Six Sigma and the Level of Quality Characteristics- A Study on Indian Software Industries

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Six Sigma is a business improvement strategy that seeks to find and eliminate causes of defects or mistakes in business processes by focusing on outputs that are of critical importance to customers (Snee, 2000). It is a powerful approach to process improvement, cost reduction, increase in business profitability and revenue growth. This study aims to examine the Critical Success Factors (CSF) for the implementation and operation of Six-Sigma and to study the level of quality characteristics in Indian software industries implementing Six Sigma.

Keywords: Six Sigma, Critical Success Factors, Software Quality Characteristics

1.Introduction

Quality is the key to survive and compete in today's increasingly fierce competitive business environment. Competitiveness, productivity, market share and survival of a company depend on quality. Most organizations are not only focusing on providing high quality products but also accentuate their high quality level of service being provided to the customers. Poor quality of products will result in loss of faith and dissatisfaction on the image of the organization with the customers. The literature reports a close relationship between customer loyalty and customer satisfaction, as high customer loyalty and retention rate induce an enhanced intention of future purchases among customers (Yang, 2004).

Quality of software has received a great deal of attention among the practitioners and academicians in 1990s. Today, software code is embedded everywhere, from hand phones, televisions, and cars to electric razors. The amount of software in consumer electronic devices is doubling at a speed of approximately every 18 months (Hong, 2003). The software firms with high quality can accurately predict cost, schedule and defects in software projects based on past performance. Such firms have the ability to handle the changing needs or requirements very effectively and deliver high quality products (software) on time with fewer defects (Jalote, 2000). This study aims to study the benefits of Six Sigma, to identify & rank the Critical Success Factors (CSF) and the level of operational performance indicators of Six Sigma implemented Software Industries in India.

2. Six Sigma

Six Sigma is a business improvement strategy that seeks to find and eliminate causes of defects or mistakes in business processes by focusing on outputs that are all critical importance to customers (Snee, 2000). It is a methodology based on statistical thinking and methods. This methodology is used to produce very large improvements in business performance and to produce a lot of bottom line savings. Six sigma projects often focus on improving productivity, process yields, production rates and process down time, which results in enhanced process performance, improved customer satisfaction, increased revenue and bottom line savings. It is a strategic approach that works across all processes, products and industries. The Sigma value of a process describes the quality level of that process. Six Sigma is defined by Motorola, as a quality improvement program with an ultimate goal of reducing the number of defects as low as 3.4 defects per million opportunities. The higher the sigma capability, the better is the performance, because it measures the capability of the process to achieve defect free work. A defect is anything that results in customer dissatisfaction (Adams,et al.,2003).Six Sigma focuses on customer needs, data driven improvements and inputs of the processes which results in:

- Reducing or eliminating defects
- Reducing process variation
- Increasing process capability

2.1 Benefits of Six Sigma

The key reasons for implementing Six Sigma are as follows:

- To be responsive and to be focused on customer needs. Transformation of organizational culture from fire-fighting mode to fire-prevention mode.
- To improve financial performance and business profitability.
- To be able to quantify its quality programs.
- Reduced Cost Of Poor Quality (COPQ) (costs associated with late delivery, customer complaints, misdirected problem solving, etc.).
- Reduced number of non-value added steps in critical business processes through systematic elimination, leading to faster delivery of service.
- Improved consistency level of service through systematic reduction of variability in processes.
- Increased employee morale.
- Increased awareness of various problem solving tools and techniques, leading to greater job satisfaction for employees.

3. Research Methodology

The objectives of the research project are

(1) To identify and rank the Critical Success Factors(CSF) for the implementation of Six Sigma.

(2) To measure the developers perception of the level of operational performance indicators in the software industries in India.

