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Samuel D. Z. Bass
BassS@schneider.com

Bruce C. Hungerford

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INSTITUTIONALIZATION OF A SOFTWARE PROCESS INNOVATION IN A LARGE FINANCIAL SERVICES ORGANIZATION: A CASE OF RE-INVENTION OF A REQUIREMENTS INSPECTION PROCESS

Samuel D. Z. Bass
University of Wisconsin Oshkosh
BassS@schneider.com

Bruce C. Hungerford
University of Wisconsin Oshkosh
Bruce.Hungerford@gmail.com

Abstract

Failed software development projects are expensive for society and individual companies. Studies indicate defects in requirements specification are the cause of many of these failures. A large financial services company recently implemented a software requirements inspection process based on the Fagan model with the assistance of the authors. Subsequently, the process was re-invented by users to be less formal, and the organization changed the official process to be consistent with the new process to encourage institutionalization. This change formed a natural experiment. The authors examined inspection documentation under both versions of the process to determine if there were any significant differences in the effectiveness of the versions or their implementation. They found that unplanned implementation effects of the new approach made it impossible to determine whether it was more effective than the original approach. Policy implications are discussed.

Keywords: Diffusion, Software Process Innovation, Deployment, Re-invention, Sustainability, Institutionalization

Introduction

Enormous resources are devoted to software development, with much of the effort being wasted. According to the CHAOS Report (Standish, 1994),

> In the United States, we spend more than $250 billion each year on IT application development…The Standish Group research shows a staggering 31.1% of projects will be canceled before they ever get completed. Further results indicate 52.7% of projects will cost 189% of their original estimates…The lost opportunity costs are not measurable, but could easily be in the trillions of dollars…The Standish Group estimates that in 1995 American companies and government agencies will spend $81 billion for canceled software projects. These same organizations will pay an additional $59 billion for software projects that will be completed, but will exceed their original time estimates.

These results are consistent with earlier and later studies. E.g., a recent study (Hayes, 2004) found that "Only 28% of IT projects succeed these days, down from 34% a year or two ago. Outright failures – IT projects canceled before completion – are up to 18% from 15%. The remaining 51% of IT projects are ‘challenged’ – seriously late, over budget and lacking expected features.”

According to CIO Magazine, “as many as 71 percent of software projects that fail do so because of poor requirements management, making it the single biggest reason for project failure – bigger than bad technology, missed deadlines or change management fiascoes.” (Lindquist, 2005) A Carnegie Mellon Software Engineering Institute study states that “authoritative studies have shown that requirements engineering defects cost 10 to 200 times as much to correct once fielded than if they were detected during requirements development…. The total percentage of project budget due to requirements defects is 25 to 40 percent.” (Mead, n.d.)

While some progress is being made using methodologies that focus on defect prevention rather than defect removal (e.g., “Clean Room” [Carnegie Mellon, n.d.]), development of quality software will require effective methods for software defect identification and removal for the foreseeable future.

Inspection and other Formal Technical Review (FTR) techniques are preferable to testing for software defect identification and removal since they can be implemented early in the development lifecycle, do not require executable code, and are an effective way to improve the development process. For an organization that has not previously inspected requirements, adding such a process represents a significant software process innovation (SPI).

Diffusion research is utilized in this study because it provides insights into the adoption, implementation, and institutionalization processes for innovations, including SPIs. (E.g., Fichman and Kemerer, 1999) This paper examines one aspect of the deployment and institutionalization of an SPI in a large financial services organization.

Theory

In the diffusion literature, institutionalization is a measure of “the degree to which an innovation continues to be used after initial efforts to secure adoption is completed.” (Rogers, 2003) Institutionalization is positively related to “the degree to which an innovation is re-invented (defined … as the degree to which an innovation is modified by adopters as it diffuses) … When an organization’s members change an innovation as they adopt it, they begin to regard it as their own, and are more likely to continue it over time, even when the initial special resources are withdrawn or diminish.” (Rogers, 2003)

Perspectives on re-invention vary. Adopters generally view re-invention positively and may even overemphasize the amount of re-invention implemented. (Rice and Rogers, 1980). Rogers (2003) notes that

> At least some implementation problems are likely to be created by individuals or organizations, so adopters of an innovation almost always attempt to make changes in the original innovation to fit their situation better.
>
> Re-invention can be beneficial to adopters of an innovation. Flexibility in the process of adopting an innovation may reduce mistakes and encourage customization of the innovation to fit it more appropriately to local and/or changing conditions. As a result of re-invention, an innovation may be more appropriate in matching an adopter’s preexisting problems and more responsive to new problems that arise during the innovation-decision process.

To the degree that re-invention encourages institutionalization, it is generally considered to be good.

However, research and development agencies generally view re-invention negatively since it may lead to reduced effectiveness. “Some designers of an innovation structure a new idea so that it is particularly difficult to re-invent … Diffusion agencies may also be unfavorable toward re-invention, feeling that they know best as to the form of the innovation that users should adopt.” (Rogers, 2003)

This research examines the effect of re-invention on the effectiveness of the requirements inspection process at the financial organization studied.

