of Six Sigma. Achieving this kind of work environment is not a natural process, and in most cases is resisted by employees at all levels alike.

A more direct criticism is the ‘rigid’ nature of Six Sigma with its over-reliance on methods and tools. In most cases, more attention is paid to reducing variation and less attention is paid to developing robustness (which can altogether eliminate the need for reducing variation). This taps into the argument of whether Six Sigma inhibits organizational innovation when it becomes part of the culture. For example, Six Sigma has been indisputably successful in eliminating waste, reducing variance and increasing productivity and profits. But its potential to create new business models for growth and innovation is barely tapped. To deal with this aspect, some practitioners have deliberately introduced Innovation as an extra element in their Six Sigma methodology. They took the original DMAIC (Define, Measure, Analyse, Improve, and Control) and introduced DMAI^{2}C (Define, Measure, Analyse, Innovate, Improve, and Control).

A more controversial criticism area is the effect on Six Sigma on organisational culture when adopted organisation-wide. It has been noted that in some cases, employees complained of the ‘Six Sigma Bureaucracy’. Organisations that adopted Six Sigma as a way of life made it essential for all organisational projects and improvement initiatives to fit within the ‘standard Six Sigma’ format. While these were seen as useful and structured in many cases, there were cases that claimed this added unnecessary burdens and even stifled some ideas and initiatives.

Moreover, and due to such rigid procedures, many complained that Six Sigma, in some cases, created a roadblock for ‘doing things fast’. Within the set corporate Six Sigma procedures, every idea has to go through the methodology and be subjected to tools and analysis. While this might have been a useful filter to scrutinise new initiatives, having to submit every idea through standard forms and subject to strict methodologies might have caused a few good ideas from being implemented, or at least delayed them. In an age were we live ‘instant’ change, this might prove a vital point to consider.

Jiju Antony (2004) has highlighted some of the limitations of Six Sigma which create opportunities for future research:

- The challenge of having quality data available, especially in processes where no data is available to begin with (sometimes this task could take the largest proportion of the project time).
- The right selection and prioritisation of projects is one of the critical success factors of a six sigma program. The prioritisation of projects in many organisations is still based on pure subjective judgement. Very few powerful tools are available for prioritising projects and this should be major thrust for research in the future.
- The statistical definition of six sigma is 3.4 defects or failures per million opportunities. In service processes, a defect may be defined as anything which does not meet customer needs or expectations. It would be illogical to assume that all defects are equally good when we calculate the sigma capability level of a process. For instance, a defect in a hospital could be a wrong admission procedure, lack of training required by a staff member, misbehaviour of staff members, unwillingness to help patients when they have specific queries, etc.
- The calculation of defect rates or error rates is based on the assumption of normality. The calculation of defect rates for non-normal situations is not yet properly addressed in the current literature of six sigma.
- Due to dynamic market demands, the critical-to-quality characteristics (CTQs) of today would not necessarily be meaningful tomorrow. All CTQs should be critically examined at all times and refined as necessary (Goh, 2002).
- Assumption of 1.5 sigma shift for all service processes does not make much sense. This particular issue should be the major thrust for future research, as a small shift in sigma could lead to erroneous defect calculations.
- Non-standardisation procedures in the certification process of black belts and green belts is another limitation. This means not all black belts or green belts are equally capable. Research has shown that the skills and expertise developed by black belts are inconsistent across companies and are dependent to a great extent on the certifying body. Black belts believe they know all the practical aspects of

advanced quality improvement methods such as design of experiments, robust design, response surface methodology, statistical process control and reliability, when in fact they have barely scratched the surface.

- The start-up cost for institutionalising Six Sigma into a corporate culture can be a significant investment. This particular feature would discourage many small and medium size enterprises from the introduction, development and implementation of six sigma strategy.
- Six sigma can easily digress into a bureaucratic exercise if the focus is on such things as the number of trained black belts and green belts, number of projects completed, etc. instead of bottom-line savings.
- The linkage between six sigma and organisational culture and learning is not addressed properly in the existing literature.

2.10.SUMMARY

The chapter covered the literature review of Six Sigma, describing the history, definitions, benefits, methodologies, and limitations of Six Sigma. In addition, the comparison of Six Sigma with other improvement approaches such as TQM, BPR, ISO 9000, and Lean Manufacturing was discussed. In short, Six Sigma is a data driven, process improvement approach that aims at elimination of defects/errors and reduction of non-value added activities, thus impacting on the bottom line. It shares similarities with other approaches in terms of process focus, customer orientation, teamwork, culture of change, and customer orientation. However, it differs from them by having a systematic and focused process improvement methodology and organized use of statistical tools to bring about significant reduction in defects.

CHAPTER 3. THEORETICAL FRAMEWORK

3.1. INTRODUCTION

This chapter presents the Theoretical Framework on which this research project is based on. The theoretical framework describes the critical success factors for Six Sigma based on the review of literature and study of previous researches. The factors cover both soft factors, such as, teamwork, effective communication, training and education, culture change, etc., and hard factors, such as, project management, statistical tools, organizational infrastructure, etc.

3.2. CRITICAL SUCCESS FACTORS FOR SIX SIGMA

Critical Success Factors (CSFs) are those factors which are critical to the success of any organization, in the sense that, if objectives associated with the factors are not achieved, the organization will fail (Rockart, 1979). In the context of six sigma project implementation, CSFs represent the essential ingredients without which a project stands little chance of success.

Many organizations have reported significant benefits today as a result of six sigma implementation. General Electric is one of the most successful companies in implementing six sigma projects. GE 1999 annual report stated:

> "… the six sigma initiative is in its fifth year – its fifth trip through the operating system. From a standing start in 1996, with no financial benefit to the company, it has flourished to the point where it produced more than $2 billion in benefits in 1999, with much more to come this decade."

Motorola, where Six Sigma was developed in the 1980s, claims to have similar savings. From 1987 to 1997, Motorola achieved a fivefold growth in sales with profits climbing nearly 20 percent per year, cumulative savings at $US14 billion and stock price gains compounded to an annual rate of 21.3 percent. Motorola was also cited as the first winner of America's Malcolm Baldrige National Quality Award in 1988. Other companies such as AlliedSignal, Citibank and Sony, have also succeeded in six sigma implementation (Antony and Banuelas, 2001).

However, not all companies can claim to have had the same benefits. According to David Fitzpatrick, worldwide leader of Deloitte Consultant's Lean Enterprise practice:

> ". . . fewer than 10 per cent of the companies are doing it to the point where it's going to significantly affect the balance sheet and the share price in any meaningful period of time."

These contrasting results make Six Sigma implementation a complex and central process. Many practitioners and scholars have identified various key factors for the successful implementation of Six Sigma (Antony and Banuelas, 2001; Hoerl, 1998; Henderson and Evans, 2000). A ''big dollar impact'' is one of five key reasons cited by Hoerl (1998) for the success of Six Sigma. The other four reasons cited by Hoerl for Six Sigma success are: continued top management support and enthusiasm, emphasis on a quantitative and disciplined approach to process improvement, value placed on understanding and satisfying customer needs, and the manner in which it combines right projects with the right people and tools.

Hendersons and Evans (2000), based on the study of GE' Six Sigma implementation, suggest upper management support/involvement, organizational infrastructure, training, tools, linkage to human-resource based actions (promotion, bonuses), early communication to employees, measurement systems, and an information technology infrastructure as the key elements for successfully implementing Six Sigma.

Antony and Benuelas (2001), based on the review of existing literature, identify that the key ingredients for the effective implementation of Six Sigma are: top management involvement and commitment; cultural change; organizational infrastructure; training; project management skills; project prioritization and selection, reviews and tracking; understanding the six sigma methodology, tools and techniques; linking Six Sigma to business strategy; linking Six Sigma to the customer; linking Six Sigma to the human resources; and linking Six Sigma to the suppliers.

From the abovementioned literature review, following CSFs of Six Sigma are identified:

3.2.1. Continued top management support and commitment

Any company-wide and result oriented initiative like Six Sigma requires top management involvement and provision of appropriate resources and training (Halliday, 2001). Those who have implemented and practice Six Sigma agree the most critical success factor is top management support. According to professor of operations and manufacturing management at the John M. Olin School of Business, "The top executive must be part of Six Sigma. [He or she] must change the agenda of upper management meetings so the quality initiative is right near the top". Lawrence Bossidy, CEO of AlliedSignal ensured that company remained competitive by implementing Six Sigma quality and achieving 7 percent year-over-year productivity (Minahan, 1997). Jack Welch, GE's CEO, while introducing Six Sigma initiative, said that it "is the only initiative he will introduce, but it will be introduced everywhere" (Murdoch, 1998). When the employees tried to dismiss Six Sigma as the program of the month, Welch changed the business structure at a corporate level to underscore the importance of the goal. Thus the top management should support the Six Sigma initiative by personally spending time in every Six Sigma training, speaking and answering questions raising by employees, dropping in (usually unannounced) on Six Sigma reviews, making site visits to observe at first-hand the degree to which Six Sigma is ingrained in the culture; and monitoring Six Sigma project progress weekly through summary reports from the tracking database and monthly reviews with the master black belt team (Henderson and Evans, 2000).

3.2.2. Suitable organizational infrastructure

"Conversion to a Six Sigma culture is an enormous undertaking. Many people have to be directly involved, and many support systems have to be in place to make it all work smoothly" (Hendericks and Kelbaugh, 1998). The organizational structure for Six Sigma consists of a hierarchy of roles depending on the level of expertise: champions, master black belt, black belt, green belt. At 3M, Six Sigma is driven by executive management teams, who are fully engaged in critical business processes and actively deploying Six Sigma methodologies throughout the organization.

Specific Six Sigma roles within 3M include: Six Sigma directors, master black belts, black belts, green belts, and Six Sigma coaches. At GE, the Six Sigma architecture includes a diverse population of technical and non-technical people, managers, and people from key business areas which have been divided into champion, master black belt, black belt, green belt, and team members. More than 200 trained master black belts are fulltime teachers with quantitative skills as well as teaching and leadership ability. More than 800 trained black belts are full-time quality executives who lead teams, focus on key processes, and report the results back to the champions (Welch, 1996a).

3.2.3. Organizational culture change

Six Sigma is a breakthrough management strategy which requires changes in organizational culture and in the attitudes of employees. Eckes (2000) identifies four different factors of people resistance to Six Sigma. First is the **Technical factor** which arises due to difficulty in understanding statistics. Education and involvement are required to overcome it. Second is the **Political factor** which is based on seeking the solution to be implemented as a loss, real or imagined. This can be avoided by creating the need for change and then showing how change can be beneficial for employees. **Individual factors** are the third factors which are highly stressed employees due to personal problems. This can be reduced by listening to the employees and sharing their problems. Forth factor is the **Organizational factor** which is based on beliefs shared within the organization. It can be diminished by better communication to the managers. GE Welsh created change in organizational culture and overcame employee resistance by changing the organizational structure at the top, investing on training, adjusting the reward and recognition system, and early communication to employees (Henderson and Evans, 2000).

3.2.4. Education and Training

Training is the single most important factor in improving quality once the necessary commitment has been assured (Oakland, 1993). Quality begins and ends with training (Ishikawa, 1985). It is critical to “communicate both the why and the how of Six Sigma as early as possible, and provide the opportunity for people to improve their comfort level through training classes" (Hendericks and Kelbaugh, 1998). Upon deciding to pursue Six Sigma as a company initiative, Welch directed that every exempt employee at GE be trained in Six Sigma methodologies. In 1998, GE spent US$400 million on Six Sigma (most of it for training) and derived about US$1.2 billion in benefits as a result (Murphy, 1998). The "green belt" training is delivered to all GE employees and is available in strategic locations across the world. At 3M, more than 23,000 3M employees were trained in Six Sigma methodologies and processes by the end of 2003. In Motorola, the training for becoming a black belt is a minimum of one year.

3.2.5. Effective use of Six Sigma methodology and tools

According to Deming, the key to achieving high quality conformance and to overcoming process-related problems is the use of statistical tools and techniques (Modaress and Aussari, 1989). A healthy portion of Six Sigma training involves introduction to, theory behind, typical use of, and practical experimentation with DMAIC methodology and three groups of tool sets: team tools, process tools, and statistical tools. Team tools (see APPENDIX 7) and process tools (see APPENDIX 8) are those used to prepare the Six Sigma project leader with the team and leadership and skills required through the run of the project. These tools also help the project leader create a shared need for the project as well as establish an extended project team. Statistical tools (see APPENDIX 9) and a disciplined methodology used by specially trained individuals can improve processes by helping identify potential causes for variation and then reducing variation and defects. At 3M, DMAIC methodology is used to achieve breakthrough improvements. Once a process-improvement project is Defined, a Six Sigma team will systematically Measure, Analyze, Improve and Control that process in their drive for defect reduction, process improvement and customer satisfaction.

3.2.6. Project Management Skills

Six Sigma is a project-based improvement approach where project teams headed by Black Belts are used to identify and implement improvements in products, services or processes. The Six Sigma team comprising of Master Black Belts, Black Belts and Green Belts, is given training on project management tools and techniques. A black belt typically handles 4-6 projects per year while a green belt works on 1-2 projects per year. Most of the projects on Six Sigma fail due to poor project management skills, setting and keeping ground rules, determining the meeting's roles and responsibilities (Eckes, 2000). By 2004, 3M was actively working on more than 9,000 global Six Sigma projects with more than 8,000 projects closed and more than 160 customer projects that were active or closed.

3.2.7. Rewards and recognition

Rewards and recognition are one of the most important steps of the quality improvement process (Crosby, 1989). They are one of the enablers which maximizes employees' potential and involvement and, in doing so, become one of the main contributors to the company's journey to quality (Johnston and Daniel, 1991). One of the notable strategic changes that Jack Welsh implemented was to link the promotional considerations of employees to Green Belt training. Thus at GE Appliances, any employee who wants to be considered for promotion must be Six Sigma green belt-trained period. This also includes senior executives (Hendericks and Kelbaugh, 1998). In fact, across all GE businesses no one will be promoted without the full Six Sigma training and a completed project.

3.2.8. Communication

Communication is part of the cement that holds together the bricks of the total quality process supporting the principle of people-based management (Kanji and Asher, 1993). Effective communication is a means of overcoming resistance to management initiatives and maintaining enthusiasm for quality initiatives within the organization. Effective communication is vital in aligning the workforce towards corporate expectations. Unclear and inconsistent communication results in employees, front-line and middle managers focusing on priorities which have little or no relevance to the organizational focus (Williams, *et al*., 1993). It is critical to "communicate both the why and the how of Six Sigma as early as possible, and provide the opportunity for people to improve their comfort level through training classes" (Hendericks and Kelbaugh, 1998). A communication plan addressing the importance of Six Sigma quality and how the method works is thought to be critical in driving out two basic fears at individual levels that come with the true cultural revolution that Six Sigma brings: fear of change and fear of not measuring up to the new standards.