3.1. The Critical Success Factors (CSF) for Six Sigma

In order to manage and optimize the process output, it is important to identify the key input variables, which influence the output. The Critical Success Factors of Six Sigma play an identical role of input variables to any process. The following section deals with the Critical Success Factors that are necessary for the effective implementation of Six Sigma program. It is also important to learn the importance of these factors in a ranking or prioritized order particularly in the Indian software Industry. The relative weightings of the Critical Success Factors would assist the people to understand what factors are essential for making Six Sigma program success. The Critical Factors for the implementation of Six Sigma in software industries identified from the literature survey and through the discussions with the managers of software organizations in India are as follows:

i) Upper Management Support

Any Successful initiative like Six Sigma requires top management involvement and provision of appropriate resources and training (Halliday, 2001). Upper management must adapt and propagate the philosophy that quality should be given the first priority over the cost or schedule and should allocate sufficient resources to the implementation of quality management efforts (Ferdows and Demeyer,1990).The underlying principles of Six Sigma must be taught to senior managers within the organization. Jach welch., the CEO of GE, has strongly influenced and enabled the restructuring of the business organization and has changed the attitude of the employees towards Six Sigma (Henderson and Evans, 2000).

ii) Cultural Change

The successful implementation of Six Sigma requires adjustments to the culture of the organization and a change in the attitudes of the employees. Quality cannot be achieved without the cooperation of each employee in the organization and the organizational culture should change before one expect significant process improvements (Kanji, 1990). The mindset of the people should be with the ultimate goal of “Doing things right first time”. The Six Sigma initiatives require the right mindset and attitudes of the people working within the organization at all levels. The people within the organization must be made known and should be aware of the need for change. Companies that have been successful in managing change have identified that the best way to tackle resistance to change is through increased and sustained communication, motivation and education.

iii) Organizational Infrastructure

Effective Organizational Infrastructure is also needed to support the Six Sigma introduction and development program within any organization. The employees in any organization practicing Six Sigma are generally highly trained, have undergone rigorous training and lead teams in identifying, executing and managing Six Sigma Projects. The CEO or Vice President, who is considered as the Six Sigma Champion, leads six Sigma initiatives. This will be followed by the formation of Master Black Belts, Green Belts and other team members who are individuals who support specific projects in their area (Harry and Schroeder, 2000). The Champions provide guidance to the project team and find and negotiate resources and budget for the project.

iv) Employee Training

It is critical to "Communicate both the 'why' and 'how' of Six Sigma as early as possible ,and provide the opportunity to people to improve their comfort level through training classes" before unleashing the employees into the world of Six Sigma (Hendricks and Kelbaugh, 1998).Training brings about changes in knowledge, skills, attitude and social behaviour of employees for doing a particular job (Pattnayak, 2001).Training Activities influence the performance in two ways viz. by improving skills and abilities relevant to employee's tasks and the development and improvement of employee's satisfaction with their jobs and workplace. Training improves employees participation and involvement in Six Sigma program. It also helps to propagate the priorities and missions of the organization (Harel and Tzafrir, 1999).

v) Project Management Skills

Six Sigma is a project driven methodology. It is a good practice for team members to have project management skills to meet the various deadlines or milestones during the course of the project (Antony and Banuelas, 2001).**"**Most of the projects on Six Sigma fail due to poor management skills, setting and keeping ground rules, determining the meeting's roles and responsibilities (Eckes, 2000).

vi) Project Prioritization and Selection

There have to be proper criteria for the selection and prioritization of projects. Poorly selected and defined projects lead to delayed results and also a great deal of frustration provide three generic categories of project selection criteria (Pande et.al.,2000).They are:

- Business benefits criteria
  - Impact on meeting external customer requirement, Financial impact & impact on core competitiveness.
- Feasibility criteria
  - Resources required, Complexity & expertise available etc.
- Organizational Impact criteria
  - Cross Functional benefits & Learning benefits.

vii) Six Sigma Methodology

The Six Sigma training involves learning the principles behind the Six Sigma methodology (D M A I C methodology)i.e. Define, Measure, Analyze, Improve and Control. During training, employees learn three groups of tools and techniques which are divided into Process improvement tools and techniques, Leadership tools and Time tools. In addition there has to be clear set of matrices that are used to measure process performance against customer requirements.

