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Six Sigma in Software Industry: Developing a framework of Critical Success Factors (CSF) for Six Sigma Implementation

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Abstract*: Present day society has an advanced demand for quality than the earlier days. The increasing complexity of software products with greater competitive pressure to provide high-quality software has become the biggest challenge of today's software industry. In order to consider the application of Six Sigma in software companies on a company-wide basis in the lines of full organizational involvement for achieving quality, the Critical Success Factors (CSF's) of six sigma in Technopark companies have been identified through systematic review of conceptual and empirical literature and through discussions with the senior software managers. Data for the study is collected using a structured questionnaire survey from software developers and is validated. The paper explores Six Sigma as an integrated holistic approach with an assortment of interdependence among the critical success factors. Based on interrelationships a conceptual framework of Six Sigma is proposed in the paper.

***Index Terms*: Critical Success Factors, Software quality, Upper Management Commitment**

I. INTRODUCTION

The execution of improved quality management strategies is imperative for adding worth to the software product by recuperating the product features or through a reduction in the cost of software development and or reworking the product again and again. The association between the quality management practices in the software projects and the upshot of the project, in requisites of cost to the developing company and quality to the customers have not yet been examined meticulously. Identifying the key input variables which influence the output is imperative for managing and optimizing the software development process output. The Critical Success Factors (CSF's) of Six Sigma in the software development process have a vital role as input variables to the software process. The factors need to be prioritized or ranked in the context of its application success in Technopark software companies. The relative weights of the factors would support the software development teams and quality team in comprehending what factors are indispensable for making sixsigma program a success in Technopark. The Critical Success Factors for the implementation of sixsigma in software process to achieve zero defects are documented from the literature reviews and also identified from the discussions/interactions with the senior managers of Technopark organizations.

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II. LITERATURE REVIEW

At all times, continued existence in a cutthroat environment has been a challenge from industrial perspective-manufacturing or service. Quality has become a mantra and success key for organizations in the era of intense competition to attain a competitive advantage in the business environment [1]. Intense competition motivated several superior managers in manufacturing organizations to appraise the manufacturing practices and competitive strategies for improving organizational performance [2]. Organizations are forced to do so because they find it hard to stay alive unless they have competitive benefit [3], [4], [5]. Quality is a vital element to accomplish competitive advantage, and its effectual management leads to an enhanced competitive facade in the existing global market [6]. Enterprises are pursuing product and service quality with the motive of satisfying customers [7]. Quality finally involved a thoughtful accomplishment of the requirements of customers. In the current scenario, organizations are not merely focusing on providing high-quality products but also providing higher quality service to customers. If the organizations are not capable of offering high-quality product or service, customers will drop trust and self-reliance with the illustration of the organization and the most awful is that they could stretch their statement of dissatisfaction to other potential customers which finally results in loss of further business. It is an established fact that poor product or service quality will amplify the costs in all organizations [8]. The mounting customer realization of quality and rising international competitive force with the mounting need to offer the increasing demands of the customers and to cope with escalating competition have enforced organizations to focus on Quality Improvement. The critical factor needed for the endurance and enlargement of an organization is quality and the companies which provide quality products and services have gained the cutthroat edge and superior market share [9]. Quality is defined as 'fitness for use' by Juran and conformance to requirements by Philip Crosby and further explains quality as "Goodness or Luxury or Shininess or Weight" [10].

Crosby saw 'zero defect' as a standard that alerted on preventing defects rather than finding and fixing them. Quality is articulated as 'meeting customers' needs and expectations, of which the customers can be internal and external to the organization. Quality as a total lies 'in the eyes of the beholder'. Quality is an obligatory requirement of a customer as quality in a straight line links to the performance factors like cost, delivery, and responsiveness [11]. Customer satisfaction is built with quality as the foundation. A customer will deem a product or service as superior quality when it meets or go above what they necessitate from that product or service. Organizations all over the world have turned their attention focusing on quality management practices. Six Sigma is a novel luminary in the quality world [12].