3.2.9. Employee involvement and empowerment

Every individual in the organization need to understand his or her role in making quality happen (Crosby, 1989). In fact, the need to maximize the involvement of all employees is one of the basic principles of change implementation in an organization. It involves the employees having a common understanding of quality and the importance of their involvement to maintain the quality momentum. The critical importance of employees' involvement and empowerment in the quality process of an organization is based on the belief that the best process innovation ideas come from the people actually doing the job. A quality environment demands that people participate in continuous improvement activities in an unhindered manner, thus pushing decision making to the lowest practical level. Employee involvement and empowerment is ensured through six sigma project teams, black/belt green belt training at all levels, and suitable rewards and recognition systems.

3.2.10. Linking Six Sigma to Customer

Quality should be customer driven (Takeuchi and Quelch, 1983). A major conclusion of Peters and Waterman (1982) was that best organizations align their corporate strategies to their customers' requirements. Satisfying customers' requirements better than the competition is widely recognized as a key to success in the marketplace (Peters, 1989). The process of linking Six Sigma to the customer can therefore be divided into two main steps: (a) identifying the core processes and defining the key outputs of these processes and defining the key customers that they serve, and; (2) identifying and defining the customer needs and requirements. An important element is the selection of critical-to-quality characteristics (CTQs). These CTQs must be identified quantitatively in the starting phase of the Six Sigma methodology. Quality function deployment is a powerful technique to understand the needs of customers and translate them into design or engineering requirements.

3.3. SUMMARY

The chapter described the theoretical framework of the research, identifying the critical factors for successful implementation of Six Sigma based on literature review and previous researches. To summarize, the critical success factors of Six Sigma includes a combination of soft factors like top management commitment, training and education, communication, rewards and recognition, etc., and hard factors such as project management skills, effective use statistical tools and techniques, organizational infrastructure, and effective use of Six Sigma methodology.

CHAPTER 4. RESEARCH DESIGN

4.1. INTRODUCTION

This chapter elaborates the research design used for planning and conducting this research project. It describes the underlying philosophy and approach used for conducting the research. It also explains the strategy and methodology used for collecting primary and secondary data. The data collection process and the sampling techniques used have also been discussed.

4.2. RESEARCH PHILOSOPHY

As discussed in the previous chapters, the objective of the research is to study the implementation of Six Sigma in UK organizations and to identify the critical success factors for Six Sigma implementation, the problems faced in Six Sigma implementation and the benefits attained through implementing Six Sigma. The underlying philosophy for this research project is **Positivism**. Positivistic approaches are founded on a belief that the study of human behaviour should be conducted in the same way as studies conducted in the natural sciences (Collis & Hussey, 2003). Positivistic approaches seek to identify, measure and evaluate any phenomena and to provide rational explanation for it. This explanation will attempt to establish causal links and relationships between the different elements (or variables) of the subject and relate them to a particular theory or practice. There is a belief that people do respond to stimulus or forces, rules (norms) external to themselves and that these can be discovered, identified and described using rational, systematic and deductive processes.

Some of the advantages of Positivistic approach are as follows:

- Suitable for research projects that require a structured and qualitative approach

- Good for research projects, for example, that are descriptive in nature, i.e. identifies and quantifies the element parts of any phenomena: the 'what' aspects of research

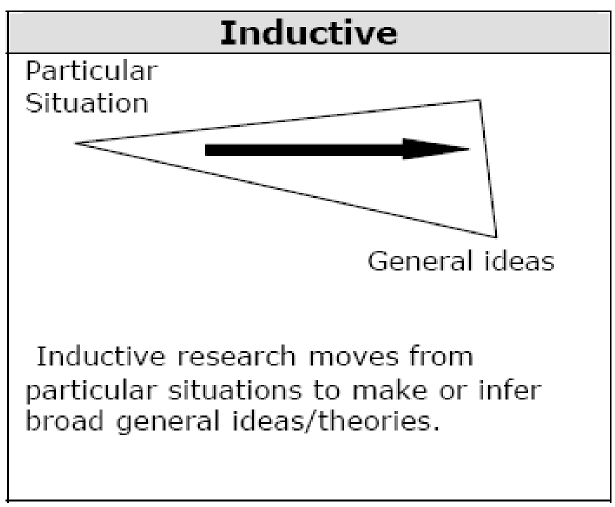
- Standardization makes collation and codifying of gathered data easier

- Research methods easier to reproduce and for other researchers to test your conclusions

4.3. RESEARCH APPROACH

The approach used for this research project is **Inductive**. The inductive research moves from particular situations to make or infer broad general ideas/theories, as shown in Figure 4-1.

Figure 4-1: Inductive Approach



Source: Collis & Hussey (2003)

The research project started by collecting data from different companies in UK which are implementing or have implemented Six Sigma Program. The companies were asked to share their experiences of Six Sigma implementation, identify the critical success factors for Six Sigma implementation, highlight the problems faced in Six Sigma implementation, and enumerate the benefits achieved. From this data, the common elements were assembled and then compared with the findings of the previous researches. The data gathered was collated and the results analysed and presented. Based on literature review and research findings, generic framework for effective implementation of Six Sigma was proposed.

The inductive approach might lead to arrive at a new finding or it might not. This approach can be very time-consuming, but the reward might be in terms of arriving at a fresh way of looking at the subject.

4.4. RESEARCH STRATEGY

The research strategy employed in this research project is **Quantitative approach**. Quantitative research is 'an objective approach which includes collecting and analysing numerical data and applying statistical tests' (Collis and Hussey, 2003). The emphasis of quantitative research is on collecting and analysing numerical data; it concentrates on measuring the scale, range, frequency etc. of phenomena. This type of research, although harder to design initially, is usually highly detailed and structured and results can be easily collated and presented statistically.

Advantages of quantitative approach are:

- more controlled;
- systematic observation
- concerned with identifiable responses
- can be clearer and more transparent in terms of research process (e.g. you can see the questionnaire)
- could be more generalisable if using large data sets or large/representative survey

4.5. RESEARCH METHODOLOGY

The research method selected for this research project is **Survey**. A survey is defined as:

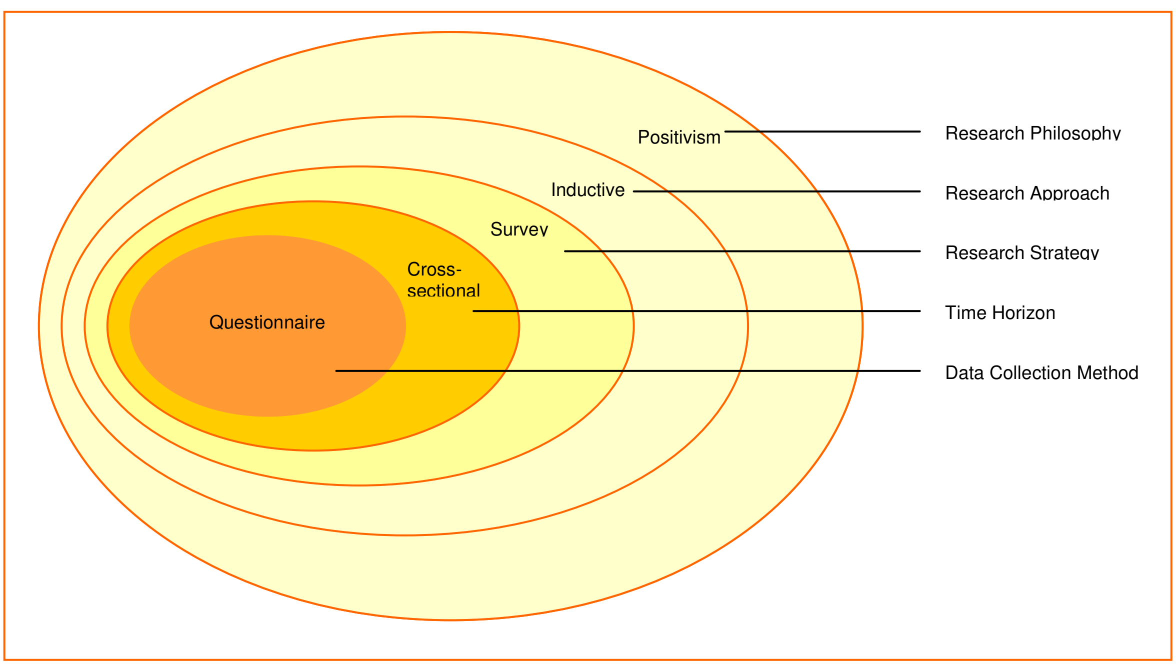
> The collection of data on a number of units and usually at a single juncture in time, with a view to collecting systematically a body of quantifiable data in respect of a number of variables which are then examined to discern patterns of association (Bryman, 1989).

The survey was conducted using the **Questionnaire method**. According to Robson and Colin (1998), the advantages of questionnaire are as follows:

- It can be one of the least resources intensive.
- It is simple to use – basic awareness training being sufficient to get things started.
- It can readily involve many people within the organization.
- The questions asked can be customized to suit the organization.
- It enables the organization to receive feedback which can be segmented by function and by level.
- It can be used in parallel with the workshop approach to provide a more balanced view of deployment team.
- It can give a good visual reference if results are graphed.

The Figure 4-2 gives an overall picture of the research design for this research project.

Figure 4-2: Research Design



4.6. LITERATURE SEARCH

A number of literary resources in published and electronic media were referred to and consulted for literature review. These included:

- **Academic journals**, such as, *Business Process Management Journal*, *Measuring Business Excellence*, *Benchmarking: An International Journal*, *Journal of Quality Technology*, *Journal of Organizational Excellence*, etc.
- **Academic and Professional Magazines**, such as, *TQM Magazine*, *Quality Progress*, *Industry Week*, *Quality Digest*, *ASQ Six Sigma Forum Magazine*, etc.
- **Best-selling Books on Six Sigma**, such as, *The Six Sigma Way*, *Six Sigma Deployment*, *The Six Sigma Revolution*, etc.
- **Web-based Six Sigma resources**, such as, www.isixsigma.com, www.onesixsigma.com, www.asq.org, etc.
- **Electronic databases**, such as, *Emerald*, *Proquest*, etc.
- **Class notes and handouts**

4.7. DATA COLLECTION

4.7.1. Design of Questionnaire

To collect data for the research project in quantitative terms, a research questionnaire was designed and then distributed to the companies. The questionnaire (APPENDIX 2) included different sections seeking information on various aspects of Six Sigma. Multiple-choice and scale-type questions were used to collect response in an objective manner. In addition, open questions were used to collect subjective information. Lickert scale of 1 to 7 was used to rate the critical success factors and the benefits of Six Sigma implementation.

The various sections of the questionnaire are outlined as follows:

- **Introduction of organization –** this part sought information about the company in terms of company name, nature of business and number of employees
- **About Six Sigma Program –** this part included questions regarding the history of Six Sigma program in the company, such as, the starting year of Six Sigma program, the reasons for initiating Six Sigma program, other improvement initiatives being implemented, etc.
- **Six Sigma Implementation –** this part included questions regarding the status of Six Sigma implementation, such as, the implementation stage of Six Sigma program, number of Six Sigma projects implemented, number of Six Sigma qualified persons, percentage of people involved in Six Sigma projects, etc.
- **Problems in Six Sigma implementation –** this part included questions regarding the problems faced in implementing Six Sigma and the level of organizational resistance to Six Sigma program
- **Critical Success factors –** this part included a list of critical success factors for Six Sigma, identified through review of literature and previous researches on Six Sigma. Lickert Scale was used to rate the factors in the order of this significance.
- **Benefits of Six Sigma –** this part included a list of potential benefits of Six Sigma, identified through literature review. Lickert scale was used to rate the significant benefits achieved through Six Sigma implementation.

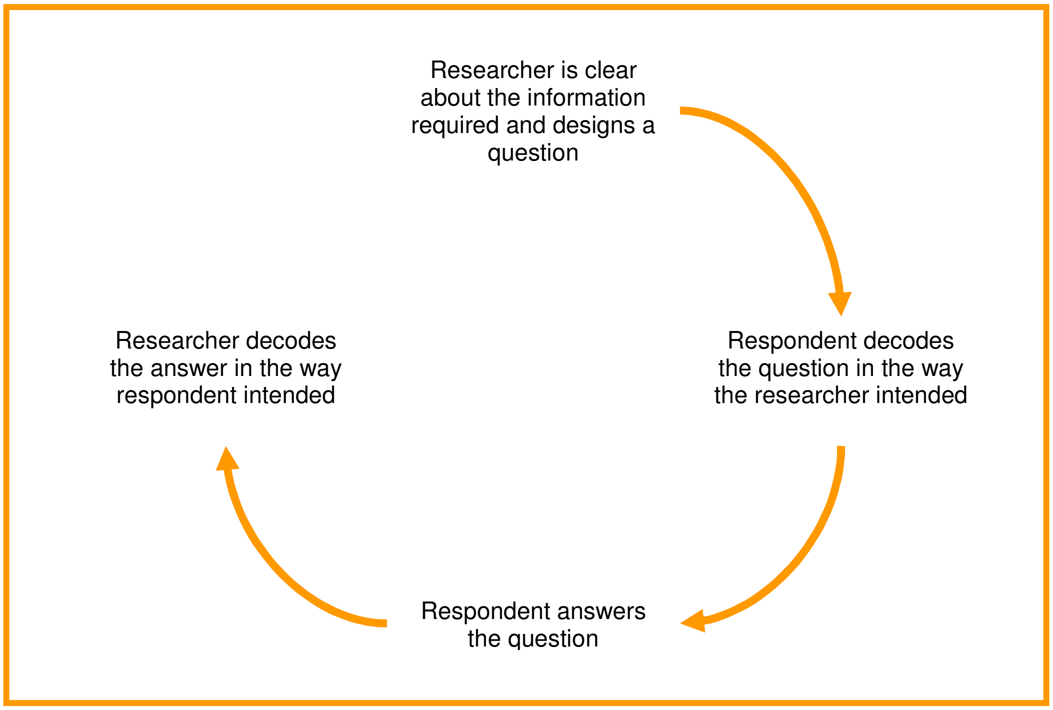
4.7.2. Validity and Reliability Testing

The validity and reliability of the data collected and the response rate achieved depends on the design of the questions, the structure of questionnaire, and the rigour of the pilot testing. A valid question will enable accurate data to be collected and one that is reliable will mean that these data are collected consistently. Foddy (1994) argues that:

> "the question must be understood in the way intended by the researcher and the answer given by the respondent must be understood by the researcher in the way intended by the respondent" (Foddy, 1994)

This means that there are at least four stages that must occur if the question is to be valid and reliable (Figure 4-3).

Figure 4-3: Stages for validity and reliability



<u>Source</u>: Foddy (1994)

To check the validity and reliability of questionnaire, it was first reviewed by the supervisor to check the design and selection of questions and the layout of the questionnaire. Adjustments were made based on the feedback from the supervisor. After review of questionnaire, a pilot survey was conducted in the class room. The purpose of the pilot test is to refine the questionnaire so that respondents will have no problems in answering the questions and there will be no problems in recording the data. In addition, it enables the researcher to obtain some assessment of the questions' validity and the likely reliability of the data that will be collected. Further adjustments were made in the questionnaire based on the results of pilot testing.

4.7.3. Population and Sampling

Population refers to the group that forms the subject of study in a particular survey. **Sampling Frame** refers to a list, or other record of a population from which a sample can be selected, e.g., Register of Electors, Kompass Directory (Collis & Hussey, 2003).

