

A Multiple Case Study Analysis of Six Sigma Practices in Indian Manufacturing Companies

Jiju Antony¹; Gijo E.V.²; Vikas Kumar³; Abhijeet Ghadge¹

¹ School of Management and Languages, Heriot-Watt University, Edinburgh, Scotland, UK

² Indian Statistical Institute, Kolkata, West Bengal 700108, India

³ Bristol Business School, University of the West of England, Bristol, UK

1. Introduction

Six Sigma was developed at Motorola by an engineer Bill Smith in the mid 1980s. Six Sigma is credited with playing a major role in the turn around Motorola accomplished in their quality at the time culminating in Motorola under the leadership of Bob Galvin winning the 1988 Malcolm Baldrige National Quality Award. Significant deployments lead by the Chief Executive Officers (CEOs) at Allied-Signal (Larry Bossidy) and General Electric (Jack Welch) was the next major step for the approach. Welch promoted Six Sigma aggressively inside and outside GE. The initiative received major usage across business and industry; first in the USA and then globally (Snee, 2010). Six Sigma is a breakthrough process improvement strategy that yields dramatic reduction in defects or errors or mistakes in any process. Improved processes lead to improved customer satisfaction, increased market share, business profitability and so on. Six Sigma is a powerful strategy developed to accelerate improvement in product, process and service quality by relentlessly focusing on reducing variation and eliminating waste (Antony and Banuelas, 2002).

Although Six Sigma approach to quality and process improvement has been predominantly used by manufacturing organizations, today the popularity of Six Sigma in the other sectors is growing exponentially, especially in banks, hospital sector, financial services, airline industry, utility services and so on (Antony et al., 2007; Gijo and Antony, 2013; Gijo and Sarkar, 2013). Over the last decade or so, it appears that a large number of Indian industries have embarked on Process Excellence methodologies such as Six Sigma and Lean. Although a decent number of Six Sigma applications related papers have been published, research has shown that very few empirical based papers on Six Sigma in Indian industries have been reported in the current literature. After globalization and liberalization, quality has been surfaced as one of the major areas of concern along with productivity. With the reduction of geographical barriers and the pressure of competing in the global market, operational and service excellence have become absolutely imperative for the Indian industries to remain globally competitive (Antony and Desai, 2009).

In India, Six Sigma implementation started in large engineering and manufacturing companies. Later on, this initiative started in small and medium sized organizations. After observing success in the manufacturing and engineering sectors, organizations in Software, business process outsourcing (BPO), service, financial and insurance sectors also started implementation of Six Sigma and Lean. Healthcare industry also followed this path little later. The success of Six Sigma implementation in all these sectors has triggered the interest of the people and organizations in Six Sigma further. As of now, quite a few industries in India are implementing this methodology and large number of successful case studies is reported as publications in various international journals. Even practitioners in Six Sigma and Lean conducted studies to

identify the potential failures of Six Sigma implementation in various sectors (Gijo and Rao, 2005; Gijo, 2011).

This paper examines the fundamental barriers in the implementation of Six Sigma, benefits from its implementation, commonly used tools and techniques of Six Sigma, impact of Six Sigma on organisational performance across three manufacturing companies in India. The paper also reports some of the quality initiatives adopted by the case study companies as well as key lessons learned from the deployment of Six Sigma. The next section delineates the research methodology adopted for the study.

2. Research Methodology

In this paper, using three manufacturing companies in India, we research the following questions related to Six Sigma.