viii) Link to Business Strategy

Six Sigma requires adherence to a whole philosophy rather than just the usage of new tools and techniques of quality improvement (Dale, 2000). It needs to be clear how Six Sigma projects and their activities link to customers, core processes and competitiveness (Pande,et.al, 2000). It focuses on reducing process variation, centering the process and on optimizing the process. The emphasis is on the improvement of process capability rather than control of product quality which

includes the improvement of quality and reduction of Cost Of Quality (Mala Murugappan and Gargi Keeni, 2000). In every project the link between project objectives and business strategy should be identified.

ix) Link to the Customers

Projects should begin with the determination of customer requirements (Harry and Schroeder, 2000). Any attribute in the deliverable sent to the customer, which does not meet the customers requirement or which is not as per the customers standards is defined as the defect. The Critical –to-quality (C T Q) characteristics must be identified in the starting phase of Six Sigma methodology. A proper understanding of the users requirements and maximizing the user satisfaction are very critical in software industries. In other words, the software must do what the customer expects to do (Weinberg, 1993). Hellens,(1997) found that the quality of the software resides in the minds of the customer and therefore how they experience the software would affect their opinion about quality.

x) Link to Human Resources

Human resources based actions (e g. Bonuses, Promotions etc.)need to be put into effect to promote desired behaviour and results. Only a certain percentage of the top performing companies link their rewards to their business strategies (Harry and Schroeder, 2000).

A questionnaire based response method was used in this study. 135 questionnaires were sent to the software industries working with Six Sigma. The questionnaire comprises of two parts; the first part is to have a clear vision about the organization with the aim to understand the fundamental issues such as the type of organization, size of the company, the position of the respondent in the company, whether the company is applying Six Sigma, whether the company has a quality department, number of projects being completed in a year, Six Sigma metrices used within the company, etc. The second part of the questionnaire is prepared based on the statements of Jiju Antony and Craig Fergusson (Jiju Antony and Cortanado, 2002 &, Jiju Antony and Craig Fergussion, 2004).The questionnaire contains 83 variables, which are grouped under 10 CSF, consisting of several critical questions.

A measurement model is specified for each construct and Confirmatory Factor Analysis is run for all constructs for checking convergent validity, unidimensionality and reliability of the instrument in the initial stages of questionnaire development. The functionality of the measurement model is briefed in the following section. Based on the comments and suggestions by the experts, the instrument has been refined.

3.1.1 Validity, Unidimensionality and Reliability and of the Measuring Instrument

In order to ensure that, the instrument enables to obtain valid and reliable information or estimates of the constructs and their inter relationships it is necessary to check its validity, unidimensionality and reliability. Validity is defined as the extent to which any measuring instrument what it is indented to measure (Carmines and Zeller ,1990).The first phase in the analysis is to ensure the construct validity of the questionnaire. Construct validity is termed as the extent to which the instrument measures the concept it is presumed to measure. It is generally used to refer to the vertical correspondence between a construct, which is at an indiscernible, latent and

abstract level and a purported measure of it, which is at an observable operational level.

- Convergent validity is obtained when a measure correlates with other measures that are believed to measure the same construct (Kaplan and Scauzzo , 1993). A scale with Bentler-Bonett Fit Index (BFI) value of 0.9 or above is an indication of convergent validity (Bentler and Bonett, 1980). Table-1 shows a BFI value greater than 0.9, demonstrating strong convergent validity for each factor.

- Unidimensionality refers to the existence of a single construct or trait underlying a set of measures (Hair, Anderson, Thatham and Black, 1998). Computing Comparative Fit Index (CFI) value for all factors tests the unidimensionality of the scale**.** Comparative Fit Index (CFI) of above 0.9 indicates unidimensionality (Byrene, 1994). The results shown in Table -1 highlights the CFI value greater than 0.9 , which justify the unidimensionality of the instrument.

- Reliability of an instrument is defined as the extent to which any measuring instrument yields the same results on repeated trials (Carmines and Zeller, 1990). The reliability or internal consistency of the instrument can be estimated using a reliability coefficient called Cronbach's Alpha (Chronbach, 1951). The Cronbach's Alpha values for all the factors were tested using E Q S software. It is seen that all the factors have Cronbach's Alpha value of greater than 0.7, which testifies the reliability of the instrument(Nunnally,1978).The results of the confirmatory factor analysis are presented in Table1.