Most of the Six Sigma implementation frameworks applied the notion of Critical Success Factors (CSF) in the software development. Amar & Davis [13] identified four CSF intended for scheming the Six Sigma implementation framework to include- Management commitment, training and communication, employee involvement and customer focus. According to Antony & Fergusson [8], the following factors were well thought-out important for six sigma implementation in software industry- leadership engagement with top management commitment, supporting organizational infrastructure, cultural change, Six Sigma training, linking Six Sigma to business strategy, accountability, customers involvement, understanding of six sigma methodology, project management and project prioritization. The critical success factors for the successful implementation of Six Sigma in the software organization are top management commitment –involvement, leadership, linking Six Sigma to business strategy, education- training, understanding Six Sigma methodology, organizational infrastructure, awareness of quality tools [14].

III. METHODOLOGY

There are 330 IT and ITES companies in Technopark Trivandrum out of which 276 companies are IT- Software development companies. In the total population of 276, eight companies operate under CMMI level5 and follow their customized version of Six Sigma which focuses on continual improvement philosophies. Forty software development companies which are in the initial mode of Six Sigma application were identified as a sample of the study. Even though Six Sigma practices are applied in software sectors, but how to apply its concepts is still unclear. There are 40 companies in which six sigma are applied for successful results. The senior management of the companies views six sigma as a quality improvement project stratagem. There are still some tribulations existing about the applicability of Six Sigma in software companies. The systems and procedures for the application of six sigma are not so far streamlined. The connection between the Six Sigma and the operational outcome in the software industry has not been taken care of systematically. Thereby it is envisaged to investigate avenues for Six Sigma applications in the software companies and endow with steps for the software companies to implement Six Sigma. The Critical Success Factors (CSF) of Six Sigma is identified through literature review and interaction between the senior management and quality heads of Technopark Software Companies.

A. *Data Collection*

A survey method is used for collecting data. The perceptions of group project managers, software quality/lead managers, senior software development members, and HR practitioners are collected, as these communities being the strategic business partners contributing to the decision towards operational excellence through Six Sigma practices. A total of 320 responses (8 responses from each company) have been obtained from 40 software development companies.

Table 1: Category wise number of responses

Category-Responses – Nos:	Each company	Total- 40companies
Group Project Managers	2	80
Software quality/lead managers	2	80
Senior Software Developers	2	80
HR practitioners	2	80
Total Responses	8	320

IV. AN EMPIRICAL MODEL TO MEASURE CSF OF SIX SIGMA PROJECTS IN TECHNOPARK SOFTWARE COMPANIES.

The primary objective is to spot out the critical factors of Six Sigma implementation in the software companies from the management perspective. It is carried out based on an empirical analysis demanding thorough research with reliable and valid instruments. The outcome of empirical analysis can be effectively applied by upper management for achieving zero defects in the software process. A measurement model is used in each construct and a questionnaire, which is an efficient tool for assessing perceptions on a particular theme, is developed for data collection. The respondents need to rank the factors, and the relative weightings would help in understanding what factors are needed for making six sigma program a success in Technopark software companies. During the progress of questionnaire finalization, discussion and pilot study was carried out with the managers and software engineers of some of the Six Sigma implemented software industries. Based on the suggestions, the questionnaire is refined. The refined questionnaire will capture the various aspects of six sigma for software industries. The respondents- software professionals were asked to rank each item using a 7 point Likert scale.

A. *The Validity of the Instrument*

The instrument is tested for face validity, done by experts in the software field by reviewing the questionnaire developed.

The experts after scrutinizing the questionnaire gave insights regarding the relevance and contents and expressed feedback and suggestions about comprehensiveness, redundancy level, and consistency in each variable. The face validity assured the instrument developed as valid.

The Content validity is ensured through intense literature review of all items listed in the instrument. The instrument has been developed as a result of a thorough analysis of the literature to ensure content validity. The face validity and content validity have assured the initial stages of questionnaire development.

B. *Reliability Statistics*

Internal consistency, reliability of the instrument is found by using the reliability coefficient. Cronbach's alpha tested is greater than 0.70 shows strong consistency of established scales [1] and is 0.95 which shows data collected is highly reliable.

ANOVA with Tukey's Test for Non-additivity gives a Grand Mean = 5.124, Tukey's estimate of power to which observations must be raised to achieve additivity = 4.362.

Inference: Data is stabilized and not repeated.