The population of the research consisted of UK organizations, manufacturing and services, which are implementing or have implemented Six Sigma. Due to limited control over the choice of the companies, non-probability sampling techniques, i.e., **convenience sampling** and **snow-ball sampling** methods, were used for selecting the companies. A total of 75 UK companies from a diverse range of sectors were selected based on the data available through Six Sigma web portals, conferences, events, news releases, articles, and print media. After selecting the companies and identifying contact persons with addresses, the questionnaire along with covering letter and return envelope was mailed to them at their postal addresses. In some cases where the postal addresses were not available, emails were sent to companies by attaching the covering letter and questionnaire.

4.8. SUMMARY

The chapter illustrated the research design, describing the philosophy, strategy, methodology and approach for research. To summarize, the research was based on positivistic philosophy using the inductive approach. The research strategy was quantitative employing the survey methodology. The primary data was collected using the questionnaire tool which was distributed to different companies. The literature search was done using multiple resources which included books, electronic journals, published articles, internet, and electronic databases.

CHAPTER 5. DATA ANALYSIS AND DISCUSSION OF FINDINGS

5.1. INTRODUCTION

This chapter covers the analysis of data collected through research questionnaire and the discussion of the results. The analysis of data has been done by compiling the data and presenting the findings using graphs and tables. The findings have then been discussed by comparing with literature review and similar researches. Some best practices have also been identified through review of case studies. Finally, a framework has been proposed for effective implementation of Six Sigma based on the literature review and discussion of findings.

5.2. DATA ANALYSIS

As discussed in the previous chapter, a total of 75 questionnaires were sent to different companies in UK for collecting primary data related to the Six Sigma research project. Out of 75 questionnaires, 19 valid responses were received and 6 questionnaires were returned undelivered. It represents a response rate of 25% which is satisfactory in this type of research and corresponds well with the similar surveys done in other academic researches. The respondents were mainly Six Sigma Project Leaders, Master Black Belts, or Quality Managers.

5.2.1. Classification of Respondents

The first part of the questionnaire was designed to classify the responding companies in terms of the nature of business and size of organization by number of employees. Figure 5-1 and Figure 5-2 present the classifications of respondents by nature of business and number of employees, respectively.

Figure 5-1: Respondents by Businesses

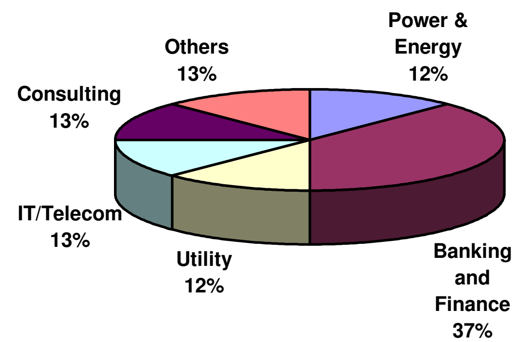
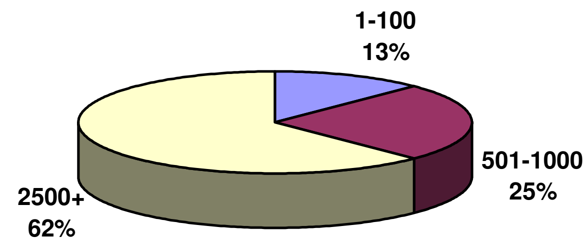


Figure 5-2: Respondents by number of employees

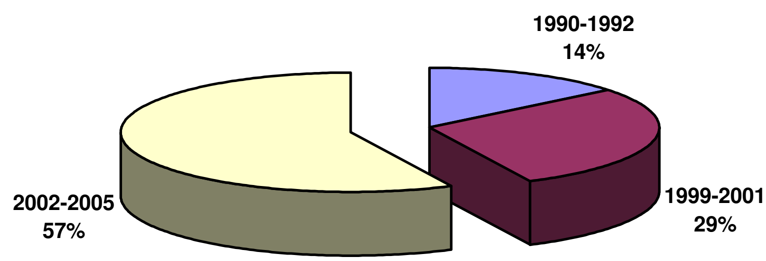


It can be seen that the primary businesses of respondents in the survey included both manufacturing and services sectors. Rather services sectors make more than 50% of the respondents. This indicates that Six Sigma, though initiated from the manufacturing sector, has equally been adopted by the services firms in UK. Also, the majority of organizations implementing Six Sigma are large organizations having more than 2500 employees. This can be explained by the fact that Six Sigma is a resource intensive program requiring significant initial investment in developing the Six Sigma organizational infrastructure and training of Six Sigma specialized team members (MBB, BB, GBB). In 1998, GE spent US$400 million on Six Sigma (most of it for training). At 3M, more than 23,000 3M employees were trained in Six Sigma methodologies and processes by the end of 2003.

5.2.2. About Six Sigma Program

In the first question about the history of Six Sigma program, the respondents were asked when the Six Sigma Program was initiated. Figure 5-3 shows the results of responses received from the companies.

Figure 5-3: Initiation of Six Sigma Program



As can be seen from the figure, more than 50 companies started the Six Sigma program during or after 2002 and more than 85% started it during or after 1999. This supports the findings made by Antony and Banuelas (2002) in a similar research of UK organizations and indicates that Six Sigma is still a relevantly newer management approach being adopted by UK companies, as compared to ISO 9000, TQM, and BPR, which were adopted in early and mid 90s. This finding has to viewed in the context that that the Six Sigma concept was pioneered in USA by Motorola in mid 80s and popularized by GE in the mid 90s.

In the next question, the respondents were asked about the events that triggered the initiation of Six Sigma program. Figure 5-4 shows the graphical presentation of the results received from the respondents.

Figure 5-4: Drivers for Six Sigma Program

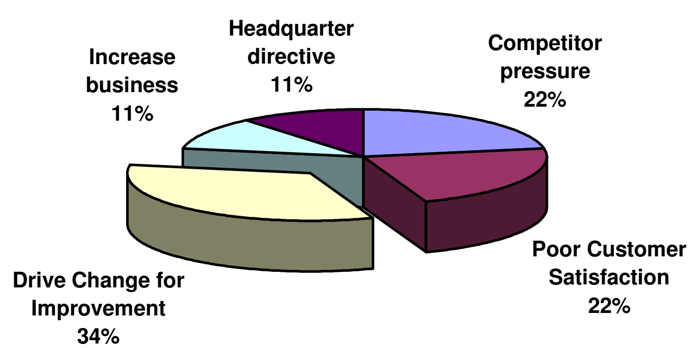
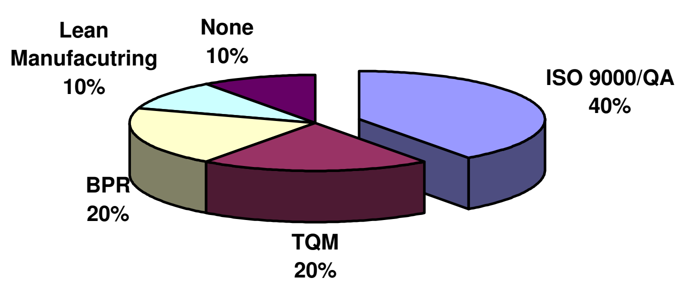


Figure indicates that the biggest trigger for Six Sigma Program in UK organizations was the need to drive change for continuous improvement. The much publicized successes of Motorola, GE, and other leading US companies presented Six Sigma as a successful tool for driving change in the organizational culture and striving for continuous improvement. Other significant drivers were competitors' pressure and poor customer satisfaction. These findings can be compared with a similar findings for BPR where the major drivers were found to be an intense need to cut cost and competitor pressure (O'Neill and Sohal, 1998).

In the next question, the respondents were asked as what other quality initiatives had been implemented or were being implemented at the time of initiation of Six Sigma program. Figure 5-5 shows the results of the responses.

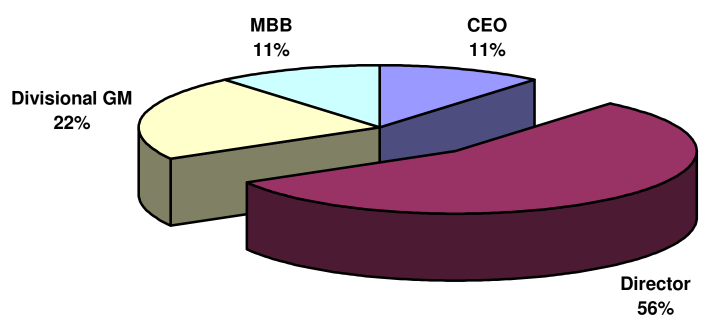
Figure 5-5: Other Quality Initiatives



It can be seen that 40% companies had adopted ISO 9001 before implementing Six Sigma. This finding reinforces the arguments made by Pfiefer et al (2004) that ISO 9000 can serve as the stepping stone for Six Sigma and can be integrated with Six Sigma to achieve maximum benefits from the two approaches. 20% of companies had either implemented TQM or BPR in addition to ISO 9000 before embarking on the Six Sigma program. These results suggest that all these quality initiatives help in developing a quality-oriented culture in the organization which emphasizes customer orientation, teamwork, employee development and involvement, and continuous improvement – all essential components of Six Sigma. Thus they pave the way for implementing Six Sigma.

The next question asked the respondents as who was the primary sponsor of Six Sigma Program in the organization. Figure 5-6 shows the results of the responses from the companies.

Figure 5-6: Primary Sponsor of Six Sigma Program



The figure indicates that in more than 50% cases the Director was the primary sponsor of the Six Sigma Program, followed by GM in 22% cases. CEO was the primary sponsor in only 11% cases. Thus, it reinforces the concept that Six Sigma initiative should be driven from the top with active management support and involvement. The findings suggest that sponsor must be from the executive management but not necessarily the CEO of the organization.

5.2.3. Six Sigma Implementation

In the initial two questions about Six Sigma implementation, the respondents were asked about the number of Six Sigma projects started/implemented and the average cycle time of a Six Sigma project. Figure 5-7 and Figure 5-8 show the findings of the survey.

Figure 5-7: Number of Six Sigma Projects

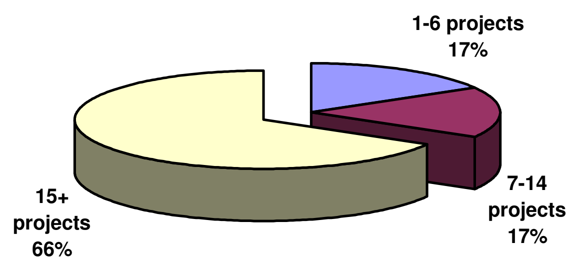
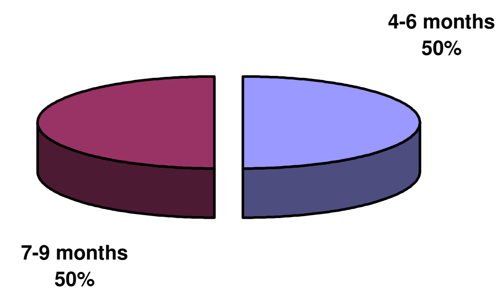


Figure 5-8: Average Time of Six Sigma Project



It can be seen that more than 15 Six Sigma projects have been initiated and implemented in 66% cases, thus indicating that Six Sigma program was started and implemented on a wider scale in most organizations. Regarding the average project time, equal proportion of respondents reported the average project time of 4-6 months and 7-9 months. This suggests that the average Six Sigma project spans between 4 to 9 months, depending on the nature and scope of project and the experience of Six Sigma team. This finding is in agreement with the project duration proposed for Six Sigma projects which is 4-6 months. The Six Sigma project duration is much shorter than that for BPR which was found to be between 2 years to 3 years (Zairi and Sinclair, 1995; O'Neill and Sohal, 1998). The finding reinforces the argument that Six Sigma projects should be of shorter duration to ensure continuous management support and consistent commitment of resources.

In the next two questions, the respondents were asked about the percentage of employees involved in Six Sigma projects and the percentage of time devoted by Six Sigma team members for Six Sigma activities. Figure 5-9 and Figure 5-10 show the findings of the survey.

Figure 5-9: Percentage of employees involved

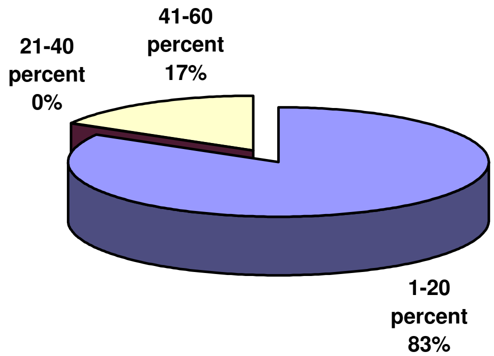
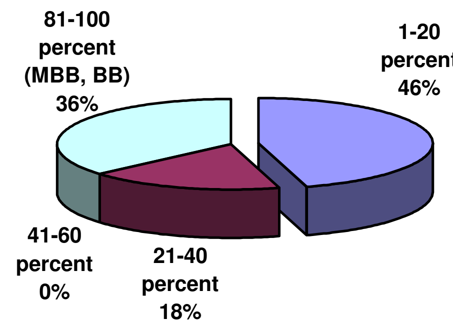


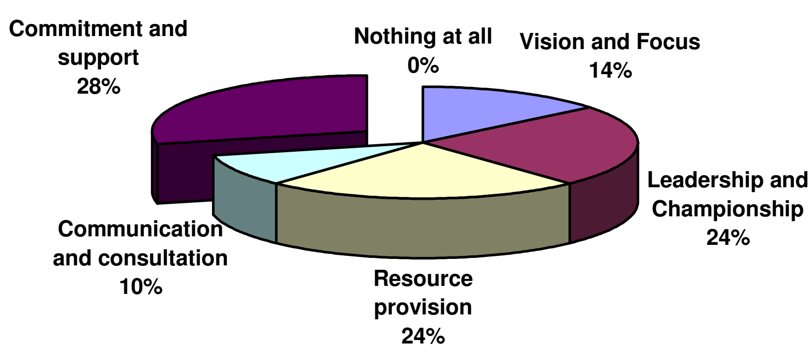
Figure 5-10: Percentage of time spend on Six Sigma



The figure indicates that in 83% cases, 1-20 percent of employees were involved in the Six Sigma projects while in 17% cases, 41-60% employees were involved. Regarding the percentage of time devoted by Six Sigma team members to project activities, it varies from role to role. While MBBs and BBs spend almost 100% of their time in Six Sigma project activities, other roles (GBs, team members) devote from 1-20% to 21-40% of their time in project activities. These findings are totally in agreement with the descriptions of roles given in the literature.

The next question asked respondents about the contribution of top management towards Six Sigma program. Figure 5-11gives the results of findings.

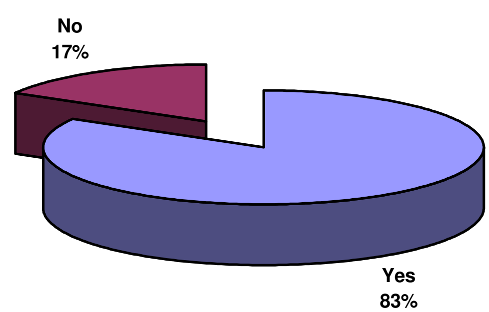
Figure 5-11: Contribution of Top Management



As can be seen in the figure that the biggest contribution of the top management to Six Sigma has been in the form of commitment and support, followed by leadership and championship as well as resource provision. As mentioned in the literature, all these elements are desired from the top management to ensure that the Six Sigma program is started on the right footings and is not dismissed by employees as the flavour of the month.