- 1. What are the fundamental barriers in the implementation of Six Sigma?*
- 2. What are the key benefits of Six Sigma?*
- 3. What are the most commonly used tools and techniques of Six Sigma in the case study companies?*
- 4. Is Six Sigma making a positive impact on companies' performance and if so, how?*
- 5. What are the key lessons learned by the case study companies?*

Given the nature of research questions, a case study research was adopted by the researchers. Case study research was chosen in order to gather in-depth, rich data on the phenomenon of Six Sigma implementation (Yin, 2003; Hussey and Hussey, 1997). In the view of Yin, the case study research represents an empirical research that investigates a contemporary phenomenon within its real-life context, and includes a method comprehensive, with the logic of planning, gathering and data analysis (Yin, 2003). Exploratory case study research is appropriate here as very little is known in the academic literature about the Six Sigma phenomenon in the Indian industries. As the case study approach was replicated across 3 different locations, the authors in this case have decided to adopt a multiple-case study analysis (Stewart, 2012; Eisenhardt, 1989). In case study research, case selection based on a set of specific criteria is deemed to be important (Siggelkow, 2007; Veldman et al. 2011). The criteria for the case selection for the research included:

- a) Size of the company, whereby companies were selected with a minimum number of 300 employees. The rationale for the choice of larger companies is that they have been utilizing Six Sigma for many years and therefore have a better maturity with implementation.*
- b) All participating companies chosen for the research had implemented ISO 9001 (Quality Management System standard), ISO 14001 (Environmental Management System standard) and ISO 18001 (Health and Safety Management System standard).*
- c) All participating companies have been using Six Sigma for a period of at least two years*

Interviews were conducted with relevant staff (Six Sigma Deployment Champions, Six Sigma Master Black Belts and Six Sigma Black Belts) in all three companies. In

order to minimise bias, an interview protocol was developed by the researchers and the protocol was pre-tested with 3 leading academics in Six Sigma area, 3 Six Sigma Master Black Belts and 2 Six Sigma consultants. Data from the companies was obtained using semi-structured interviews and all the interviews were carried out on a face-to-face basis using mainly note taking and a tape recorder where appropriate. Interview data were transcribed and coded using the methodology suggested by Strauss and Corbin (1990). For each case, we summarise the following:

1. Demographic details of the companies
2. Six Sigma Organisational Infrastructure
3. Barriers/challenges in the implementation
4. Key Benefits of Six Sigma
5. Commonly used tools and techniques of Six Sigma
6. Impact of Six Sigma on companies' performance
7. Key lessons learned from the Six Sigma deployment

3. Case Study Results

3.1 *Company A: Solar Cell Manufacturer*

Background: The first case represents a Solar Cell manufacturing company based in southern part of India which manufactures different types of solar powered products. They have a customer base throughout the country and outside. Since the demand for non-conventional energy is increasing, this is a fast growing organisation. This company employs around 850 people. The company has developed a good quality culture where every employee feels the importance of quality in everything they do. Although the company has been quite successful in implementing Six Sigma across the manufacturing operations, it has extended the applications of Six Sigma to non-manufacturing operations such as HR and Finance.

Six Sigma Organisational Infrastructure: Company A has embarked on Six Sigma journey for over 7 years. The senior management team in Company A has proposed a long-term plan to ensure that all employees participate in Six Sigma methodology. During the first year of the Six Sigma program, 22 projects across the manufacturing operation were selected. These projects were assigned to Black Belts in the company. This company today has over 2 Master Black Belts, 3 Six Sigma Champions, 32 Black Belts, 60 Green Belts and over 100 Yellow Belts.

Barriers/Challenges to implementation: There was strong resistance from shop floor workers and some supervisors towards the Six Sigma journey in the early days of its adoption. There was a clear lack of understanding of the benefits of Six Sigma and the need for change using Six Sigma as a catalyst for change. The senior management team decided to provide a one day awareness program for the people on the shop floor so that they understand the expectations and the need for the Six Sigma initiative within the company. Moreover an Executive awareness was also introduced to all senior management team so that they understand the importance of Six Sigma and the benefits Six Sigma can be brought into the business.

Benefits of Six Sigma: There were a number of benefits reported from a direct application of Six Sigma methodology from Company A. These included:

- ◆ Improvement in the yield of the printing process – yield was improved by close to 4% from the use of DMAIC methodology and resulted in savings of over \$140k per annum.
- ◆ Reduction of rejection or rework rate from a number of projects was reported across the company – one project has looked into the high rework and rejection rate of solar cell panel lantern. The application of DMAIC methodology has helped the company in reducing the rework and rejection rate from 18% to nearly 5% and saved over \$65k per annum.

