

SOFTWARE PROCESS IMPROVEMENTS: A STUDY OF CRITICAL FACTORS FOR ENHANCING THE SOFTWARE QUALITY

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Abstract- This paper presents the comprehensive overview of the state of the art software process improvements(SPI) domain. The core discussion of the paper is based on the overview of SPI history, frameworks of SPI, research methods concerning SPIs. The most commonly used methods for SPI literature are, organizational paradigms and affinity analysis. We used organizational paradigms to find the different critical factors and discussed the effectiveness of each factor. These factors are used to find out the success or failure of software process improvement in any organization. These organization paradigms involve open system view, rational system view, natural system view and complex adaptive system view. After finding the critical factors we try to sub categorized these critical factors using affinity analysis. These factors involve management, organization, project, process, team and users. Furthermore, we explained that how much these critical factors affect the success or failure of SPI. We critically analyze the difference between the factors determined by the researchers by applying the organization paradigms. The detailed analysis of the factors and methods gives contribution to the field of software industry.

Index Terms- Software process improvement, Organizational Paradigms, Research Methods, factor Affinity Analysis, open systems, natural systems, rational systems, complex adaptive systems

1. INTRODUCTION

There are many organizations small level organizations and high level organization in the world. Those organizations [1] where software process improvement techniques are not applied mostly lead to the failure as comparing to those organizations where SPI techniques are applied. These organization are much better in term of results and gives better performance. Without SPI it is very difficult to know that in organization which areas should be improved, what areas we should focus to improve the results of our organization. There are some organizations which increase the process formality as well as there also some organizations which decrease the process formality. Some organizations consider management and commitment most important factors. These organizations properly plan, control, track, and measure their projects.

In our paper we will focus on the following areas:

- Which research methods can be used for SPI research?
- Which organizational paradigms can be used in an organizations?
- What are the key factors involves in the success or failure of SPI?
- What are the common factors determined by our research and other organizational paradigms?

In our research paper will involved overview of SPI literature which involves the SPI history, SPI frameworks. We will try to explain different research methods used for SPI research in organizations. We will provide detail about the two research methods used in our research. These two methods are organizational paradigms and affinity analysis. After that we will provide the result summary related to our research areas i.e. four questions to answer. Discussion section will explain about the influence of the critical factors on the SPI detected by our research, this section also includes the limitation of our study. Conclusion section includes the final summary and findings of our research paper as well as it include the suggestions for the researchers for future research. And after conclusion section the References section is included. And at last we write the Appendix section in which we have made seven tables listings all the critical factors at different organizational paradigms and are grouped with the help of factor affinity analysis.

2. OVERVIEW OF SPI LITERATURE SPI HISTORY

According to the Lehman the concept of SPI firstly introduced in 1951 in a book which was written by wikes, wheeler and Gill. In 1986 when the third international process workshop was conducted, it create some interest in modeling of software development process. In that workshop it was suggested that rather than process we should focus on objects of software development. In 1986, software engineering institute [2] develop the CCM (capability mature model), with which the growth of the software process improvement rapidly increase.

Software Engineering institute published CCM in 1991. CCM is the most popular assessment model with more than 2400 organization is using this assessment model.

2.1 SPI Frameworks

In the duration of 15 to 20 years of history of SPI research SPI [3] community has developed several process frameworks for the organizations. Capability Mature Model Software (CMM- SW), Software Process Improvement and capability determination (SPICE) and ISO 9001 are some useful frameworks. These frameworks are used by many organizations for the improvement in their processes. CMM-SW and SPICE are totally used for the improvement of software process and ISO 9001 framework is used to improve the quality within the organization. There are also other frameworks such as Total Quality Management (TQM), BOOTSTRAP, and Quality Improvement Paradigms. These all frameworks are very essential tools for software process improvement. There are many SPI organizations working in the field of software process improvement expanding SPI literature. These organizations include Software Engineering Institute-SPI Network (SEI-SPIN). Recently the concept of complex adaptive systems has appeared in SPI literature. From these frameworks and assessment model we can extract high level overview methods which will be used to study the SPI literature.