Table 2: ANOVA with Tukey's Test for Non-additivity

ANOVA with Tukey's Test for Non-additivity			Sum of Squares	df	Mean Square	F	Sig.
Between People			5149.330	319	16.142		
Within People	Between Items		2166.561	65	33.332	48.51	0.000
	Residual	Non-additivity	227.446	1	227.446	336.38	0.000
		Balance	14019.402	20734	.676		
		Total	14246.848	20735	.687		
	Total		16413.409	20800	.789		
Total			21562.739	21119	1.021		

Hotelling's T-Squared test confirms that the data is related and validated

Table 3: Hotelling's T-Squared Test

Hotelling's T-Squared	F	df1	df2	Significance
5845.436	71.887	65	255	0.000

V. SIX SIGMA CERTIFICATION AND THE CRITICAL SUCCESS FACTORS

The relevance of Six Sigma certification- champions, black belts, green belts, yellow belts and the critical success factors of Six Sigma implementation at software companies is analyzed. Based on score values of means (SCORE <4.96-LOW, SCORE 4.97-5.20-MODERATE, SCORE 5.21-5.44-HIGH, SCORE >5.45- VERY HIGH) the critical success factors for Six Sigma can be prioritized (See Table 4).

Table 4: Prioritization and ranking of CSF's based on Scores range

Sl No	Factors	Mean	Rank	Score
1	Upper management leadership	5.441	1	High (5.21-5.44)
2	Customer Involvement	5.362	2	
3	Organizational Facilities	5.314	3	
4	Organizational Culture	5.295	4	
5	Project Prioritization and Tracking	5.1016	5	Moderate (4.97-5.20)
6	Business Strategy	5.0414	6	
7	Project Management Skills	5.000	7	
8	Human Resource based actions	4.971	8	Low (<4.96)
9	Employee Training Empowerment	4.815	9	
10	Six Sigma Methodology tools techniques	4.691	10	

The analysis unveils that Six Sigma is an integrated approach with an assortment of interdependence among the critical success factors. This emphasis the belief that Six Sigma is a holistic approach that has to be executed as a whole. Ranking concerning each critical factor is calculated by considering the average value of the respondent's score for that particular factor. These indices can be used as a reference point upon which improvement efforts can be planned and executed in the software development companies. The ranking of the factors with respect to the order of preference are tabulated in Table 5 and are as follows, Upper management leadership, involvement of customers, organizational facilities, organizational culture, project prioritization and tracking, business strategy, project management skills, human resource based actions, employee training empowerment and Six Sigma methodology tools techniques.

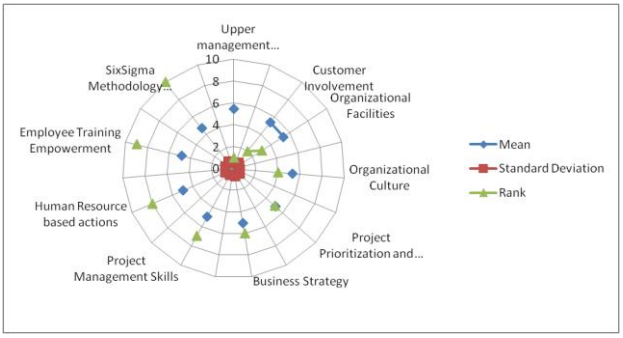

Figure 1: Ranking of CSF's of Six Sigma

Inference: Upper management leadership and their commitment, involvement of customers in the development process, organizational facilities and organizational culture have a crucial role in the success of Six Sigma in the software development process. Project prioritization and tracking, business strategy and project management skills have a moderate role whereas human Resource-based actions, employee training empowerment and Six Sigma methodology tools techniques have a low impact on the success of Six Sigma in software companies. To analyze the order of preference, the mean value can be used and ranked accordingly.