Commonly used tools and techniques of Six Sigma: The Six Sigma Black Belts and Green Belts have used a number of tools and techniques across a number of projects. Based on the interviews, it was found that the most commonly used tools and techniques were:

- ◆ Supplier-Input-Process-Output-Customer analysis (SIPOC)
- ◆ Cause and Effect Analysis or Ishikawa diagram
- ◆ Cause Validation Plan
- ◆ Control Charts (Individual chart, P-chart, U-chart etc.)
- ◆ Hypothesis tests (2 sample t-test, F-test, Kruskal-Wallis test (non-parametric test), etc.)
- ◆ Graphical tools to understand variation and patterns (Histogram, Box-plot, Dot plot, etc.)

Impact of Six Sigma on Business Performance: One of the questions asked by the researchers to two Six Sigma champions was about the impact of Six Sigma on Business Performance. In fact, both Six Sigma champions explicitly stated that Six Sigma did have a positive impact on Business Performance. It was reported that there has been a significant improvement in customer satisfaction on two performance indicators (on-time delivery to customers and cost of poor quality) consistently across the business as a result of the DMAIC projects. The two champions also reported that Six Sigma has a direct impact on process innovation. In other words, they have agreed that Six Sigma fosters incremental innovation for many of their business processes today.

Key lessons learned: Company A had a strong culture of making decisions based on gut feeling and intuition for many years. This has created a culture of “fire-fighting” when it comes to problem solving scenarios whereby root causes were never determined for problems. Moreover, only the symptoms were treated and the same problems occur again and wasted a lot of energy, time and costs across the business. However the execution of Six Sigma projects created a culture of systematic data collection for the problem at hand and moreover the team members from various business functions come together to develop an appropriate solution for the problem. The morale at both team and individual levels has been significantly increased in the business. Design of Experiments (DoE) was rarely used before for process improvement activities in the company. However after the use of DoE to a couple of projects, a number of employees have seen the true power of the technique and is utilizing this powerful process optimisation technique for a number of problems,

especially in understanding the relationship between process output and a set of key input process parameters.

3.2 *Company B: Electrical manufacturing company*

Background: Company B is a large electrical manufacturer based in northern part of India. This company employs around 12000 people and is one of the leading public sector companies in India. Company B manufactures large turbines, transformers etc. used in power stations. They have a customer base in India and abroad. This company has been very serious on quality issues. The company has also been using quality circles throughout the organisation with the active involvement of shop floor personnel and supervisors. Company B has extended the applications of Six Sigma from pure manufacturing to support functions such as Finance, HR, Sales, Purchasing, Maintenance etc.

Six Sigma Organisational Infrastructure: Company B has embarked on Six Sigma journey for nearly 3 years. The company has developed a strategy for Six Sigma with a leadership team involving the Chief Executive Officer, Chief Operating Officer, Chief Finance Officer, Head of Quality, Director of Human Resources, Head of Production, Head of Sales and Marketing and Head of Customer Service. The head of the business functions was chosen as the Six Sigma project champions and they were provided with a one day training program. During the first 2 years of the program, about 60 projects were identified across the business and they were assigned to Black Belts who have gone through the 4 weeks intensive Black Belt training provided by a leading consultancy firm in India. This company today has over 5 Master Black Belts, 6 Six Sigma Champions, 90 Black Belts, 150 Green Belts and over 300 Yellow Belts.

Barriers/Challenges to implementation: One of the challenges encountered by Company B was about retaining the Six Sigma Black Belts in the business. A number of Black Belts after the training and execution of projects left Company B for highly paid jobs in other competitive companies. This has created massive issues in terms of finding suitable candidates for executing strategic Six Sigma projects across the business. Although the company has an ERP system with rich data, the accuracy of the data is still questionable to many Black Belts who are dealing with data collection.