3. SPI RESEARCH METHODS

For the purpose of SPI research [4] we can have a variety of research methods. These methods are use to evaluate the performance of SPI within the organizations, these methods are also used to find the critical factors of the SPI which can be the cause of failure or success of the SPI within the organization. The world most biggest and successful organization Microsoft use the research methods such as feedback, self criticizing, focusing creativity, hiring smart people, chaos theory etc for controlling its software product/project, process and people. These research methods can be experimental or non experimental such as case studies, surveys, qualitative and quantitative methods. Some research methods are used to study artificial interface between the software artifacts made by man himself and its environment.

Rainer and Hall [4]say that we should support the multiple strategy approach for SPI research. They use the multiple strategy approach to investigate some critical factors which are involved in affecting the SPI. They combine the results of qualitative and quantitative methods of case studies and then compare these results with the survey data. By doing this different investigated methods were found for finding critical factors.

4. METHODS STUDIED IN OUR RESEARCH PAPER

There are many approaches used by the researchers to research about research literature. Such as Hansen, Rose, and Tjornhoj used a three part framework for the SPI research, in which they assess 322 articles related to the SPI research. They try to assess that whether the contribution of these articles in SPI research is prescriptive, descriptive or reflective. Rainer and Hall [4] used research methods for SPI research. Stelzer and Mellis reviewed some articles to study the organization change. In our research method we select two methods for SPI literature review. These two methods are organizational paradigms and factor affinity analysis.

4.1 Artical Selection

We used IEEE online library, internet in general and Google scholars for the article selection to be reviewed for this research paper. Different research terms such as “software process improvement”, “critical factors”, “Research Methods”, “Success”, “failure” etc were used for the purpose of research.

4.2 Organizational Paradigm

In our Paper we review the three traditional organizational paradigms [4,5] rational system view, natural system view and open system view. With these three traditional paradigms we also review a fourth emerging organizational paradigm. This fourth organizational paradigm is complex adaptive system emerged from chaos theory. Chaos theory [6] emphasis on continuous process improvement, stability and evaluation of process in an organization.

Table-4.1 Organizational Models (Paradigms)

Article elements	RS view	NS view	OS view	CAS view
Managerial Characteristics	High Goal exclusively High Formalization	Multiple interest's comfortable configuration	Environmental power co-dependent actions	co-dependent parts co-dependent on environment unbalanced relations
Keywords	managerial technical	disagreement consent supportive	rivalry possibility environmental	Adaptive, Agile, Chaos, Complexity

	CMM comprehensive control Formal ISO 9000 Quantitative controlled Six Sigma	Organizing	science traditional Process Resources management contract	self-motivated stability Irreversibility Nonlinearity Nonreplicability prototype calculation unfeasibility Self-arrangement formless
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From the above table we can see that the classification model of organizational paradigms has two steps, first the characteristics of organizations were highlighted by organizational paradigms and summarized by scoot (2003) and Thietrat and forgues. The above table 1 is used to classify the research articles review for this research paper. Some of these research articles evaluated with some organizational paradigms and some research articles openly acknowledged their paradigms. While some articles required some extensive tools for the cleaning of process defined by models. All research articles reviewed were inspected using model and were classified according to indirect organizational paradigms.

4.3 Factor Affinity Analysis

After categorizing the organizational paradigms, we examined these organizational paradigms for finding those critical factors [7] involves in making the SPI successful or failure. The factors listed by the organizational paradigms were grouped using factor affinity analysis (Pande et. 2000). Six resulting groups of factors were found. These groups are management, organization, process, team, project and users. There were some factors which were found in more than one article. We count the number of times these factors occurred in different articles while reviewing these articles and indicated the occurrence of these factors with numerical suffix in parenthesis. Our study is qualitative in nature, exact counts were considered.

5. RESULTS

Result of our research paper indicated that all the quantitative, qualitative, experimental and non-experimental methods were used. Organizational paradigms were heavily subjective towards rational system views. The critical factors [7,8] which we found were very frequent and conflicting but become very comprehensive when categorized by the organizational paradigms and grouped by factor affinity analysis. Now here we are going to answer the four questions which were asked in our introduction section.