The next question asked respondents whether or not external consultants were used in the planning and implementation of Six Sigma. Figure 5-12 gives the results of findings.

Figure 5-12: Use of Consultants

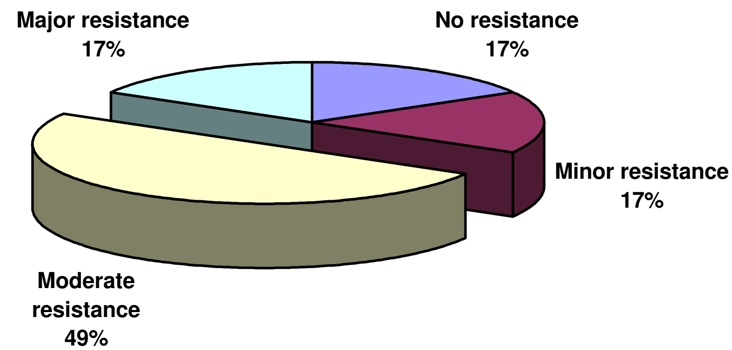


The data results indicate that an overwhelming majority (83%) of companies used external consultants to assist them in implementing Six Sigma. The consultants were mainly involved in training the Six Sigma teams and, in some cases, project planning and implementing Six Sigma methodology.

5.2.4. Problems faced in Six Sigma implementation

In the first question in this section, the respondents were asked as what was the level of organizational resistance to the Six Sigma initiative. The Figure 5-13 gives the results of the responses received from the companies.

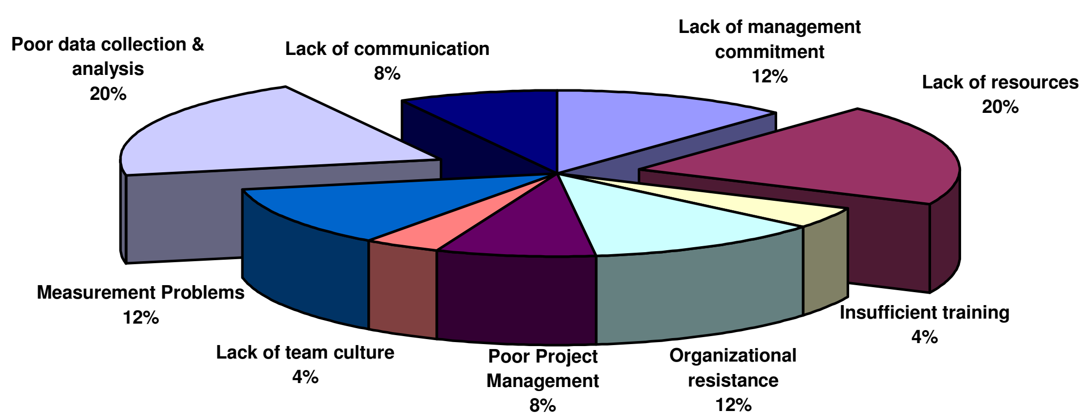
Figure 5-13: Level of organizational resistance



The figure indicates that in most cases (49%), moderate level of organizational resistance was faced by the Six Sigma initiative, with major resistance and no resistance in equal number of cases. The moderate level of resistance is explained by the fact that most of the organizations had implemented other quality initiatives like ISO 9000, TQM, BPR, etc., before implementing Six Sigma, thus creating the culture and environment conducive to the new change initiative.

In the next question, the respondents were asked about the nature of problems faced in Six Sigma. The Figure 5-14 shows the results of the findings.

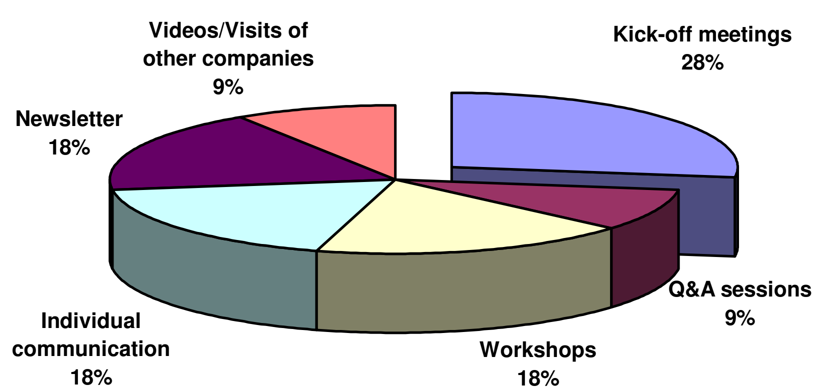
Figure 5-14: Problems faced in Six Sigma implementation



As can be seen from the figure, lack of resources and poor data collection and analysis were the biggest problems faced, in 20% of cases. Other significant problems were the lack of management commitment, the organizational resistance to change, and problems with measurement system, in 12% of cases. As mentioned earlier, Six Sigma is a resource intensive program that requires consistent commitment of resources in terms of developing the organizational infrastructure and training of employees. Thus lack of resources can be a major constraint to the effective implementation of Six Sigma program. In addition, Six Sigma involves extensive measurement, data collection and data analysis activities by project teams to identify defects, investigate the root causes, and propose solutions for improvement. This requires good understanding and practical skills of application of statistical tools and techniques – an element generally lacking the in employees.

The next question asked the respondents regarding the communication media used to overcome the resistance to change and create Six Sigma buy-in. The Figure 5-15 in the figure shows the results of the findings.

Figure 5-15: Communication media used for Six Sigma



The figure indicates that the most commonly used communication medium was kick-off meetings with managers (in 28% of cases), followed by workshops and individual communication with employees (in 18% of cases). Initiating Six Sigma program through kick-off meetings with managers ensure that they are taken into confidence about the nature of the program and their support is secured for the program. Similarly, workshops and individual communication with employees help to alleviate the employees' concerns about the program and ensure that they are involved in the projects.

5.2.5. Critical Success Factors for Six Sigma Implementation

This section included a list of critical success factors for Six Sigma implementation, arranged in random order. These critical factors were identified through literature review and study of previous researches on Six Sigma. A semantic differential scale from 1 to 7 was provided against each factor, with score 1 indicating no criticality and score 7 indicating the maximum criticality. The respondents were asked to rate the success factors based on their experience of Six Sigma implementation in their organizations, in order of their criticality.

The Table 5-1 gives the ranking of success factors based in terms of mean and standard deviation of the rating given by the respondents.

Table 5-1: Success Factors for Six Sigma

Ranking	Success Factors for Six Sigma	Mean	Standard deviation
1.	Creating an effective change culture	6	1.4
2.	Top Management support	6	1.4
3.	Effective communication	5.8	0.7
4.	Teamwork	5.6	1.1
5.	Employee education and training	5.5	1.4
6.	Effective use of Six Sigma methodology	5.5	0.95
7.	Organizational infrastructure for Six Sigma	5.2	0.9
8.	Effective use of Six Sigma tools	5	1.6
9.	Project Management skills	4.8	0.9
10.	Liking incentives with Six Sigma	4.5	2.2
11.	Role of IT	3.8	1.9
12.	Use of consultants	2.2	1.0

Figure 5-16 shows the graphical presentation of the critical success factors in the form of bar charts:

Figure 5-16: Success Factors for Six Sigma

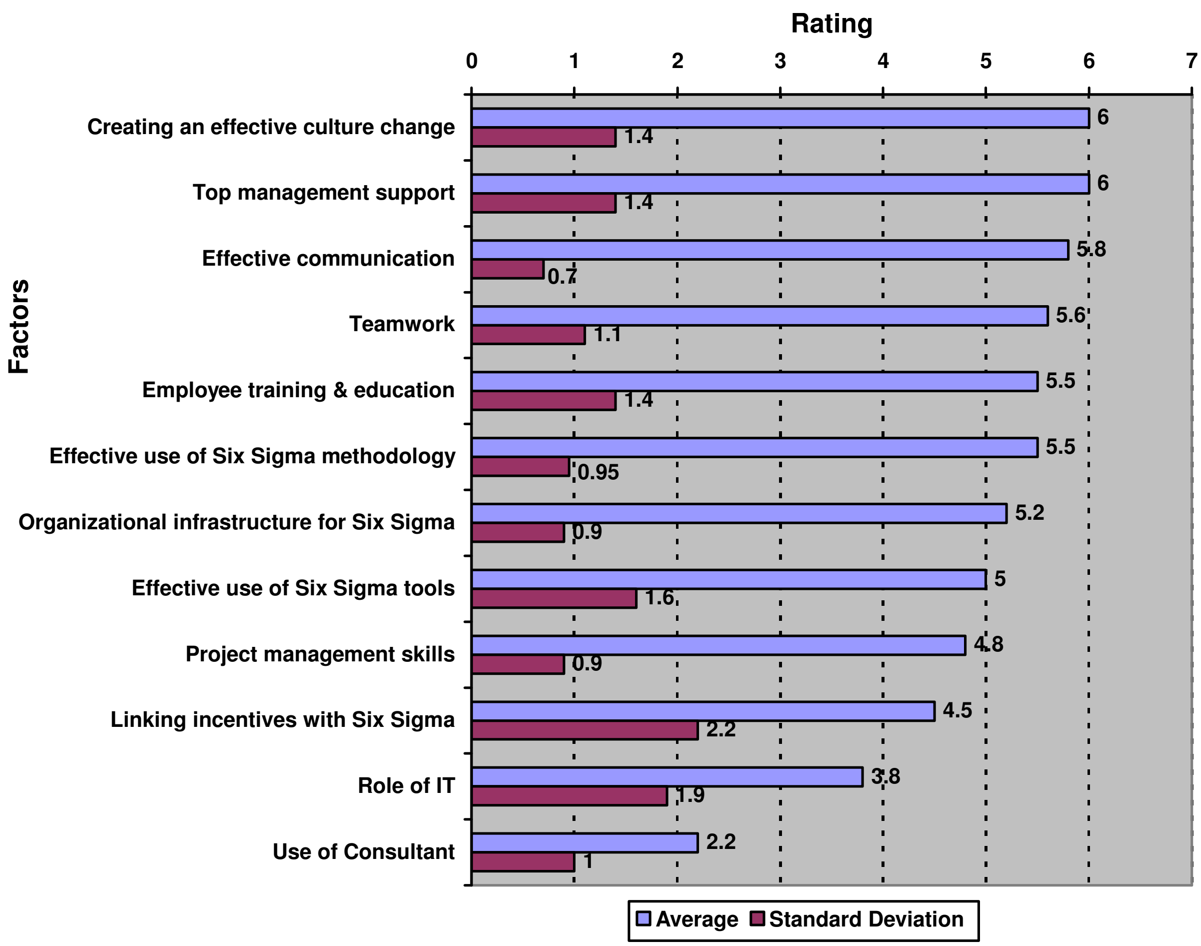


Figure indicates that an effective organizational culture of change and top management support were rated as the two most critical factors for successful implementation of Six Sigma. The next critical factor was effective communication of Six Sigma program, followed by teamwork, employee training and education on Six Sigma, effective use of Six Sigma methodology, and organizational infrastructure for Six Sigma. On the lower end, use of external consultants and role of IT were rated as less critical factors for successful implementation of Six Sigma.

5.2.6. Soft and Hard Factors

The critical success factors given above can also be analyzed from the perspective of soft factors and hard factors. Systems and tools and techniques such as those that impact on internal efficiency (e.g. quality management systems, cost of quality and statistical process control (SPC) and external effectiveness (e.g. benchmarking and customer satisfaction surveys) are examples of **hard factors**. **Soft factors** are intangible and difficult-to-measure issues and are primarily related to leadership and employee involvement (Oakland, 1993).

The "**soft**" factors may best be seen as issues discussed under leadership, internal stakeholders management and policy. They are issues that impact on maximizing organization-wide support and involvement in attaining the quality goals of an organization. They may be seen as "internal marketing" issues (Wilkinson and Witcher, 1992). They include:

- Senior executives commitment and involvement, actively demonstrated;
- Comprehensive policy development and effective deployment of goals;
- Entire workforce commitment to quality goals of the organization;
- Supervisors, unit heads and divisional managers assume active new roles;
- Empowerment; effective communication;
- Internal customer supplier concept; teamwork; system for recognition and appreciation of quality efforts; and
- Training and education.

While the effective manipulation of the "soft" factors is essential to the attainment of the quality goals of the organization, they must be supported by the "**hard**" factors to manage, track and improve the journey towards achieving the goals. They include:

- Benchmarking;
- Performance measurement;
- Management by processes and fact;
- Quality control tools and techniques;
- Cost of quality process;
- Documented quality management system;
- Supplier management;
- Customer management.

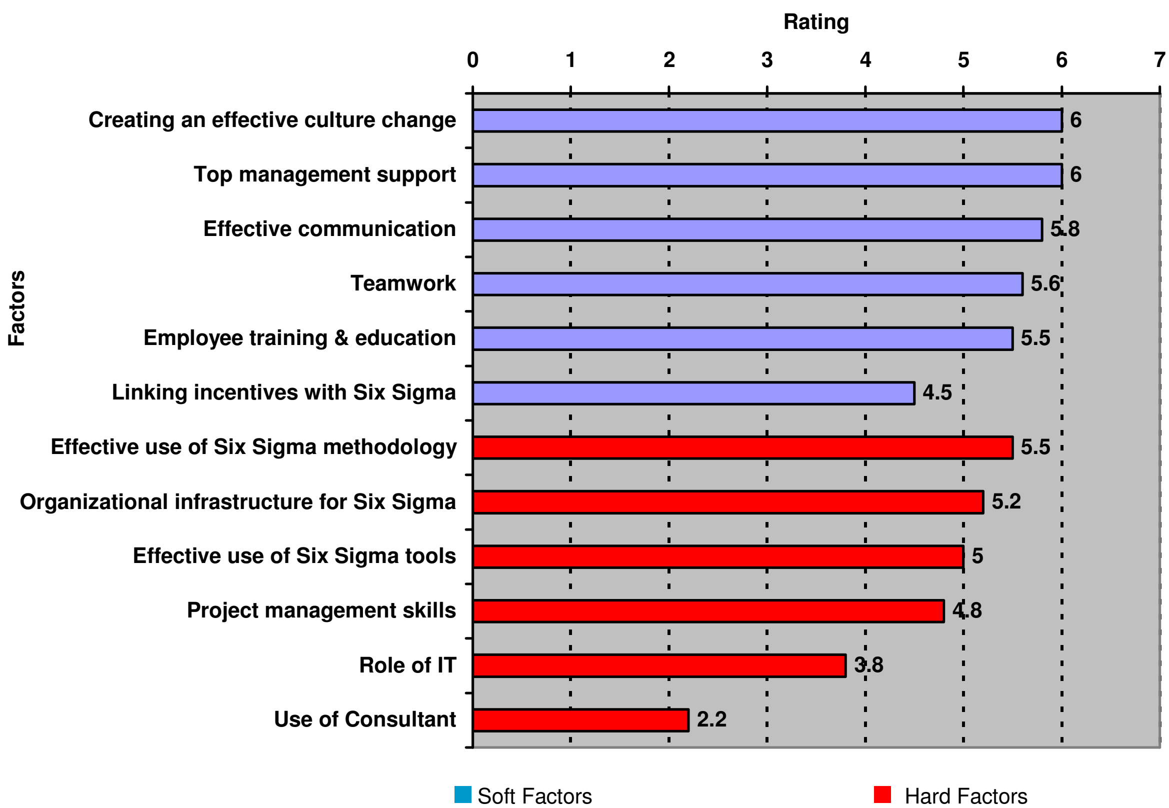
Table 5-2 gives the ranking of CSFs as soft factors and hard factors.