Benefits of Six Sigma: There were a number of benefits reported from a direct application of Six Sigma methodology from Company B. These included:

- ◆ Improvement in the productivity of a CNC notching machine – over 55% productivity was achieved from a project which has resulted in savings of over \$ 3 million US per annum.
- ◆ Reduction of rejection or rework rate from excessive commutator ovality of a traction motor– a Six Sigma project was executed and the rework/rejection rate was reduced from 16% to less than 3%. This project has resulted in a savings of close to \$2 million US per annum. This project has also helped to reduce the lead time of assembly process and thereby improving on-time delivery to customers.
- ◆ A hospital was attached to the company and one of the projects was focused on the improvement of patient satisfaction by reducing patient waiting time at the out-patient department. The average waiting was reduced by over 40%. This

has helped the hospital to serve patients better and faster and the patient satisfaction scores were improved by 25% as a result of this project.

Commonly used tools and techniques of Six Sigma: The Six Sigma Black Belts and Green Belts have used a number of tools and techniques across a number of projects. Further to interviews with the Black Belts who have led projects in Company B, the following tools and techniques were identified to be the most commonly used ones across a number of projects.

- ◆ Supplier-Input-Process-Output-Customer analysis (SIPOC)
- ◆ Cause and Effect Analysis or Ishikawa diagram
- ◆ Pareto analysis (80/20 analysis)
- ◆ Process Mapping/Value Stream Mapping (VSM)
- ◆ 8 Forms of waste analysis
- ◆ Control Charts (Individual chart, X-bar and R chart, P-chart, U-chart etc.)
- ◆ Hypothesis tests (2 sample t-test, F-test, Chi-squared test, Kruskal-Wallis test (non-parametric test), etc.)
- ◆ Conjoint Analysis (used to capture the feedback from potential clients)

Impact of Six Sigma on Business Performance: A Six Sigma project champion and a MBB confirmed during the interview that Six Sigma had a positive impact on Business Performance. In fact, the deployment of Six Sigma in company B had a high impact on cash flow and on time delivery. The execution of Six Sigma projects have resulted in high customer satisfaction scores, increased employee morale, improved productivity, reduced cost of poor quality and a better employee engagement.

Key lessons learned: One of the key lessons learned by Company B is that it has moved from guess work and experience to data-driven culture in making effective decisions. The power of data was never appreciated in the company for many years and the introduction of Six Sigma has changed the mindset of many employees and senior management team over the years. The use of DMAIC methodology for problem solving has improved team participation and communication between employees across various business functions in company B. The management has made mandatory that all employees to attend the awareness of Six Sigma and the power of the DMAIC methodology and this would make everyone to speak the same language. The senior management also realised that Six Sigma should not be confined to manufacturing rather it should be extended to other business functions. A number of Six Sigma projects were kicked-off to make innovative improvements in the non-manufacturing areas such as finance, human resources, etc.

3.3 *Company C: Industrial Compressor manufacturing company*

Background: Company C is a rather medium sized to large engineering company who manufactures compressors for industrial applications. The company has been around for over 20 years and currently employs 360 people. They have a customer base in India and also in other Asian countries. The company has been very active with Quality Circles since 2002. The company has been utilizing the concepts of Lean for over 3 years and has been using 5S as the foundation tool for process improvement.

Six Sigma Organisational Infrastructure: Company C has been using Six Sigma since 2007. This company does not have any MBB in coaching and mentoring projects but

has appointed an external consultant for delivering training and coaching and mentoring projects carried out by Six Sigma Black Belts and Green Belts. The management team in the business in this company made a bold decision that all functional heads to attend the Black Belt training followed by executing Black Belt projects. 11 Black Belt projects were selected and executed as part of the first wave of Six Sigma implementation and all projects were successfully completed with impressive results. The company today has 15 Black Belts, 3 Six Sigma Champions, 47 Green Belts and 50 Yellow Belts.