5.1 What Research Methods are used for SPI Research

According to SPI literature we studied that there are 83% of researchers who applied the qualitative methods and 33% of researchers applied the quantitative methods for SPI research. The sum of both types of research methods is greater than 100% because there are some researchers who involved both type of research methods qualitative and quantitative in their research. Within the qualitative research 40% experimental methods are used and 60% non-experimental methods are used. The most experimental methods were case study and survey while non-experimental methods were model and conceptual framework. While in quantitative research 10% of researchers used experimental methods and 90% of researchers used survey methods with using cross sectional approach.

5.2. What Organizational Paradigms are Used by Organizations

Over the 50% of the researchers used rational systems for SPI research. CMM is an example of rational system of software process. In 1991, rational systems were mostly selected for literature as well as recently in 2004. After rational system view, second mostly used organizational paradigm was open system view. Open system view approximately appears one third research papers for review. Another one third of the researchers divide their research between NS view and CAS view. But now complex adaptive systems view is becoming more important for SPI research. Article related to CAS view firstly appeared in 1997. After that in 2005 50% of articles used CAS view for the SPI research.

5.3 What Key Factors are Involved in the Success or Failure of SPI Research

Critical factors are those factors which are used to find out the success or failure of SPI. While studying different articles [9, 10] of different researcher's total of 63 critical factors were identified in total of 16 articles of rational system views, 12 factors were mentioned in 4 articles related to the natural systems, 57 factors were identified while studying 9 open system view articles and there were 26 factors were mentioned in 5 complex adaptive systems view articles. A total of 158 factors were identified while studying different articles related to the different organizational paradigms.

Some critical factors [10] such as commitment, management, external competition, realistic management expectation and organization skills occurs frequently in different articles. These were those factors which

appeared in more than one research articles but none of these factors appeared in all organizational paradigm. Overall management and commitment are those factors which appear frequently in many research articles. After the management and commitment, second most common critical factor was team. Third most common factor was user involvement. These all critical factors were common in different articles related to the open systems or rational systems view.

Table-5.1 Classification of Studies by Organizational Models

RS view (x =16)	NS view (x = 4)	OS view (x = 9)	CAS view (x = 5)
Conradi, 1997	Baddoo, Hall, and Wilson, 2000	Berander and Wohlin, 2003	Lahman article, 1997
Conradi and Fuggeta, 2002*	Halvorsen and Conradi, 2002*	Ceschi, et al., 2005	Lahman article, 2000
Aaen and Damsgaard, 1998	Kautz and Nielsen, 2004*	Conradi and Fuggeta, 2002*	Little's article, 2005
Diaz and Sligo, 1997	Abrahamsson and Jokela, 2000	Dyba, 2005	Peculi's article, 2005
Goldenson and Herbsleb, 1995		Halvorsen and Conradi, 2002*	Thomsett article, 2002
Humphrey, Snyder, & Willis, 1991		Jalote, n.d.	
Esteves, Pastor, and Casanovas, 2002		Kautz and Nielsen, 2004*	
Iverson, Nielsen, and Norberg, 1998		McConnell, 2001	
Kautz & Nielsen, 2004*		Wieggers, 1999	
Paulk, 1999			
Rainer & Hall, in press			
Statz, Oxley, & O'Toole, 1997			
Pourkomeylian, 2000			
Wieggers, 1996b			
Wixom & Watson, 2001			
Stelzer & Mellis, 1999			

5.4 What are the Common Factors Determined by Our Research and Other Organizational Paradigms

Yes, the critical factors suggested by the affinity groups are differ by researcher's organizational paradigms. For example, in natural systems view management was not mentioned while in rational system view study management frequently mentioned. All the Studies mentioned the management factors but rational system focus on the expectation, leadership, while open system highlighted commitment, measurement, expectation. Complex adaptive system does not emphasizes on management; instead its focus was change and self organization. Open system represented many organization factors; CAS view represented the flexibility, communication and partnership. Rational systems view mentioned project and user in organization. All the four organizational paradigms include the process factor.