Table 5-2: Soft and Hard Factors for Six Sigma

	Ranking	Success Factors for Six Sigma	Average	Standard Deviation
Soft Factors	1	Creating an effective change culture	6	1.4
	2	Top Management support	6	1.4
	3	Effective communication	5.8	0.7
	4	Teamwork	5.6	1.1
	5	Employee education and training	5.5	1.4
	10	Liking incentives with Six Sigma	4.5	2.2
Hard Factors	6	Effective use of Six Sigma methodology	5.5	0.95
	7	Organizational infrastructure for Six Sigma	5.2	0.9
	8	Effective use of Six Sigma tools	5	1.6
	9	Project Management skills	4.8	0.9
	11	Role of IT	3.8	1.9
	12	Use of consultants	2.2	1.0

Figure 5-17 shows the soft factors and hard factors in blue and red bars, respectively.

Figure 5-17: Soft and Hard Factors for Six Sigma

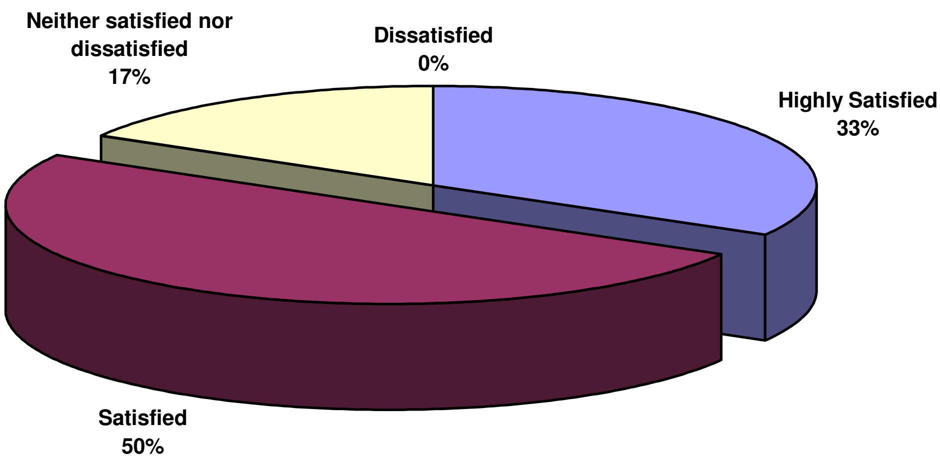


As can be seen, soft factors have been rated higher as compared to the hard factors, thus indicating that soft factors play a more significant role in successful implementation of Six Sigma than the hard factors. This is a significant finding since Six Sigma is thought to be a more technical approach with hard factors like statistical tools, project management, process management, etc., given more importance and attention.

5.2.7. Benefits of Six Sigma Implementation

In the first question in this section, the respondents were asked about their satisfaction with the results achieved trough Six Sigma program. Figure 5-18 shows the results of the responses.

Figure 5-18: Satisfaction with Six Sigma Program



The figure indicates that most of the companies were satisfied (50%) with the results of Six Sigma program. Only a small portion (17%) of companies were neither satisfied nor dissatisfied with Six Sigma program with no respondent showing dissatisfaction with the results. This implies that in most cases, the companies are achieving positive results from Six Sigma implementation.

The next part in this section consisted of a list of potential benefits for Six Sigma implementation, arranged in random order. These benefits were identified through literature review and study of previous researches on Six Sigma. A semantic differential scale from 1 to 7 was provided against each, with score 1 indicating no criticality and score 7 indicating the maximum criticality. The respondents were asked to rate the significant benefits achieved based on their experience of Six Sigma implementation in their organizations.

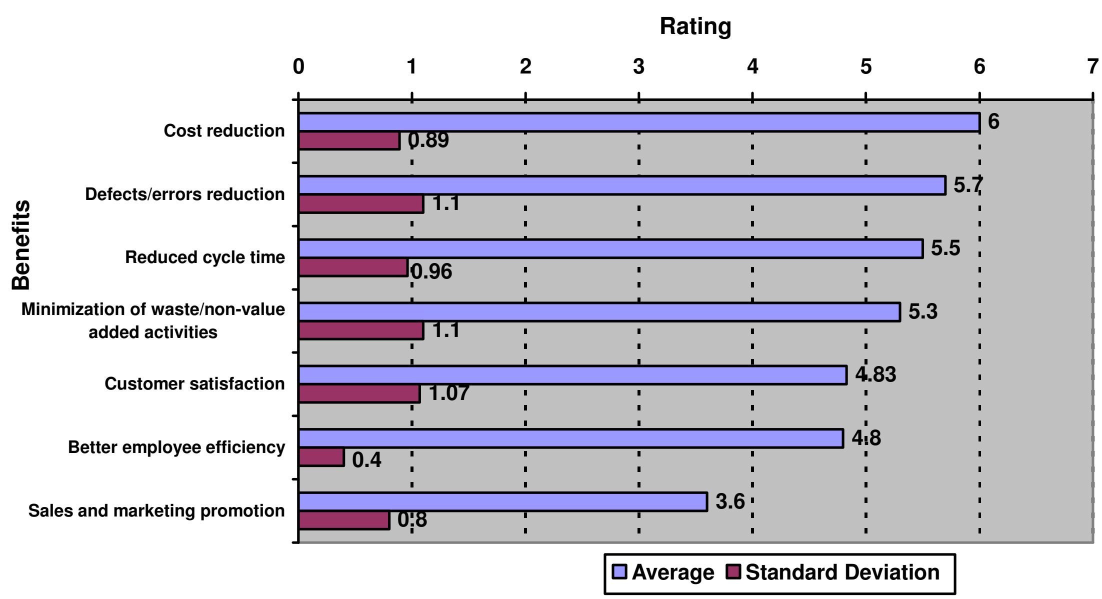
Table 5-3 gives the ranking of benefits based on the average of the rating given by the respondents. Also given in the table is the standard deviation of each factor to measure the level of variation in the ratings.

Table 5-3: Benefits of Six Sigma

Ranking	Benefits	Average	Standard deviation
1.	Cost reduction	6	0.89
2.	Defects/error reduction	5.7	1.1
3.	Reduced cycle time	5.5	0.96
4.	Minimization of waste/non-value added activities	5.3	1.1
5.	Customer satisfaction	4.83	1.07
6.	Better employee efficiency	4.8	0.4
7.	Sales and marketing promotion	3.6	0.8

Figure 5-19 shows the graphical presentation of Six Sigma benefits in the form of bar charts:

Figure 5-19: Benefits of Six Sigma



As shown in the figure, the most significant benefit achieved through Six Sigma implementation is cost reduction. This validates the argument that Six Sigma impacts the bottom line and creates a “Big dollar impact”. The next significant benefit attained is the defect/error reduction, which invariably is the core objective of Six Sigma Program. Other significant benefits achieved were reduced cycle time, and minimization of waste/non-value added activities.

5.3. BENCHMARKING THE FINDINGS WITH OTHER RESEARCHES

Some practitioners and scholars have also attempted to identify the key factors for the successful implementation of Six Sigma (Antony and Banuelas, 2001; Henderson and Evans, 2000).

Hendersons and Evans (2000), based on the study of GE’ Six Sigma implementation, suggest upper management support/involvement, organizational infrastructure, training, tools, linkage to human-resource based actions (promotion, bonuses), early communication to employees, measurement systems, and an information technology infrastructure as the key elements for successfully implementing Six Sigma.

Antony and Benuelas (2001), based on the review of existing literature, identify that the key ingredients for the effective implementation of Six Sigma are: top management involvement and commitment; cultural change; organizational infrastructure; training; project management skills; project prioritization and selection, reviews and tracking; understanding the six sigma methodology, tools and techniques; linking Six Sigma to business strategy; linking Six Sigma to the customer; linking Six Sigma to the human resources; and linking Six Sigma to the suppliers.

Comparing this research findings with the critical factors mentioned by Henderson and Evans (2000) and Antony and Benuelas (2002), we find that they share some common factors while differ in other factors. Top management commitment has been identified as the most critical factor by all the researches. Similarly, cultural change, organizational infrastructure, training, Six Sigma methodology, and tools have also been identified as the critical factors. However, there are some differences in the ranking of these factors. Also some of the factors like teamwork, linking incentives with Six Sigma, role of IT, and use of consultants were not addressed by previous researches. One important finding is the less significant role of IT in Six Sigma implementation which can be compared with the role of IT in BPR where it is considered as the fundamental enabler. Thus, it confirms the argument that IT has a lesser role to play in Six Sigma success than that in BPR's success.

Comparing the Six Sigma research results with a similar BPR research project by O'Neill and Sohal (1998), we find that they share some common findings while differ in others. Both researches identify competitors' pressure and cost reduction as the major drivers for Six Sigma and BPR. Furthermore, they show that executive management (Director or Group GM) has been the primary champion in both cases and has contributed to the program through commitment and leadership. Also, both programs received medium to moderate resistance and the communication used to overcome the resistance involved kick-off meetings with managers and conducted workshops. However, they differ in terms of implementation problems faced and the benefits attained. While Six Sigma impacts the most on cost reduction and elimination of defects, BPR has the greatest impact on productivity and profitability. In terms of critical success factors, though some of the factors are common such as management support and communication, other critical success factors differ from each other.

5.4. BEST PRACTICES FOR SIX SIGMA IMPLEMENTATION

A critical review of literature and case studies of leading organizations such as Motorola, Honeywell, General Electric, 3M, DuPont, Dow Chemical, Raytheon Corporation, etc., help us to identify some best practices related to the various soft and hard aspects of Six Sigma implementation.

- **Executive management support and involvement** - Top executive must be part of Six Sigma. Lawrence Bossidy, CEO of AlliedSignal ensured that company remained competitive by implementing Six Sigma quality and achieving 7 percent year-over-year productivity (Minahan, 1997). Jack Welch, GE's CEO, while introducing Six Sigma initiative, said that it "is the only initiative he will introduce, but it will be introduced everywhere" (Murdoch, 1998). When the employees tried to dismiss Six Sigma as the program of the month, Welch changed the business structure at a corporate level to underscore the importance of the goal. Top management support the Six Sigma initiative by personally spending time in every Six Sigma training, speaking and answering questions raising by employees, making site visits to observe the Six Sigma implementation; and monitoring Six Sigma project progress.

- **People involvement and teamwork –** At 3M, Six Sigma is driven by executive management teams, who are fully engaged in critical business processes and actively deploying Six Sigma methodologies throughout the organization. Specific Six Sigma roles within 3M include: Six Sigma directors, master black belts, black belts, green belts, and Six Sigma coaches. At GE, the Six Sigma architecture includes a diverse population of technical and non-technical people, managers, and people from key business areas which have been divided into champion, master black belt, black belt, green belt, and team members. More than 200 trained master black belts are fulltime teachers with quantitative skills as well as teaching and leadership ability. More than 800 trained black belts are full-time quality executives who lead teams, focus on key processes, and report the results back to the champions (Welch, 1996a). By 2002, DuPont had more 11,000 Green Belts, 1,800 Black Belts, and 250 Master Black Belts. In Dow Chemical at any given time, 3 percent of Dow employees are required to fulfill a two-year commitment to Six Sigma. In fact, all employees are expected to have at least one personal goal associated with Six Sigma.

- **Organizational culture change** – Six Sigma is a breakthrough management strategy which requires changes in organizational culture and in the attitudes of employees. GE Welsh created change in organizational culture and overcame employee resistance by changing the organizational structure at the top, investing on training, adjusting the reward and recognition system, and early communication to employees (Henderson and Evans, 2000). In DuPont, the culture of Six Sigma was created by using a Six Sigma Champion Network, which has the specific purpose of looking after strategic issues. In Dow Chemical, senior managers led by example, living and breathing Six Sigma through their behavior, language and constant promotion of its values. Using effective communication helped to educate and pave the way for gradual change.

- **Education and Training** – A healthy portion of Six Sigma training involves introduction to, theory behind, typical use of, and practical experimentation with DMAIC methodology and three groups of tool sets: team tools, process tools, and statistical tools. Upon deciding to pursue Six Sigma as a company initiative, Welch directed that every exempt employee at GE be trained in Six Sigma methodologies. In 1998, GE spent US$400 million on Six Sigma (most of it for training) and derived about US$1.2 billion in benefits as a result (Murphy, 1998). The "green belt" training is delivered to all GE employees and is available in strategic locations across the world. At 3M, more than 23,000 3M employees were trained in Six Sigma methodologies and processes by the end of 2003. DuPont trained more than 1200 employees in two years to become full Black Belts. In Motorola, the training for becoming a black belt is a minimum of one year.

- **Project Management** – Six Sigma is a project-based improvement approach which requires in-depth project management skills. A black belt typically handles 4-6 projects per year while a green belt works on 1-2 projects per year. By 2004, 3M was actively working on more than 9,000 global Six Sigma projects with more than 8,000 projects closed and more than 160 customer projects that were active or closed. Across all GE businesses no one will be promoted without the full Six Sigma training and a completed project.

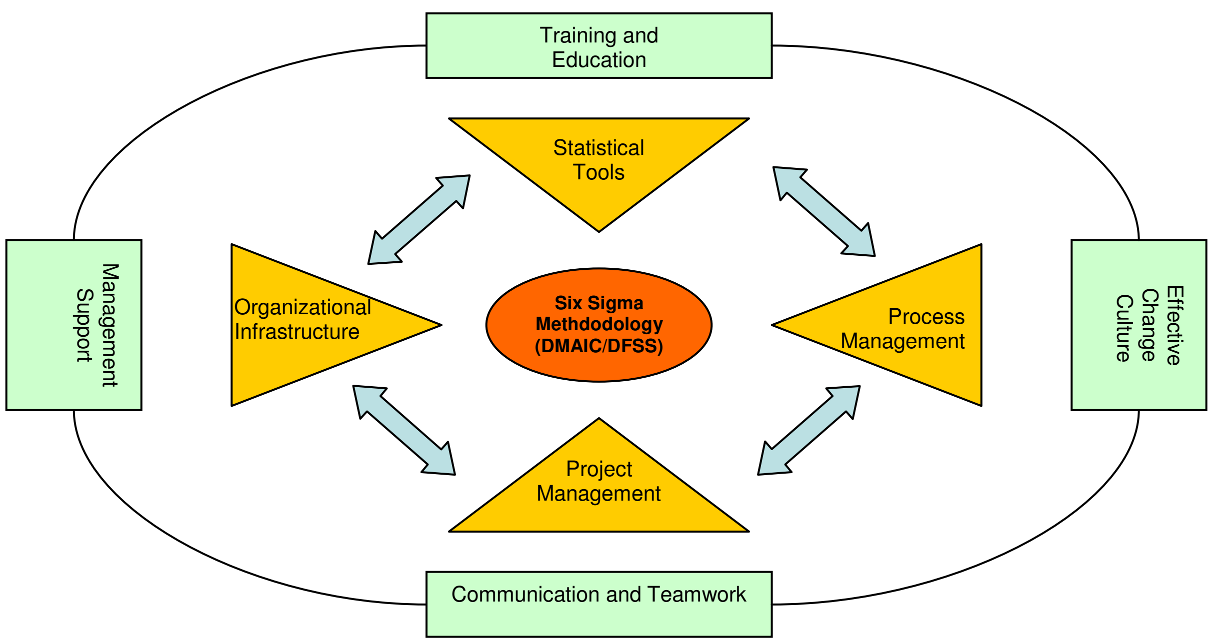
- **Rewards and Recognition** – Rewards and recognition are enablers which maximize employees' potential and involvement. At Dow, compensation linked to the successful completion of Six Sigma projects also forms part of the motivational package. One of the notable strategic changes that Jack Welsh implemented in GE was to link the promotional considerations of employees to Green Belt training. Thus at GE Appliances, any employee who wants to be considered for promotion must be Six Sigma green belt-trained period. This also includes senior executives (Hendericks and Kelbaugh, 1998).