Table 5: Robust test of equality of means using Brown-Forsythe

Six Sigma Certification		N	Mean	SD	Rank
Upper management leadership	1.0	56	5.777	0.4805	1
	2.0	24	5.279	0.5030	
	3.0	33	5.367	0.4635	
	4.0	207	5.381	0.5770	
	Total	320	5.441	0.5651	
Robust Tests of Equality of Means		Brown-Forsythe	P Value	0.000	Significant
Organizational Facilities	1.0	56	5.636	0.4110	3
	2.0	24	4.925	0.5334	
	3.0	33	5.394	0.3220	
	4.0	207	5.259	0.6037	
	Total	320	5.314	0.5724	
Robust Tests of Equality of Means		Brown-Forsythe	P Value	0.000	Significant
Organizational Culture	1.0	56	5.544	0.4567	4
	2.0	24	5.537	0.4845	
	3.0	33	5.370	0.3639	
	4.0	207	5.188	0.5229	
	Total	320	5.295	0.5157	
Robust Tests of Equality of Means		Brown-Forsythe	P Value	0.000	Significant
Business Strategy	1.0	56	5.4554	0.4525	6
	2.0	24	5.3229	0.4747	
	3.0	33	5.0379	0.58001	
	4.0	207	4.8973	0.72576	
	Total	320	5.0414	0.68918	
Robust Tests of Equality of Means		Brown-Forsythe	P Value	0.000	Significant
Employee Training Empowerment	1.0	56	5.243	0.4928	9
	2.0	24	5.075	0.3467	
	3.0	33	4.682	0.9710	
	4.0	207	4.690	0.7894	
	Total	320	4.815	0.7725	
Robust Tests of Equality of Means		Brown-Forsythe	P Value	0.000	Significant
Project Management Skills	1.0	56	5.329	0.5835	7
	2.0	24	5.184	0.6053	
	3.0	33	5.025	0.5916	
	4.0	207	4.886	0.6918	
	Total	320	5.000	0.6777	
Robust Tests of Equality of Means		Brown-Forsythe	P Value	0.000	Significant
Project Prioritization and Tracking	1.0	56	5.4420	0.7214	5
	2.0	24	5.2813	0.3635	
	3.0	33	5.0758	0.5394	
	4.0	207	4.9928	0.7181	
	Total	320	5.1016	0.7014	
Robust Tests of Equality of Means		Brown-Forsythe	P Value	0.000	Significant
Customer Involvement	1.0	56	5.7780	0.5434	2
	2.0	24	5.7440	0.3623	
	3.0	33	5.3766	0.5270	
	4.0	207	5.2028	0.7453	
	Total	320	5.3620	0.7105	
Robust Tests of Equality of Means		Brown-Forsythe	P Value	0.000	Significant
SixSigma Methodology tools techniques	1.0	56	5.157	0.6480	10
	2.0	24	4.925	0.4204	
	3.0	33	4.691	0.6146	
	4.0	207	4.537	0.8426	
	Total	320	4.691	0.7995	
Robust Tests of Equality of Means		Brown-Forsythe	P Value	0.000	Significant
Human Resource based actions	1.0	56	5.350	0.6453	8
	2.0	24	5.042	0.7483	
	3.0	33	4.745	0.9978	
	4.0	207	4.896	0.8542	
	Total	320	4.971	0.8472	
Robust Tests of Equality of Means		Brown-Forsythe	P Value	0.002	Significant

VI. FINDINGS OF THE STUDY

The relationship between Six Sigma certification and critical success factors of implementation is examined to identify whether certifications- champions, black belts, green belts, and yellow belts contribute significantly. Further equality of means is found using the Brown- Forsythe test. P value greater than 0.05 shows there is no difference between the means and a P value less than 0.05 shows the result is significant and there is a difference in the mean value. Robust tests for equality for all the CSF's, the P value is 0.000 which shows that the result is significant with differences in the impact between critical factors on Six Sigma implementation. Based on the interrelationships of critical success factors, a conceptual model of Six Sigma is proposed for the software companies. The conceptual model represents an integrated approach to Six Sigma implementation at software industry with its critical success factors. The framework implies that Six Sigma initiative and its control ought to arrive from the upper management since they are responsible for continual quality management and policy decisions.

Six Sigma requires support from various subsystems be executed as a whole. The most driving force is the inclusion of customer throughout the software development process as a reduction of defects/variations is the goal of the initiative. The feedback from the customer is treated as the input of the system using the organization's facilities and developing a culture towards quality revolution.