6. DISSCUSSION

In this paper, we studied different articles relates to the four organizational paradigms. Three organizational paradigms were traditional such as rational systems, open systems and natural systems view and one from chaos theory such as complex adaptive systems view. All the organizational paradigms showed different result while analyzing the critical factors controlling the SPI achievement or disappointment. The real power of SPI in any organization is cost reduction and profitability. These two factors motivate the organizations to produce the

better results and improve their performance. The Chaos theory application complex adaptive system is discussed in our study. It is new field of study and have significant role in the development of the organizations and management.

6.1 Limitation of Our Study

In our study, we cannot determine that whether SPI is different from other organization change effort or not. We cannot determine that by changing the current environment i.e. by changing current processes, how much it will affect the complex product. By our study we are not sure that that whether we can combine SPI literature with other software project literature or organizational change. The critical factors which we identified using organizational paradigms, we do not perform analysis on these factors.

7. CONCLUSION

In our research paper, we have identified different critical factors which are used to determined SPI success. These critical factors are heavily dependent on the organizational paradigms. User influence or project teams which were also investigated in our research are also dependant on organization paradigms. The focus and satisfaction of success factors within same group assorted across different studies from many models of organizations.

7.1 Suggestions for Professionals

Professionals need to be aware of how organization can have big impact on the SPI success or failure. They should understand their organization and their organizational paradigms. (Schein, 1985) says that organizational culture strongly controls the way we tackle the challenges, opportunities and problems. According to chaos theory [2] a little management can control a complex adaptive organization. Manager should defeat the “delusion of management” and should study about the chaos theory and organizations. A little planning can make managers more comfortable with their work and can help them in formal decision-making process to validate their decisions after the information (Thietart & Forgues, 1995).

7.2 Suggestions for Researchers

From our study, it is clear that the success or failure of SPI depends on the organizational paradigms. Researchers need to identify which paradigms they should chose for the SPI research. Literature review is the important approach while making SPI research, it reduces conflicting results and simplify the researchers conclusion. Complex adaptive systems paradigms can be very helpful for researchers and practitioners as it is emerging field and has the capability to reconsider many research areas of SPI research.

7.3 Inquiries for Future Research

How interaction can be made between software processes and organizations regarding CAS? What is the production significance of SPI and prospect of SPI research? Can chaos theory be used as an additional organizational paradigm? Majority of the organizations do not apply rational methods, is this because structural methods have constraints difficult to follow? IS SPI is different from other software process or organizational change efforts? Dose SPI really helps the organizations? Can quality improvement theory to large scale software development? Can SPI review the success of software Development Company such as success or user satisfaction? Should we automate our software processes? Is chaos theory and its complex adaptive system view being a better approach for studying organizations?

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APPENDIX

Occurrence of factors identified by organizational paradigms (clustered and controlled)

Table-A Management

RS (x = 16)	NS (x = 4)	OS (x = 9)	CAS (x = 5)
Management buy-in to SPI(2)	Management economic assurance	Management assurance (4)	Management importance on self association
Management assurance (9)		Management apprehension for dimension	Management importance on joint function, values, principles supervision cares for change
Management potential rational (2)		Management potential rational for time	
Management focal point on production objectives (2)		Management contains software group	
Management guidance (3)		Management short term and long term goals	

Table-B Organization

RS (x = 16)	NS (x = 4)	OS (x = 9)	CAS (x = 5)
Organizations production constraint for revolution	Organization capability for extra work	Organizations approval of structures and size	Organization declaration and response
Organizations production engineering	Organization ability for revolutionize	Organizations change involvement	Organization background of few but important limitations
Organization SPI supporter (3)	Organization approval	Organizations change willingness	Organization fast rate and inventive
Organizations modification conflicts defeat, unfixing (2)	Organization combination between tasks and clusters	Organizations contact prosperity	Organization litheness through agreement
Organizations information transport (2)	Organization improvement (change) willingness	Organizations rivalry from marketplace	Organization corporation
Organization account of change achievement (2)	Organization process rights	Organizations interior capability	Organization personnel's with bright people
Organization record of plan achievement	Organization SEPG collection	Organizations background change	Organization maintenance system cleanness
Organization guidance	Organization SPI proficiency	Organizations background is domestic	
Organizations development direction		Organizations aim to move up the assessment succession	
		Organizations export direction	