- **Communication** – It is critical to "communicate both the why and the how of Six Sigma as early as possible, and provide the opportunity for people to improve their comfort level through training classes" (Hendericks and Kelbaugh, 1998). A communication plan addressing the importance of Six Sigma quality and how the method works is thought to be critical in driving out two basic fears at individual levels that come with the true cultural revolution that Six Sigma brings: fear of change and fear of not measuring up to the new standards. Using effective communication helped to educate and pave the way for gradual change in Dow Chemicals.

5.5. PROPOSED FRAMEWORK

Based on the review of literature and best practices, and the analysis of the survey findings, a framework for effective Six Sigma implementation is being proposed, as shown in the Figure 5-20.

Figure 5-20: Six Sigma Framework



The framework encompasses the key hard and soft factors which contribute towards successful implementation of Six Sigma. At the core of the Six Sigma implementation is the DMAIC methodology which provides the systematic approach for deployment of Six Sigma projects to improve the existing processes.

The DMAIC methodology is supported by four key and interlinked elements, also referred to as hard factors, i.e., Six Sigma Infrastructure, Project Management, Process Management, and Statistical Tools. The first of these elements is the organizational infrastructure for Six Sigma, consisting of a hierarchy of roles of management and employees depending on the different level of expertise. These roles, classified as Champion, Master Black Belt, Black Belt, Green Belt, and team members, play the central role in the implementation of Six Sigma project, ensuring the management support at one end and providing the technical expertise and skills on the other. The second element or hard factor supporting DMAIC methodology is Project Management. Since Six Sigma program involves identification and prioritization of improvement projects, it requires effective use of project management tools and techniques to ensure that the improvement projects are planned, monitored, tracked and implemented within the defined timeframe. The third hard factor which is critical to Six Sigma program is Process Management. The Define phase of DMAIC requires the identification of core and supporting processes in the organization and defining each process using process mapping or flowcharting techniques. The remaining phases of DMAIC then focus on measuring, analyzing, improving and controlling the process to achieve Six Sigma defect level. The fourth hard factor supporting the DMAIC methodology is the application of statistical tools. The Six Sigma program involves extensive application of statistical tools, basic and advanced, to measure the existing process defects, analyze the root causes of problems, identify the improvement solutions, and control the improved process to maintain the gains. Master Black Belts and Black Belts are Six Sigma professionals having high level of expertise and skill in the application of statistical tools.

The DMAIC methodology and the interlinked hard factors must be supported by certain soft factors to ensure maximum organization support and involvement in the implementation of Six Sigma program. These critical soft factors include top management commitment and support, effective change culture, training and education, effective communication, and teamwork. The first of these critical soft factors is the top management commitment and support. The top executive must be part of Six Sigma and should support the Six Sigma initiative by personally spending time in every Six Sigma training, speaking and answering questions raising by employees, dropping in (usually unannounced) on Six Sigma reviews, making site visits to observe at first-hand the degree to which Six Sigma is ingrained in the culture; and monitoring Six Sigma project progress. Another critical soft factor is the ability of organization to create an effective culture of change. Six Sigma is a breakthrough management strategy which requires changes in organizational culture and in the attitudes of employees. The third soft factor which is critical to Six Sigma success is the continuous education and training of employees on Six Sigma tools and techniques. The Six Sigma team members (Master Black Belts, Black Belts, Green Belts) are trained and certified in the use of a wide variety of tools and techniques related to project management, process management, statistical analysis, etc. Effective communication is another soft factor which plays an important role in alleviating employees' concerns towards Six Sigma. Effective communication is a means of overcoming resistance to management initiatives and maintaining enthusiasm for quality initiatives within the organization. A communication plan addressing the importance of Six Sigma quality and how the method works is thought to be critical in driving out two basic fears at individual levels that come with the true cultural revolution that Six Sigma brings: fear of change and fear of not measuring up to the new standards.

5.6. SUMMARY

The chapter presented the analysis of data and discussion of findings. To summarize the findings, the study revealed that Six Sigma is still a recently adopted approach in

UK organizations. However, both manufacturing and services organizations are implementing Six Sigma. In most cases, the Six Sigma program is championed by the executive management which contributes through commitment and support, championship and leadership, and focus and vision. The major problems faced in Six Sigma implementation include lack of resources, poor data collection and analysis, lack of management commitment, and organizational resistance to change. The significant benefits gained through Six Sigma implementation include cost reduction, elimination of defects, and minimization of non-value added activities. The research's findings showed that the critical factors of Six Sigma include management commitment and support, an effective change culture, teamwork, effective communication, and suitable use of Six Sigma methodology. In the end, a framework for effective Six Sigma implementation has been proposed which encompasses soft and hard factors impacting on Six Sigma results.

CHAPTER 6. CONCLUSION AND RECOMMENDATION

6.1. INTRODUCTION

This chapter presents the conclusions of the research based on the analysis of data and discussion of research findings. The conclusion briefly describes the objective of research and the methodology used for research. It then summarizes the key findings leading to the proposed framework. Finally, the recommendations for effective implementation of Six Sigma have been proposed and the potential areas for future research have been identified..

6.2. RESEARCH CONCLUSION

The aim of the research project was to study the implementation of Six Sigma in UK organizations, assess the problems faced in Six Sigma implementation, identify the critical success factors, and enumerate the significant benefits achieved through Six Sigma implementation. The research was unique in the sense that such a broad analysis of Six Sigma implementation was never carried out before in the UK. Previous researches focused primarily on the identification of critical success factors for Six Sigma but did not focus on the status of Six Sigma implementation in UK organizations and the problems faced in the Six Sigma implementation. The research led to some interesting, yet important, findings. First, Six Sigma has been adopted in both manufacturing and services organizations in UK, thus dispelling the myth that Six Sigma is more applicable in the manufacturing environments. Second, though Six Sigma was pioneered in mid 80s, it was mainly adopted by UK organizations during or after 2000. Third, the major drivers for Six Sigma implementation are a need for change for continuous improvement, competitors' pressure, and poor customer satisfaction. Fourth, most of the organizations had implemented ISO 9000 and, in some cases, TQM or BPR before embarking on implementing the Six Sigma program.

Regarding the implementation status of Six Sigma, most of the organizations have initiated Six Sigma program on a wider scale, starting and implementing more than

15 projects in various functions of the organization. One significant finding was the average time of the Six Sigma project which ranged between four to nine months, thus implying that Six Sigma projects are short-term projects. Another important finding showed that around 1-20% of employees have been involved in Six Sigma projects, thus indicating that Six Sigma program so far has been focused on a selected group of people, which include the Champions, Sponsors, MBBs, GBBs, and team members. Also it was found that the percentage of time devoted by Six Sigma project team members vary from role to role, with Six Sigma leaders, MBBs and BBs devoting 100% of their time on Six Sigma projects while other team members spend around 1-20% of time. The major roles of top management in the Six Sigma program have been in the form of commitment and support, championship and leadership, and resource provision. The study also revealed that most of the organizations used external consultants, mostly for training of Six Sigma team members, to facilitate the implementation of Six Sigma.

Regarding the problems faced in Six Sigma implementation, the study indicated that most common problems faced by the organizations included lack of resources, poor data collection and analysis, lack of management commitment, measurement problems, and organizational resistance to change. Most of the organizations faced moderate level of resistance to Six Sigma initiative. To overcome this resistance, the most common communication media used included kick off meetings with managers, workshops, and individual communication with employees.

The core theme of the project was to identify and categorize the Critical Success Factors for Six Sigma implementation. The research concluded that the most critical factors for successful Six Sigma results are top management support and creating an effective organizational culture of change. Also, effective communication, teamwork, and employee education and training are considered as important factors for Six Sigma implementation. On the other hand, role of IT and use of Six Sigma consultants are less significant in the successful implementation of Six Sigma though the study also indicated that majority of companies used the services of external consultants for Six Sigma training and implementation. The study also classified the critical factors into soft factors and hard factors and concluded that soft factors play a more significant role in Six Sigma success than the hard factors.

Regarding the potential benefits achieved through Six Sigma implementation, the survey results showed that the most significant benefits attained through Six Sigma implementation were cost reduction, reduced defects/errors, cycle time reduction, and minimization of waste and non-value-added activities. Another significant finding of the research was that most of the companies are satisfied with the implementation results of Six Sigma.

Based on the literature review and the analysis of results of the survey, a Six Sigma framework has been proposed incorporating the key elements for effective implementation of Six Sigma. At the core of the framework is the DMAIC methodology which is supported by interlinked hard factors and soft factors. The critical hard factors include organizational infrastructure for Six Sigma, project management, process management, and statistical tools. The soft factors impacting on them are top management support and commitment, effective culture of change, education and training, effective communication, and teamwork.

6.3. LIMITATIONS OF RESEARCH

The research project was constrained by certain factors. First, Six Sigma has not yet been fully exploited and adopted by UK organizations as compared to American companies where this concept has really taken roots and adopted by hundreds of companies. Hence, it was not an easy task to find companies in UK which are implementing Six Sigma. Second, since the research was a cross-sectional study of Six Sigma implementation in UK organizations, the time span of the project was limited, thus constraining the scope of the research. Third, Six Sigma is still a relatively newer concept from an academic perspective and there is not much depth and width of academic research and articles on Six Sigma as compared to other improvement approaches such as TQM and BPR.

6.4. RECOMMENDATIONS

In light of the research findings, following recommendations are being proposed for effective Six Sigma implementation:

- **Top management commitment and support** for Six Sigma program is vital and crucial. Top executives must be part of Six Sigma and should contribute towards its implementation through visible commitment and support, leadership and championship, resource provision, and communication and consultation. They should support the Six Sigma initiative by personally spending time in every Six Sigma training, speaking and answering questions raising by employees, dropping in on Six Sigma reviews, making site visits to observe at first-hand the degree to which Six Sigma is ingrained in the culture; and monitoring Six Sigma project progress.

- An **effective Six Sigma organizational infrastructure** of Champions, Master Black Belts, Black Belts, and Green Belts should be established. Champions should come from the top executives ensuring that Six Sigma initiative has the top management support and appropriate resources are made available for projects. Master Black Belts will be the Six Sigma leaders acting as coaches and mentors for Black Belts and other team members and, hence, should be competent in terms of experience, training and skills related to project management, process improvement, and statistical analysis. Black Belts are the frontline project leaders, facilitating the planning and implementation of Six Sigma projects in collaboration with Green Belts and team members. Black Belts should be selected based on their knowledge of organizational processes and their command on application of statistical and project management tools and techniques.

- A **well-defined training and certification program** of Champions, Master Black Belts, Black Belts and Green Belts should be established. The body of knowledge for each level of training should be developed and the qualification criteria should be defined. This program should then be applied for selection and training of employees for the different Six Sigma roles.

- **Effective communication** is critical to overcome resistance to Six Sigma and maintain enthusiasm for quality initiatives within the organization. A communication plan addressing the importance of Six Sigma quality and how the method works should be developed and implemented to drive out two basic fears at individual levels: fear of change and fear of not measuring up to the new standards. The most commonly used communication media are kick-off meetings with managers, workshops, and individual meetings with employees.

- Six Sigma is an advanced quality initiative and should be preceded by other simpler quality initiatives such as ISO 9000 Quality System. This will help in developing a quality-oriented culture in the organization and prepare the employees to adopt more complex initiatives like Six Sigma.

- Six Sigma, being a breakthrough management strategy, requires **changes in organizational culture and in the attitudes of employees**. The organization should identify the factors (technical, political, individual, organizational) which cause employee's resistance to Six Sigma and address these factors through education and involvement, creating the need for change, listening to employees, and better communication. GE's CEO Welsh created change in organizational culture and overcame employee resistance by changing the organizational structure at the top, investing on training, adjusting the reward and recognition system, and early communication to employees (Henderson and Evans, 2000).

- The **effective use of DMAIC Methodology** is a key to successful implementation of Six Sigma. To affect this, the Six Sigma team should be fully conversant and trained on the application of certain tools and techniques, the most critical of which include project management, statistical analysis, and process management. A balanced combination and smart application of these tools is a recipe for successful Six Sigma results.

- While the **hard factors** like tools and techniques must be there to support the DMAIC methodology, it is the **soft factors** that play a more significant role in Six Sigma success and hence should be given higher attention. Top management commitment, cultural change, effective communication, teamwork, and employee training and education are critical soft factors which should be effectively constituted in the organizational culture in conjunction with the hard factors to maximize the probability of Six Sigma success.

- The most significant benefits of Six Sigma are achieved in terms of **cost reduction and elimination of defects/errors** to maximize customer satisfaction. Based on these factors, a project selection criteria for Six Sigma projects should be established. Each proposed Six Sigma project should be evaluated against the criteria and those projects should be selected which create the maximum impact on the customer satisfaction and ultimately the bottom line.

6.5. AREAS FOR FURTHER RESEARCH

As mentioned earlier, there is a dearth of academic research and articles on Six Sigma. Most of the existing literature focuses on the introduction and explanation of concepts and very little research material is available on the implementation aspects of Six Sigma. This research project attempts to discuss the Six Sigma concept from a practical perspective, exploring the implementation status of Six Sigma in UK organizations and identifying the problems faced and benefits. The research concludes by proposing a framework consisting of hard and soft factors for effective implementation of Six Sigma. Future research projects may be carried out to validate the framework in different sectors and even in different regions. Furthermore, the implementation of Six Sigma can be explored separately in non-manufacturing organizations. Another potential area for Six Sigma research projects is to review the existing body of knowledge for certification of Master Black Belt, Black Belt, and

Green Belt, and propose a standardized body of knowledge to provide a uniform system of Six Sigma certifications. The miraculous yet contrasting results of Six Sigma demand that this concept should be given as much time, effort and space in the academic research as have been given to other quality concepts such as BPR and TQM.