A questionnaire survey method has been used to collect the data. Questionnaire was sent to different software industries in India like, Tata Consultancy Services, Wipro, Infosys , Sathyam etc.102 responses were made and out of which 25% is suitable for the study. From the responses related to the study, most of the respondents came from large industries with more than 1000 employees (70%). The distribution of the respondents to the questionnaire was black belts (30%), Champions (26%), General Managers (12%), Quality Managers (10%) and Project Engineers (22%). About 80% of the industries involved in the study has less than three years experience with Six Sigma initiative, 11% of the companies has been involved with the Six Sigma for three to five years and 9% of the companies has more than five years experience with Six Sigma.

The respondents have been asked to indicate their perception of each item in their organization in a Seven Point Likert Scale (1 = Extremely low, 2 = Very low, 3 = Low, 4 = Medium, 5 = High, 6 = Very high & 7 = Extremely high). The Quality Index is calculated for a particular organization, with respect to a particular factor. The Quality Index is the average value (mean value of the respondent's score) of that factor score per item. Higher the score, the greater is the importance of the factor. The ranking of the Critical Success Factors (CSF) for successful implementation of Six Sigma program in the descending order are as follows (see Table 2)*:* Upper management support/involvement, Cultural Change, Employee Training, Link to the Customers, Organizational Infrastructure, Project Prioritization and Selection, Six Sigma Methodology, Project Management Skills, Link to Business Strategy and Link to Human Resources.

Table 1 *The Results of the Confirmatory Factor Analysis of Six Sigma Factors*

Sr. No.	Factors	Comparative Fit Index CFI	Cronbach's Alpha	Bentler-Bonett Fit Index (BFI)
1	Upper Management Support	0.960	0.914	0.925
2	Cultural Change	0.915	0.932	0.910
3	Organizational Infrastructure	0.982	0.762	0.980
4	Employee Training	0.976	0.822	0.963
5	Project Management Skills	0.960	0.868	0.954
6	Project Prioritization and Selection	0.908	0.733	0.986
7	Six Sigma Methodology	0.910	0.845	0.916
8	Link to Business Strategy	0.904	0.896	0.908
9	Link to the Customers	0.913	0.808	0.902
10	Link to Human Resources	0.918	0.942	0.913
	Overall	0.9346	0.8522	0.9357

Table 2 *Ranking of the CSF for Six Sigma*

Rank	Critical Success Factors	Mean	Standard Deviation
I	Upper Management Support	6.0254	0.3357
II	Cultural Change	5.8873	0.1959
III	Employee Training	5.7492	0.2571
IV	Link to the Customers	5.7355	0.3741
V	Organizational Infrastructure	5.4753	0.3068
VI	Project Prioritization and Selection	5.4619	0.3390
VII	Six Sigma Methodology	5.0989	0.2606
VIII	Project Management Skills	4.9871	0.2926
IX	Link to Business Strategy	4.7613	0.2624
X	Link to Human Resources	4.5238	0.3971

It was not surprising that Upper Management Support has been identified as the most important factor as most of the authors of Six Sigma (Harry and Schroeder, 2000; Pande et al., 2000) agree with this. Linking Six Sigma to Human Resources finds least place in the ranking agreeing with the findings of Jiju Antony and Richardo Banuelas(Jiju Antony, 2004). The study about the level of operational performance indicators in the software industries implementing Six Sigma is explained in the following section.

3.2 The level of Operational Performance Indicators of the Software Industry

The improvements of the attributes of the developed software (i.e., the product attributes) can be treated as one of the outcomes of the quality programme, from the management point of view. Based on an extensive survey of literature on software quality management and discussions with experienced professionals in the software industry, the following two operational performance indicators of the software quality have been identified.

- Product Attributes (P A)
- Return on Quality (R O Q)

Hence, in this study, the above-mentioned factors are considered as the two operational performance indicators of the software industry.