Barrier/Challengess to implementation: A major challenge for Company C was the high attrition rate of talented people in the organisation. For instance, out of 47 trained Green Belts, about 10 of them have left the company before completion of projects. The extended application of Six Sigma in non-manufacturing areas has been a big challenge for a number of years. This is because a large proportion of employees including some of the senior managers had a misconception that Six Sigma is only relevant to manufacturing processes and it cannot be transferred to non-manufacturing processes such as marketing, sales, finance, etc.

Benefits of Six Sigma: Although Company C has carried out a number of Six Sigma projects and benefited from its application, it was surprised to see that the financial savings or hard dollar savings attached to the projects were not reported or shared. The following benefits were reported from the systematic application of DMAIC methodology.

- ◆ Improvement in the on-time delivery of a particular model of compressors—the baseline data showed the existing on time delivery for a particular model of compressors was less than 50%. The on-time delivery has improved to over 90% after the execution of Six Sigma methodology
- ◆ Reduction in raw material inventory – A Six Sigma project was carried out to reduce the raw material inventory. The project has helped the organisation in reducing raw material inventory from 45 days to less than 30 days.
- ◆ Reduction in lead time for supplier bill processing – This project was carried out in the finance department. It was found that only 25% of the bills were processed within 3 working days after supply of materials. The application of Six Sigma methodology has improved the figure from 25% to over 80%.

Commonly used tools and techniques of Six Sigma: Having reviewed over 20 projects within the company, the following list of tools and techniques were identified to be the most commonly used ones across the projects.

- ◆ Supplier-Input-Process-Output-Customer analysis (SIPOC)
- ◆ Cause and Effect Analysis or Ishikawa diagram
- ◆ 8 Forms of waste analysis
- ◆ Failure Mode and Effects Analysis (FMEA)
- ◆ Hypothesis tests (2 sample t-test, F-test, Chi-squared test, etc.)
- ◆ Analysis of Variance (ANOVA)
- ◆ Control Charts (Individual chart, X-bar and R chart, P-chart, U-chart etc.)
- ◆ Simple graphical tools such as Histograms, Box plots, Dot plots etc.

Impact of Six Sigma on Business Performance: A Six Sigma champion and a Black Belt were interviewed to understand if Six Sigma was making any impact on Business Performance. As a result of implementing Six Sigma in Company C, the on-time delivery of products to customers has improved significantly and this has resulted in increased customer satisfaction levels. The cash flow of the organisation has also improved from a number of projects which focused on the reduction of raw material inventory. Six Sigma projects also helped to make innovative improvements in marketing, sales, finance and other transactional related processes in Company C.

Key lessons learned: Company C did not have a data driven culture and the execution of a number of Six Sigma projects helped Black Belts and Green Belts to appreciate the power of data based decision making over intuition and experience. The application of Six Sigma in non-manufacturing processes helped company C to perceive that Six Sigma is not just confined to production or manufacturing processes. In fact, this company has already reported some good successes of projects in Finance, Marketing and Human Resources.

4. Discussion

In this section, we compare and contrast the findings from the three case study organisations presented above in terms of barriers, benefits, commonly used tools and techniques, organizational infrastructure for Six Sigma and impact of Six Sigma. The findings of the study clearly indicated that Indian companies have demonstrated some positive impact from the adoption of Six Sigma. It would be interesting to compare the organisational performance of non-Six Sigma (NSS) companies with those companies who have been actively employing Six Sigma as a business strategy.

In terms of barriers/challenges, high attrition rate of Six Sigma Black Belts was quite common across companies B and C. The deployment of Six Sigma across the business has also observed to be a big challenge/barrier. Lack of awareness of the benefits of Six Sigma was also reported to be a typical barrier. Further investigation has suggested that there has been a lack of communication from the senior management team about the benefits of Six Sigma and what Six Sigma can be brought into the business. Moreover, it was also felt that the need for change was not communicated to all levels of employees in all companies.