6.6. SUMMARY

The chapter presented the conclusion of the research findings and proposed recommendations for effective implementation of Six Sigma. In short, the research concluded that Six Sigma is still a newer approach in UK organizations but has been adopted in both manufacturing and service organizations. The major drivers for Six Sigma have been the competitors' pressure and the need for change. The major problems faced in Six Sigma implementation include lack of resources, poor data collection and analysis, and lack of management commitment. Six Sigma projects have been initiated throughout the organizations and the average time of projects ranges between 4- 9 months. The critical factors for Six Sigma have been identified as the top management commitment, culture change, effective communication, and training and education. The key benefits of Six Sigma include cost reduction, elimination of defects/errors, cycle time reduction, and minimization of waste and non-value added activities. A number of recommendations have been proposed focusing on management commitment and support, appropriate organizational culture, suitable organizational infrastructure, effective use of Six Sigma methodology, people involvement, teamwork, effective communication, and a balance between hard and soft factors.

APPENDIX 1: RESEARCH PROPOSAL

A STUDY OF CRITICAL SUCCESS FACTORS FOR SIX SIGMA IN UK ORGANIZATIONS

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1. RESEARCH TOPIC AND FOCUS

The topic of research is "**A study of Critical Success Factors for implementing Six Sigma in UK organizations**". The scope of the research will be the UK manufacturing and/or service organizations implementing Six Sigma.

2. BACKGROUND

The most challenging question confronting business leaders and managers in the new millennium is not "How do we succeed?" It's; "How do we stay successful?" Business today offers the spectacle of a succession of companies, products, and even industries getting their peak for a short period of time and then fading away. It's like riding the wheel of fortune as consumer tastes, technologies, financial conditions and competition change ever more quickly.

Many quality models and frameworks have been proposed to improve the competitiveness of businesses in the modern world. TQM, BPR, Kaizen, Benchmarking, Balanced Scorecards, Business Excellence models, and other improvement programs have been adopted and implemented by various organizations. Six Sigma is another approach aimed at achieving significant improvements in business performance and popularized by the success stories of Motorola, GE, and Allied Signals. Looking at the exemplary achievements of these companies, many organizations have embarked upon the implementation of six sigma. The results of these efforts have been mixed with some organizations achieving significant quality improvements while others failing to bring any results.

This variation in Six Sigma program results has raised the need to investigate the critical success factors for Six Sigma. This research focuses on analyzing the success factors for Six Sigma in UK manufacturing and/or service organizations and the benefits and problems associated with its implementation.

3. RESEARCH OBJECTIVES

The aim of the research is to identify the factors, soft and hard, which are critical for the successful implementation of Six Sigma. Also, the research aims to highlight the barriers that might be encountered while implementing Six Sigma and the benefits achieved through Six Sigma implementation.

4. RESEARCH QUESTIONS

5. What are hard and soft factors which impact on the successful implementation of Six Sigma?

6. What are the barriers to the implementation of Six Sigma?

7. What are the benefits achieved by implementing Six Sigma?

5. LITERATURE REVIEW

5.1. BRIEF HISTORY OF SIX SIGMA

In separate articles by two Motorola veterans, Mikel J. Harry (1998) and Dennis Sester (2001), each author explained how the idea of Six Sigma was first conceived by experts at Motorola in the early 1980s. Bob Galvin, who was chairperson of Motorola at the time, presented an incredibly demanding quality goal to his employees in 1981, which may have been the stimulus for Six Sigma. Engineer Bill Smith's research regarding process capability and defect reduction around 1985 became the basis for Six Sigma innovation. Leadership at Motorola later asked Mikel J. Harry, then part of Motorola's technical staff, to pioneer the strategic methodology that would soon become Six Sigma. Harry and his colleagues refined the Six Sigma strategy by decade's end.

Since then Six Sigma has been touted in numerous articles for having improved countless business processes as well as the overall vitality of several major organizations. Motorola, GE, Allied Signal [now Honeywell], Ford, Johnson Controls, TRW, Delphi, Raytheon, Lockheed-Martin, Texas Instruments, Sony, Bombardier, Polaroid, 3M, and American Express are some of the organizations that have implemented Six Sigma (Hahn et al., 1999; Harry, 1998; Lanyon, 2003; Miller, 2001; Snee, 1999; Williams, 2003).

Six Sigma activities and achievements, seen mainly in large manufacturing operations, are also becoming more prevalent in small businesses, transactional business processes (e.g., HR and purchasing), and in the service sector (Gnibus & Krull, 2003; Goh, 2002; Hammer & Goding, 2001; Harry, 1998; Smith, 2003). Smaller companies have had similar financial success compared to larger companies but on a smaller scale (Brue, 2002; Gnibus & Krull, 2003; Harry, 1998). From at least a financial perspective, it appears that Six Sigma has had a considerable impact on numerous organizations across a variety of industries.

5.2. WHAT IS SIX SIGMA?

Some scholars and practitioners have attempted to describe Six Sigma in one or two definitions (e.g., Breyfogle, Cupello, & Meadows, 2001; Dambolena & Rao, 1994). However, many have concluded that there are at least three definitions (e.g., Adams, Gupta, & Wilson, 2003; Eckes, 2001; Pande & Holpp, 2002): Six Sigma can be viewed as a metric, a mindset, and a methodology.

The first logical and commonly heard definition for Six Sigma is that it is a statistical expression – a metric (Breyfogle et al., 2001; Brue, 2002; Dambolena & Rao, 1994; Hahn et al., 1999; Harry, 1998). The lowercase Greek symbol σ (sigma) is the metric or fundamental statistical concept that denotes a population's standard deviation and is a measure of variation or dispersion about a mean. Mikel J. Harry (1998) and Forrest W. Breyfogle et al. (2001) among others explained how Six Sigma can be defined as a term for process performance that produces a mere 3.4 defects per million opportunities (DPMO). In layperson terms, Six Sigma is a metric representing a process that is performing virtually free of all defects.

As a second definition, Six Sigma is considered an organizational mindset that emphasizes customer focus and creative process improvement (Brue, 2002; Dambolena & Rao, 1994; Hahn et al., 1999; Pande & Holpp, 2002). As Mikel J. Harry (1998) aptly stated, "The philosophy of Six Sigma recognizes that there is a direct correlation between the number of product defects, wasted operating costs, and the level of customer satisfaction". With this mindset, individuals are prepared to work in teams in order to achieve Six Sigma and its ultimate goal of reducing process variation to no more than 3.4 defects per million opportunities (Harry, 1998).

As a third definition, Six Sigma is viewed as a strategic improvement methodology, termed as DMAIC (Breyfogle et al., 2001; Brue, 2002; Eckes, 2001; Harry, 1998; Pande & Holpp, 2002; Pande et al., 2002). DMAIC is an abbreviation of the five systematic steps in the Six Sigma methodology. The steps used for breakthrough thinking and improvements are: Define, Measure, Analyze, Improve, and Control. This methodology is used to carry out the structured philosophy of Six Sigma in places that include but are not limited to manufacturing, design, engineering, human resources, purchasing, and customer service.

5.3. WHY CHOOSE SIX SIGMA?

According to Henderson and Evans (2000), the reasons for implementing Six Sigma are:

- To be responsive to and focused on the customer base
- To improve product and service performance
- To improve financial performance and profitability of business
- To be able to quantify its quality programs
- To be considered as a supplier for a business

According to Pande et al (2002), the benefits of Six Sigma are:

- Generates sustained success
- Sets a performance goal for everyone
- Enhances value to customer

- Accelerates the rate of improvement
- Executes strategic change
- Promotes learning

5.4. SIX SIGMA'S DMAIC METHODOLOGY

Define (D) is the first step of the Six Sigma methodology where leaders are expected to select projects, selects the appropriate team members, set initial goals or targets, and develop a project charter or statement of work (SOW).

Measure (M) is the second step of the Six Sigma methodology where a baseline measure is taken using actual data (Eckes, 2001; Pande et al., 2002; Snee, 2003). The measure then becomes the origin from which the team can gauge improvement.

The third step is **Analyze (A)**. Here teams identify several possible causes (X's) of variation or defects that are affecting the outputs (Y's) of the process. One of the most frequently used tools in the analyze step is the cause and effect diagram (Eckes, 2001; Snee, 2003).

The team then enters the **Improve (I) step**. Here a team would brainstorm to come up with countermeasures and lasting process improvements that address validated root causes.

The final step for at least the black belt and many of the team members is **Control (C)**. The ultimate goal for this step is to reduce variation by controlling X's (i.e., the inputs) and monitoring the Y or Y's (i.e., the outputs) (Pande et al., 2002).

5.5. ROLES AND RESPONSIBILITIES FOR SIX SIGMA

Several experts have recognized the various roles in Six Sigma (Adams et al., 2003; Breyfogle et al., 2001; Brue, 2002; Eckes, 2001; Hoerl, 2001; Pande et al., 2002; Pyzdek, 2000b). George Eckes (2001, 42) maintained that team sponsor, champion, master black belt, black belt or green belt, and team members make up the core of Six Sigma.

The **Champion** identifies the specific projects in line with the business objectives, secures stakeholders buy-in, selects black belts, removes project barriers, and conducts project reviews monthly. The **Master Black Belt** trains and coaches Black Belts, assists with project identification and scoping, assists will black belt selection, and provides technical input to the monthly project reviews. The front line leaders of Six Sigma are called **Black Belts**. Black belt candidates are described as disciplined problem solvers who possess a fair amount of technical ability, are comfortable with basic statistics, and are not afraid to question conventional wisdom (Hoerl, 2001; Adams et al., 2003). As a chosen leader, the black belt will guide a team through DMAIC. The **Green Belts** are the project members who are trained by the Black Belt and are involved in the implementation of DMAIC process under the supervision of Black Belt.

6. THEORETICAL FRAMEWORK

The theoretical model to be used for this research is Six Sigma Methodology, which is defined by Pande et al (2000) as:

> "a comprehensive and flexible system for achieving, sustaining, and maximizing business success. Six Sigma is uniquely driven by close understanding of customer needs, disciplined use of facts, data, and statistical analysis, and diligent attention to managing, improving, and reinventing business processes."

According to Antony and Banuelas (2001), Six Sigma is:

> ". . . a business improvement strategy used to improve business profitability, to drive out waste, to reduce costs of poor quality and to improve the effectiveness and efficiency of all operations so as to meet or even exceed customers' needs and expectations"

The research will aim to classify the Critical Success Factors (CSFs) of Six Sigma in terms of their significance based on data collection from the organizations implementing Six Sigma**. Critical Success Factors (CSFs)** are those factors which are critical to the success of any organization, in the sense that, if objectives associated with the factors are not achieved, the organization will fail (Rockart, 1979). In the context of six sigma project implementation, CSFs represent the essential ingredients without which a project stands little chance of success.

Corronado and Anthony (2002) suggest the following CSFs for Six Sigma:

- Management Commitment
- Culture Change
- Communication
- Organizational Infrastructure
- Training
- Linking Six Sigma to Business Strategy
- Linking Six Sigma to Customers
- Linking Six Sigma to Human Resources
- Linking Six Sigma to Suppliers
- Understanding tools and techniques within Six Sigma
- Project Management Skills
- Project prioritization and selection

7. RESEARCH APPROACH AND METHODOLOGY

7.1. RESEARCH APPROACH

The objectives and research questions of this project are mainly related to the validation and analysis of Critical Success Factors for Six Sigma. The research methodology that would be used is **quantitative** approach. This type of approach demands the collection of research data quantitatively and interpreting it using statisitcal tools. It enables researcher to quantifying the research data and generalizing the results for other organizations.

7.2. DATA COLLECTION

A **survey** approach will be used to collect data from the UK companies, which will help in building and argument, recommendations and suggestions according to the survey. A **questionnaire** will be designed and distributed to the companies for collecting primary data. Around 100 questionnaires will be distributed to the different companies.

According to Robson and Colin,(1998), the advantages of questionnaire are as below

- Can be one of the least resources intensive.
- Simple to use – basic awareness training being sufficient to get things started.
- Can readily involve many people within the organization.
- The questions asked can be customized to suit the organization.
- Enables the organization to receive feedback which can be segmented by function and by level.
- Can be used in parallel with the workshop approach to provide a more balanced view of deployment team.
- Can give a good visual reference if results are graphed.

7.3. LITERATURE SEARCH

The sources of literature review and primary data for research will be as follows:

- Secondary data for literature review will be collected from publications such as TQM Magazine, Business Process Management Journal, Measuring Business Excellence Journal, Quality Progress, etc.
- Also, secondary data will be collected through books (*The Six Sigma way* by Pande et al, etc.) and websites on Six Sigma, such as www.isixsigma.com , www.asq.org , etc.
- Primary data for research will be collected by distributing questionnaires to the companies

7.4. DATA ANALYSIS

The data obtained through questionnaires will be compiled using data spread sheets. This data will then be presented and analyzed using simple statistical tools such as bar charts and pie charts. The analysis will be followed by discussions on the Six Sigma's CSFs identified by the respondents and the order of their significance. It will also discuss the benefits achieved through Six Sigma implementation and the main barriers to Six Sigma implementation, as reported by the respondents. Based on research results, conclusions will be drawn and reported.

8. RESOURCES REQUIRED

The resources required for the research project will include:

- Access to the list of UK companies (manufacturing and/or services)
- Access to the management of UK organizations
- Postage expenses
- Travel expenses, in case of visits to the organizations

9. PROJECT TIMELINES

The Gantt chart defining the project activities, timeframe for each activity, and responsible functions or persons, is given at the end of proposal.

10. DISSERTATION OUTLINE

Chapter 1: Introduction

- Background of the Six Sigma
- Purpose of the Study
- Scope of the Study
- Research Questions

Chapter 2: Review of the Literature

Chapter 3: Research Methods

- Quantitative vs. Qualitative Methods
- Data Sources
- Data Collection
- Data Analysis

Chapter 4: Research Findings

Chapter 5: Conclusions and Discussion

- Summary
- Conclusions
- Discussion

APPENDIX 2: RESEARCH QUESTIONNAIRE

1. Name of Business: ____________________

2. Type of Business:

□ Banking and Financial Services
□ Automobile
□ Chemicals
□ Professional Services
□ Electronics
□ Healthcare services
□ Retailers
□ IT and Telecommunications
□ Logistics
□ Any other , please specify: ____________________

3. Number of Employees:

□ 1 - 100
□ 101 - 250
□ 251 - 500
□ 501 - 1000
□ 1001 – 2500
□ 2500 +

ABOUT SIX SIGMA PROGRAM

4. When was the Six Sigma Program started?

□ Before 1990
□ 1990 - 1992
□ 1993 - 1995
□ 1996 - 1998
□ 1999 - 2001
□ 2002 - 2005

5. What triggered or served as driver for the Six Sigma Program in your organization?

□ Competitive Pressure
□ Loss of Market Share
□ Management Changes
□ Mergers/Acquisitions
□ Poor Customer Satisfaction
□ Intense need to cut costs
□ Headquarter directive
□ Any other , please specify: ____________________

6. What other quality improvement programs had been implemented or were being implemented at the time of initiation of Six Sigma program.