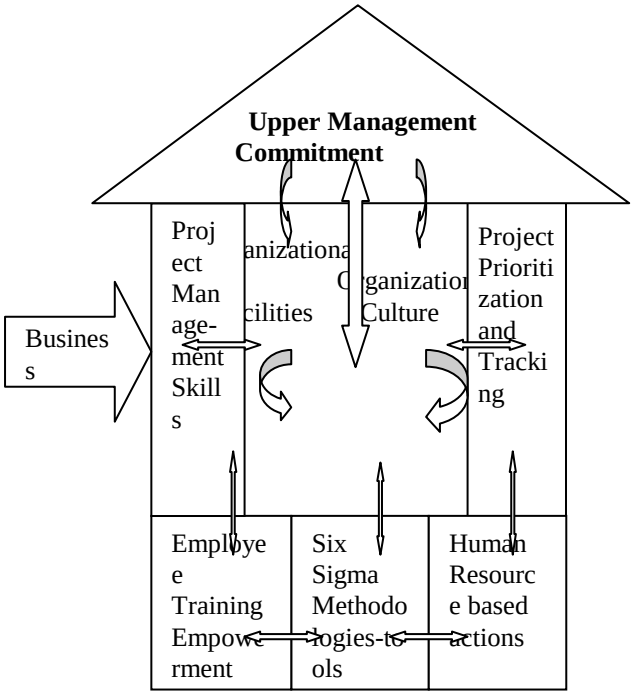

Figure 2: A conceptual framework of Six Sigma critical success factors

VII. CONCLUSIONS

All the critical success factors of Six Sigma extracted from literature reviews and discussions with software developers seem essential for Six Sigma implementation at Technopark. The critical factors are prioritized according to the mean values and the influence rates of each success factors are explored. The study reveals that the factors are inter-dependent and there is also a significant difference between the impacts of various success factors on Six Sigma implementation. Upper management leadership has the highest mean value and priority, and customer involvement being the second. The paper concludes proposing a conceptual framework of Six Sigma implementation based on the prioritized critical factors.

REFERENCES

1. Sureshchandar G.S, Rajendran C. and R.N.Anantharaman. (2001). A holistic model for Total Quality Service. International Journal of Service Industry Management, Vol.12 pp.378-412.
2. D.Samson, Terziovski M. (1999). "The link between total quality management practice and organizational performance." International Journal of Quality and Reliability Management, Vol.16 pp.226-237.
3. G.K.Kanji. (1998). Measurement of business excellence. Total Quality Management, Vol.9 pp.633-643.,.
4. G.K Kanji, M.Asher,. (1999). 100 Methods for total quality management. Delhi: Sage Publications.
5. Adam (Jr.) E.E. Flores B.E. and A.Macias. (2001). "Quality Improvement practices and effect on manufacturing firm performance: evidence from Mexico and USA." International Journal of Production and Research, Vol.39 pp.43-63.
6. Kuei C.H. and C.N.Madu. (1995). Manager's perceptions of factors associated with quality dimensions for the different types of firms. Quality Management Journal, Vol.2 pp.67-80.
7. Yang C.C. (2004). "An Integrated model of TQM and GE- Six-Sigma." International Journal of Six Sigma and Competitive Advantage, Vol.1 pp.97-111.
8. Antony J. and C.Fergusson. (2004). Six Sigma in the Software Industry: results from a pilot study. Managerial Auditing Journal, Vol.19 pp.1025-1032.
9. Khanna V.K. Vrat P. Shankar R. and B.S.Sahay. (2004). "Managing the transition phases in the TQM journey: a system dynamics approach." International Journal of Quality and Reliability Management, Vol.21 pp.518-544.
10. Crosby P.B.(1979). Quality is Free: The art of making Quality certain. Ny: McGraw-Hill.
11. S.E.Fawcett, L. T. (2002). Benchmarking the challenge to quality program implementation. Benchmarking: An International Journal, Vol.9 pp.374-387.
12. Willborn W. and T.C.E.Cheng. (1994). Global Management of Quality Assurance Systems. New York: Mc Graw-Hill .
13. Amar, K., & Davis, D. (2008). A Review of Six Sigma Implementation Frameworks and Related Literature. In Proceedings of International Multi Conference of Engineers and Computer Scientists, Vol. 2.
14. Antony, J., Bhuller, A. S., Kumar, M., Mendibil, K., & Montgomery, D. C. (2012). Application of Six Sigma DMAIC methodology in a transactional environment. International Journal of Quality and Reliability Management, Vol. 29(1), pp. 31–53. http://doi.org/10.1108/02656711211190864.

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