In terms of benefits from the implementation of Six Sigma, all companies have reported that Six Sigma projects did demonstrate significant savings to the bottom-line as well as intangible benefits such as employee morale, improved teamwork, increased productivity, etc. The authors have observed that most of the projects carried out were in manufacturing or production areas and very few projects were executed in Finance, Human Resources, Marketing and Sales business functions. Our findings also indicated that the application of Six Sigma in the supply chain, logistics, Research and Development (R & D) are still in their infancy stages. Moreover, the applications of Six Sigma methodology to tackle some of the environmental issues (i.e., Green Environment) seem to be lacking across the case study companies.

It was felt that all the case study companies are actively using a number of both statistical and non-statistical tools and techniques across many projects we have reviewed as part of the research. The most commonly used statistical tools included:

hypothesis tests, non-parametric tests, simple regression analysis, control charts, etc. However very few projects have utilised more sophisticated and advanced tools and techniques such as Design of Experiments, Taguchi Methods, and so on. Further investigation into those projects which had utilized Design of Experiments, the authors have found that more basic factorial or fractional factorial experiments or Taguchi's orthogonal array experiments were employed. The most commonly used non-statistical tools included: SIPOC, Cause and Effect Analysis, Pareto Analysis, Process Mapping/Value Stream Mapping, Dot plots, Box plots, etc.

All the three case study companies have reported that they had a positive impact on Business Performance from the application of Six Sigma methodology. Some of the KPIs that have been influenced from the implementation of Six Sigma included: customer satisfaction resulted from reduction of reject or rework rates, on-time delivery of products; improved engagement of the workforce due to cross-functional teamwork in the execution of projects; increased productivity from a systematic reduction of waste using the 8 forms of Waste Analysis and VSM exercises. The authors also found that Six Sigma has a positive impact on process innovation. Further investigation into this has showed that Six Sigma projects lead to incremental process innovation rather than radical or breakthrough process innovation.

The three case study companies reported that they all have learned that the emphasis on data collection and making decisions based on process data instead of hunches and gut feeling results in better decisions at both strategic and operational levels. There has been a major shift in the mindset of employees across all the case study companies as a result of the above and all three companies began to perceive a cultural change in problem solving scenarios. The need for change was not so well communicated to people on the shop-floor and there has been a clear lack of transparent communication in the case study companies. One of the major lessons learned by senior managers in all three companies is that Six Sigma is not about solving problems in manufacturing or production setting rather it can be extended to all business functions. The costs associated with misdirected problem solving efforts have been significantly reduced in all three companies as a result of the introduction to Six Sigma methodology for problem solving exercises.

5. Conclusion and Future Research Agenda

This paper has explored the fundamental barriers, benefits, commonly used tools and techniques, key lessons learned etc. of Six Sigma journey in three Indian manufacturing companies. A multi-case study analysis has led to the identification of a number of valuable insights. Most of the Six Sigma projects are selected on the basis of cost savings and defect reductions but are not necessarily aligned with strategic goals of the business. It was observed from our findings that there is a lack of use of Hoshin Kanri (Policy Deployment) in ensuring the project alignment with business goals. The authors also found that Design of Experiments (DoE) as a powerful technique in the Six Sigma tool box is less frequently used in projects and moreover further investigation has showed that case study companies are currently utilizing basic fractional factorial designs or Taguchi's Orthogonal Array experiments for process characterisation and optimisation. The barriers, benefits, commonly used tools and impact of Six Sigma across all case study companies are consistent with the existing literature (Pulakanam, 2013; Snee and Hoerl, 2004; Foster, 2007). It was surprising to learn that none of the case study companies had a sustainability model

on Six Sigma. The authors would like to explore this aspect further in other Indian companies as part of the future research. The main limitation of this research is in the number of companies studied and the access of data in Indian companies and of course the availability of people for interviews. The focus of our research was limited to large manufacturing companies and it would be worth exploring how the results vary when the same protocol is tested in small and medium sized enterprises as well as leading service oriented companies in India.

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