□ ISO 9001
□ Total Quality Management
□ Business Process Reengineering
□ Benchmarking
□ Lean Manufacturing
□
□ Any other , please specify: ____________________

7. Who are the Primary Sponsors of Six Sigma Program in the organization?

□ CEO
□ Director
□ Division General Manager
□ Functional Manager
□ Any other , please specify: ____________________

SIX SIGMA IMPLEMENTATION

8. At which stage of Six Sigma Program is your organization in?

□ Planning
□ Start-up
□ Define & Measure
□ Analyze
□ Improve
□ Control & Review

9. How many six sigma projects have been started and implemented so far?

□ 1-3
□ 4-6
□ 7-9
□ 10-12
□ 13-15
□ 15+

10. What has been the average project time for the implementation of Six Sigma Project?

□ 1-3 months □ 4-6 months □ 7-9 months
□ 10-12 months □ 13-15 months □ 15+ months

11. How many Six Sigma qualified or certified people are there in your organization?

Master Black Belts ____________ Black Belts _____________ Green Belts ____________

12. What percentage of employees is involved in Six Sigma Programs?

□ 1-20% □ 21-40% □ 41-60%
□ 61-80% □ 81-100%

13. What percentage of time is devoted by team members for Six Sigma activities?

□ 1-20% □ 21-40% □ 41-60%
□ 61-80% □ 81-100%

14. How many man-hours of trainings were conducted for Six Sigma at different levels of organization?

Top Management ____________ Middle Management ____________ Workers _____________

15. What was the top management's contribution towards Six Sigma Program?

□ Vision and Focus □ Leadership and championship □ Resource provision
□ Communication and consultation □ Commitment and support □ Nothing at all
□ Any other , please specify: ____

16. Were external consultants involved in the planning and implementation of Six Sigma Program?

□ Yes □ No

PROBLEMS IN SIX SIGMA IMPLEMENTATION

17. What was the level of organizational resistance to Six Sigma Program initiative?

□ No resistance □ Minor resistance □ Moderate resistance
□ Major resistance □ Great resistance

18. What type of communication media were used to overcome the resistance and create Six Sigma buy-in?

□ Kick off meetings with managers □ Q&A sessions □ Conducted workshops
□ Individual comm. with employees □ Newsletter □ Videos/Visits of other companies
□ Any other , please specify: ____

19. What type of implementation problems were experienced within Six Sigma Program?

□ Lack of management commitment □ Lack of resources □ Insufficient training
□ Organizational resistance □ Poor project management □ Lack of team culture
□ Measurement problems □ Poor data collection & analysis □ Lack of communication
□ Any other , please specify: ____

CRITICAL SUCCESS FACTORS FOR SIX SIGMA IMPLEMENTATION

20. Based on your Six Sigma implementation experience, please rate, in order of their significance, the critical factors for successful implementation of Six Sigma Program.

S/ No.	Success Factors	Rating						
		Does not matter						Critical
1.	Creating an effective change culture for Six Sigma	1	2	3	4	5	6	7
2.	Top management support and involvement	1	2	3	4	5	6	7
3.	Effective communication on Six Sigma Program	1	2	3	4	5	6	7
4.	Employee training & education on Six Sigma	1	2	3	4	5	6	7
5.	Teamwork	1	2	3	4	5	6	7
6.	Organizational infrastructure for Six Sigma	1	2	3	4	5	6	7
7.	Linking incentive system with Six Sigma Program	1	2	3	4	5	6	7
8.	Understanding and effective use of Six Sigma tools	1	2	3	4	5	6	7
9.	Project Management Skills	1	2	3	4	5	6	7
10.	Effective use of Six Sigma Methodology (DMAIC/DFSS)	1	2	3	4	5	6	7
11.	Role of Information Technology	1	2	3	4	5	6	7
12.	Use of external consultants	1	2	3	4	5	6	7
Any others, please specify								
13.		1	2	3	4	5	6	7
14.		1	2	3	4	5	6	7
15.		1	2	3	4	5	6	7

BENEFITS OF SIX SIGMA IMPLEMENTATION

21. How do you rate the satisfaction with the results achieved through Six Sigma Program?

□ Highly satisfied □ Satisfied □ Neutral
□ Dissatisfied □ Highly dissatisfied

22. Please rate the organizational benefits that your organization achieved from Six Sigma?

S/ No.	Benefits	Rating						
		None						Significant
1.	Customer satisfaction	1	2	3	4	5	6	7
2.	Defects/Errors reduction	1	2	3	4	5	6	7
3.	Cost reduction	1	2	3	4	5	6	7
4.	Reduced cycle time	1	2	3	4	5	6	7
5.	Better employee efficiency	1	2	3	4	5	6	7
6.	Minimization of waste/non-value added activities	1	2	3	4	5	6	7
7.	Sales & Marketing promotion	1	2	3	4	5	6	7
Any others, please specify								
8.		1	2	3	4	5	6	7
9.		1	2	3	4	5	6	7
10.		1	2	3	4	5	6	7

23. Any valuable comments/information which you would like to share regarding Six Sigma Program

THANK YOU FOR YOUR VALUABLE INPUT AND COOPERATION

APPENDIX 3: DMAIC DELIVERABLES AND TOOLS

Strategic Steps	Common Strategic Section Deliverables	Traditional Tools
Define	Project Charter or Statement of Work (SOW) -Process and Problem -Scope and Boundaries -Team, Customers & Critical Concerns -Improvement Goals & Objectives -Estimate Sigma & Cost of Poor Quality (COPQ) Gantt Chart / Timeline High Level Process Map Step Documentation and Next Steps Exit Review	Spreadsheet/Word Processor Critical to Customer Concept Project Charter or SOW Gantt Chart / Timeline Flowchart or Process Map Balanced Scorecards Pareto Chart & Control Charts QFD / House of Quality Suggestions / Complaints Surveys / Interviews / Focus Groups
Measure	Baseline Figures (Sigma & Cost) Process Capability Measurement System Analysis (MSA) or Gage R&R Refine Project Charter, including COPQ Refine Process Map Fix Gantt Chart / Timeline SIPOC or IPO Diagram Step Documentation and Next Steps Exit Review	Data Gathering Plan Surveys / Interviews / Focus Groups Checksheets / Spreadsheets SIPOC or IPO Diagram Descriptive Statistics & Capability Pareto Chart / Control Charts Measurement System Analysis Flowchart or Process Map Project Charter or SOW Gantt Chart / Timeline
Analyze	Identified Root Cause(s) -Cause and Effect -Statistical Analyses Validated Root Cause(s) Step Documentation and Next Steps Exit Review	Fishbone Diagram (5-Why) FMEA Interrelationship Diagram Histogram Scatter Diagrams (Correlation) Hyp Testing / Chi-Square Confidence Intervals Pareto Chart / Control Charts Regression ANOVA DOE Response Surface Methods Flowchart or Process Map
Improve	Selected Root Cause(s) & Countermeasures Improvement Implementation Plan Validated Solutions or Improvements -Statistical Analyses Revised Flowchart or Process Map Step Documentation and Next Steps Exit Review	Affinity Diagram Hypothesis Testing Confidence Intervals DOE FMEA Trial and Error / Simulation Flowchart or Process Map Implementation & Validation Plan
Control	Control Plan -Tolerances, Controls, and Measures -Charts and Monitor -Standard Operating Procedures (SOP) Response Plan -Ownership or Responsibilities -Corrective Actions Validated In-Control Process and Benefits -Process Capability -Measurement System Analysis (MSA) or Gage R&R Step Documentation and Final Report Exit Review - Project Completion and Handoff to Owner	Control Charts Process Map / Monitor / Response Plan Poka-Yokes Standardization SOP / Work Instructions Process Dashboards Capability Studies MSA or Gage R&R Documentation Final Report Presentation

Note: tools should be used only as necessary

<u>Source</u>: Goffnett (2004)

APPENDIX 4: COMPARISON OF SIX SIGMA ROLES

Table I Comparison of role, profile and training in six sigma belt system

	Green belts	Black belts	Champions
Profile	Technical background Respected by peers Proficiency in basic and advanced tools	Technical degree Respected by peers and management Master of basic and advanced tools	Senior manager Respected leader and mentor of business issues Strong proponent of six sigma who asks the right questions
Role	Leads important process improvement teams Leads, trains and coaches on tools and analysis Assists black belts Typically part-time on a project	Leads strategic, high impact process improvement projects Change agent Teaches and mentors cross-functional team members Full-time project leader Cover gains into £	Provides resources and strong leadership for projects Inspires a shared vision Establishes plan and creates infrastructure Develops metrics Converts gain into £
Training	Two three-day sessions with one month in-between to apply Project review in second session	Four one-week sessions with three weeks in-between to apply Project review in sessions two, three and four	One week champion training Six sigma develop and implementation plan
Numbers	One per 20 employees (5 per cent)	One per 50 to 100 employees (1-2 per cent)	One per business group or major manufacturing site

Source: Air Academy Associates (1998)

APPENDIX 5: COMPARISON OF VARIOUS QUALITY APPROACHES

Parameters	Total Quality Management	Business Process Reengineering	Six Sigma	Lean Manufacturing
1. Focus	Overall organizational improvement	Process redesign	Reduction in process variation	Elimination of waste and effective use of resources
2. Nature of change	incremental (kaizen)	radical	radical	incremental (kaizen)
3. Methodology	a wide range of methodologies	Management accounting/ information system based methodologies	DMAIC/DFSS	Kaizen, JIT, 5S
4. Tools and techniques	a collection of tools and techniques	Process mapping, information technology	Basic and advanced statistical techniques	Value streaming
5. Application	all types of organizations	all types of organizations	mainly manufacturing, but also some service organizations	Manufacturing
6. Customer focus	√	√	√	√
7. Continuous improvement	√	√	√	√
8. Teams	√	√	√	√
9. Process orientation	√	√	√	√
10. Organizational and cultural change	√	√	√	√

APPENDIX 6: PROJECT SELECTION MATRIX

Projects and Impact Ratings	Direct links to Strategic Goals	Relates to Key Business /Process (Objectives)	Customer satisfaction impact	Financial payback – increasing revenue/ cost takeout	Return on Investment (RoI)	Employee satisfaction impact	Resource availability (Ttime, People, Capital)	Project Scope/ Complexity	Data Availability	Overall
Significance Ratings										
Notes:										
Significance rating set by Senior Management				1-Low through to 10-Very high						

Category Scoring Definitions

Scoring Category	**0-2**	**3-4**	**5-7**	**8-10**
Direct links to strategic goals	Indirect alignment	Some direct alignment	Strong alignment	Very strong and direct alignment
Relates to key business/process (objectives)	Indirect relationship	Some direct relationship	Strong relationship	Very strong and direct relationship
Customer satisfaction impact	Customer may notice	Customer will appreciate	Major customer concern	Customer demands improvement
Financial payback – increasing revenue/cost takeout	0-150m	150-250m	250-500m	500m+
Return on Investment (RoI)	2+ years	1-2 years	1 year	6 months
Employee satisfaction impact	Employee may notice	Employee will appreciate	Major employee concern	Employee demands improvement
Resource availability (Time, People, Capital)	None	Low	Moderate amount	Committed amount
Project scope complexity/scope	Across 4 or more functions	Across 3 functions	Across 2 functions	Across single function
Time to resolve problem	180+ days	91-180 days	31-90 days	30 days

Source: Jackenthal, 2004

APPENDIX 7: TEAM TOOLS

Team Tool	Description
15-word flipchart	Allows individual team members to draft a simple 15-word statement of the project's scope. Then, the team identifies key words or phrases they feel best about and uses these to write a final version of the project definition statement
Action workouts	A team-focused improvement activity to implement immediate, concrete, and significant operating improvements
ARMI model	A tool to ensure that the person leading the project has identified key stakeholders by determining individuals and/or groups whose commitment is essential for project success by listing individuals/ groups involved in the process and identifying project function
Critical success factors	This tool challenges the team to identify and agree upon the 6-8 intangibles that will make or break the project
GRPI checklist	This tool is based on a simple model for team formation. It challenges the team to consider four critical and interrelated aspects of teamwork: goals; roles; processes; and interpersonal relationships. It also helps a group become a team
In/out frame	A visual tool based on the analogy of a picture frame. It challenges the team to identify those aspects of the project (the type and extent of end results or deliverables, the people impacted, timing, product lines impacted, sites involved, etc.) which are in the frame (meaning clearly within the scope of work), half-in-half-out, or out of the frame
Includes/excludes chart	A process tool that helps the team to clarify and agree on what is included in and excluded from the scope of work
Responsibility grid	A useful tool to help the project team sort out "who will do what" in terms of decision making
Threat vs opportunity matrix	This tool requires the team to find ways to frame the need for a change as a threat and an opportunity over both the short and long term. By doing this, they begin to get the attention of key stakeholders in a fashion that ensures their involvement beyond what can be gained from a short-term sense of urgency

Source: Henderson and Evans (2000)

APPENDIX 8: PROCESS TOOLS

Process tool	Description
Action workouts	A team-focused improvement activity to implement immediate, concrete, and significant operating improvements
Brainstorming	A traditional tool to generate ideas without judgment
CTQ drill down	A tool by which a large and complicated process/system can be broken in to manageable pieces which are then addressed or to create a time-ordered sequence and address those pieces
Fishbone diagram	A tool to identify possible causes (Xs) for a particular effect (Y)
Pareto analysis	A tool to classify data and rank categories in decreasing order of occurrence to separate significant categories from trivial ones. This is done by separating data into categories, counting occurrences in each category, arranging categories from highest to lowest frequency, and drawing and labeling bars for each category
Process mapping	A process tool that identifies process steps, responsibilities, hand-offs, critical to quality factors, and non-value added operations. A graphical display of the steps, events, and operations in time sequence that make up a process. Process maps may be used to provide a view of the process from a very high level to a very detail level, leveraging the notion that you cannot improve what you cannot understand. It allows identification of process deficiencies, responsibilities of process owners; waste; rework loops, non-value added steps, where defects may be occurring, and causes of variation
SIPOC	SIPOC (suppliers, inputs, process, outputs, customers) is a high level process tool that identifies major steps in the process that may be presented in more detail later in process development, and can provide a map as to how CTQs (high customer expectations) are delivered

Source: Henderson and Evans (2000)

APPENDIX 9: STATISTICAL TOOLS

Statistical/graphical tool	Purpose
One-sample *t*-test	Compares mean to target
Two-sample *t*-test	Compares two means
ANOVA	Compares two or more means
Box and whisker plot	To look for differences in the distribution of the data in a graphical fashion
Chi-square test	Compares the number of items in groups or categories
Dot plot	To visually represent all data points and enable graphical comparisons of two or more processes
Homogeneity of variance or *F*-test	Compares two or more variables
Kruskal-Wallis test	Compare two or more means with unknown distributions
Matrix plot	To screen for relationships between factors, and save time as compared to running individual scatter plots
Normal probability charts	Used to identify unstable and stable operations
One-way ANOVA	To examine statistical differences among different populations
PC-based statistics tool set	A statistical software package; provides many statistical tools for analyzing data; presents results in an easy to understand format; can be used to present data in several different graphical formats
Scatter plot	To evaluate the theory that two variables are related; the straight line and tightness of cluster indicate strength of relationship

Source: Henderson and Evans (2000)

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