Organizations development rights		Organizations development	
Organization development support		Organizations production	
Organization excellence background		Organizations communication	
Organization risk supervision		Organizations directness and familiarity	
Organization SPI expertise		Organizations inner stress for enhancement	
Organizations guidance and counseling		Organizations knowledge creation	
		Organization offshore representation	
		Organization hurting inspiration	
		Organization involvement and commitment (2)	
		Organization investigative center	
		Organization development and invention center	
		Organization SEPG grouping (2)	
		Organizations benefits environment	
		Organizations shareholders participation	
		Organizations delegation importance	

Table-C Process

RS (x = 16)	NS (x = 4)	OS (x = 9)	CAS (x = 5)
Process evaluation success	Process fittingness to business	Process evaluation with a easy scorecard	Process self-motivated expertness
Process configuration with total quality management	Process best performances	Process configuration with business objectives and approach	Process advancement
Process computerization		Process foundation (baseline)	Process response accepting
Process data gathering			Process modeling (2)
			Process affinity

and investigation (2)		Process certification (records)	Process self-compensation
Process distinct by professionals, not external specialist		Process response between projects	
Process center of attention on new plans		Process center on critical needs	
Process enhancement implementation		Process enhancement implementation	
Process metrics		Process storage area of good performances	
Process excellence declaration		Process configuration	
Process quantitative calculation		Process management	
Process sizing to project sizing		Process tackle modified to the groups	
Process strength before computerization			
Process establishment after modification			
Process consistency			
Process correctness to business			
Process adapted to organization (2)			
Process top-down access			

Table-D Project

RS (x = 16)	NS (x = 4)	OS (x = 9)	CAS (x = 5)
Project management	Project requirement and configuration	Project agile techniques	Project advance techniques
Project output definite		Project certification (documents)	Project core on assessment
Project assessment apparatus		Project chain vs. parallelism	Project interdependencies decrease
Project scheduling and trailing			Project task criticality reduce
Project needs supervision			
Project appraisal and assessment			

Project hazard supervision			
Project boundaries administration			
Project plan supervision			
Project values			

Table-E Team

RS (x = 16)	NS (x = 4)	OS (x = 9)	CAS (x = 5)
Team alteration manager		Team common age	Team field awareness
Team change supervision knowledge		Team production direction	Team skill
Team dedication to result		Team cooperation	Team query, knowledge, testing
Team declaration and partnership (2)		Team symphony more engineers than computer analyst	Team size suitable
Team approval Team guidance		Team current understanding	
Team project manager distribution (2)		Team proficiency (2) Team inspiration	
Team project manager success (3)		Team flexibility	
Team assets tolerable (3)		Team corporal effort surroundings	
Team premium (2)		Team project manager contribution in project effort	
Team software production capability (4)		Team practitioner contribution	
Team expertise		Team assets adequate	
Team SPI knowledge (7)		Team responsibility understandable	
Team guidance (3)			

Table-F User

RS (x = 16)	NS (x = 4)	OS (x = 9)	CAS (x=5)
User participation (3)		User participation (2)	
User remained up			

to date			
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Table-G Total of factors

RS (x = 16)	NS (x = 4)	OS (x = 9)	CAS (x = 5)
Organization (15)	Organization (8)	Organization (24)	Organization (7)
Management (5)	Management (1)	Management (5)	Management (3)
Project (10)	Project (1)	Project (3)	Project (4)
Process (17)	Process (2)	Process (11)	Process (6)
Client(user) (2)	Client(user) (0)	Client(user) (1)	Client(user) (0)
Group(team) (14)	Group(team) (0)	Group(team) (13)	Group(team) (6)
Sum (63)	Sum (12)	Sum (57)	Sum (26)
Grand Total = 158			

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