Product Attributes (P A)

The quality of software is estimated by many of its attributes such as Reliability, Integrity, Maintainability, Enhancability (Extensibility), Usability, Portability and Reusability. These are referred to as the "ilities" of software (Yang, 2004), Jorgensen also stated that the software quality can be indirectly measured /predicted with the help of these characteristics. Researchers have pointed out that these characteristics could be used as a measure of software quality, since they affect the customer satisfaction, which is ultimately treated as the indicator of the product quality.

Return On Quality (R O Q)

The outcomes of quality implementation are often measured indirectly with the help of certain performance indicators such as reduction of errors, better process management and control, improved ability to complete the project within budget and within scheduled delivery dates and decrease in customer complaints. Software quality could be measured as a function of error density (Jorgenson, 1999). The percentage decrease in error density could be treated as a Return On Quality. The improvement in Mean-Time-To-Failure (M T T F) could be treated as another indicator of quality improvement, since it leads to reduction in complaints and reduction in maintenance costs. Therefore, M T T F could be treated as another element of R O Q.

The respondents have been asked to indicate their perception of each item in their organization in a Seven Point Likert Scale as mentioned in the previous section. The unidimensionality (CFI greater than 0.9), convergent validity (BFI greater than 0.9) and reliability (Cronbach's alpha greater than 0.7) were tested using E Q S software.

It is seen from the analysis (Table 3) that both the constructs exhibit strong unidimensionality (CFI greater than 0.9), convergent validity (BFI greater than 0.9) and reliability (Cronbach's alpha greater than 0.7).

Table 3 *The Results of Confirmatory Factor Analysis*

Sr. No.	Factors	Comparative Fit Index CFI	Cronbach's Alpha	Bentler-Bonett Fit Index (BFI)
1	Product Attributes (PA)	0.916	0.894	0.919
2	Return On Quality (R O Q)	0.922	0.831	0.916
	Overall	0.919	0.8625	0.9175

From the respondent's rating, the scores were added together and then divided by number of observations per factor to determine the mean score of each factor, higher the score, the greater is the importance of the factor. Ranking of the level of operational performance indicators in software industry is shown in Table 4.

Table 4 *Ranking of the Level of Operational Performance Indicators in Software Industries Implementing Six Sigma*

Rank	Product Attributes	Mean	Std. Deviation	Return on Quality	Mean	Std. Deviation
I	Security	6.15	1.0952	Customer Satisfaction	6.48	0.6273
II	Accuracy	6.03	0.4133	Complaints Reduction	6.46	0.5009
III	Maintainability	5.71	0.4777	Within Budget	6.40	0.6178
IV	Modifiability	5.61	0.7385	Employee's Attitude	6.39	0.6178
V	Aesthetics	5.60	0.6356	Error Density	5.87	0.3667
VI	Learn ability	5.53	0.6428	Rework Reduction	5.86	0.5322
VII	Serviceability	5.49	1.0396	Overall Satisfaction	5.85	0.9252
VIII	Availability	5.47	0.6269	Employee Satisfaction	5.36	1.1679
IX	Install ability	5.29	0.7921	M T T F	5.24	1.5117
X	Documentation	5.20	1.1101	Completion in Time	5.13	1.1251
XI	Expandability	4.72	0.9110	Module Reuse	4.95	0.9562

The results indicate that almost all factors have a mean value of more than 5, which shows the improvement in the level of operational performance indicators in software industries. However the two factors namely, Expandability of Product Attribute and Model Reuse of Return on Quality have a mean score of less than 5, indicate the necessity for the improvement of these two factors.

4. Conclusion

Six Sigma employs a disciplined approach to tackle process variability using the application of statistical and non-statistical tools and techniques in a rigorous manner. This paper reports the Critical Success Factors for the implementation of Six Sigma in software industries, their ranking and the need to improve the level of two Operational Performance Indicators such as Product Attributes and Return on Quality. Thus, Six Sigma is well recognized as an imperative for achieving and sustaining operational and service excellence.

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