Hypotheses

One would expect any major change (re-invention) in the requirements inspection process methodology would have a significant effect on the effectiveness of that process. We examine two measures of process effectiveness: (1) number of critical or high defects found per page, and (2) the number of process errors. Critical and high defects are utilized because of their generally disproportionate effects on the system; defects *per requirements page* are used to scale for differences in project size. Process errors are defined as defect tracking sheets filled out inconsistently or incorrectly; these errors are considered a (negative) measure of effectiveness since an error with no or an incorrect indication as to its cause, seriousness, etc. is more difficult to allocate resources for than one that is properly specified. Conversations with organization representatives indicated that they expected the change from the formal to the more informal process would be at least neutral in its effects on effectiveness. Stated as nulls, our hypotheses are as follows:

H1: There is no significant difference between the formal and informal reviews in the number of serious (defined as critical or high) defects found per page.

H2: There is no significant difference between the formal and informal reviews in the number of process errors per defect sheet.

Method

Background

In 2003, the first author (then a graduate student in the second author's class) asked the second author for advice in implementing a requirements inspection program at the major financial services company where he then worked. This led to some informal consulting during which the second author made suggestions and critiqued materials developed by the first author. The new requirements inspection program was instituted at the beginning of 2004. The process developed was fairly strict and implemented some of the more formal structures of the Fagan Inspection, such as independent moderators and formal meetings. Internally, the process was simply called the "Formal Review."

At the beginning of 2005, the review process changed. Less emphasis was placed on the formal elements (moderator, documentation, etc.), and process users were allowed to focus on quickly moving through the process vs. keeping the process elements pure. The intent was to address employee feedback that had stated that the more formal elements were not effective and were a waste of time. By this time, the first author had changed employment and the second author was no longer involved.

In mid-2005, the authors contacted the organization looking for a real-world research project. In the ensuing discussions, it was decided that an objective examination of the deployment and institutionalization of the requirements inspection process would be useful to the organization and had the potential to provide data for several studies. (A second, related study is now in process.)

Analysis

Review documentation for five software projects, each with multiple subprojects, was analyzed. For each subproject, we recorded the number of pages and the number of defects in each severity type and class. We also noted the number of process errors found per defect sheet.

Results

Critical and High Defects

Prior to the process change instituted at the beginning of 2005, the requirements inspection process averaged 0.699 serious defects found per page of requirements. After the process change, this number increased 1.149 defects per page. To test the statistical significance of the difference in the means of the two processes, several statistical tests were performed. One of the assumptions for parametric statistics is that the variances for the two samples are equal. The 95% Bonferroni confidence intervals for the formal and informal samples are 0.384, 0.872 and 0.958, 2.767 respectively; since these intervals do not overlap, equal variances cannot be assumed. Two nonparametric tests, Mann-Whitney and Kruskall-Wallis, both showed $p = 1.0$ (adjusted for ties). So, while the means suggest there is a difference in the effectiveness of the two processes in detecting critical and high defects, the difference is not statistically significant and H1 cannot be rejected.

Table 1. Analysis of Serious Defects by Inspection Type

Inspection Type	Subproject	Defect Type		Page Count	Defects / Page	Mean	Std Dev
		Critical	High				
Formal	Formal 01	1	7	37	0.216	*0.699*	*0.537*
	Formal 02			4	0.000		
	Formal 03	5	14	16	1.188		
	Formal 04	1	10	15	0.733		
	Formal 05	9	21	15	2.000		
	Formal 06		10	10	1.000		
	Formal 07	4	12	30	0.533		
	Formal 08	1	4	8	0.625		
	Formal 09		7	12	0.583		
	Formal 10		1	13	0.077		
	Formal 11	2	20	20	1.100		
	Formal 12	1	4	9	0.556		
	Formal 13		4	10	0.400		
	Formal 14		6	17	0.353		
	Formal 15		10	68	0.147		
	Formal 16	1	30	*20*	1.550		
	Formal 17	3	38	*50*	0.820		
Informal	Informal 01	1	2	9	0.333	*1.149*	*1.440*
	Informal 02		2	9	0.222		
	Informal 03	3	5	2	4.000		
	Informal 04	1	7	5	1.600		
	Informal 05		6	*88*	0.068		
	Informal 06		6	87	0.069		
	Informal 07		6	6	1.000		
	Informal 08		3	4	0.750		
	Informal 09	8	57	*17*	3.824		
	Informal 10	3	23	*50*	0.520		
	Informal 11	1	4	*20*	0.250		
	Note: Page counts in *italics* are estimated						

Process Errors

Proper use of defect sheets declined after the new process was put into effect. Under the less formal (2005) requirements inspection process, the percentage of process errors per defect sheet rose from 2.529 per review to 15.182. Since the p-value for Levene's Test for the two distributions is 0.060, parametric statistics are not appropriate. A Mann-Whitney Test indicated the two distributions are not equal at the 0.0030 level (0.0018 adjusted for ties). Hypothesis H2 is therefore rejected.

Table 2. Process Errors by Review Type

Inspection Type	Subproject	Process Errors	Total Errors	Mean / Review	Std Dev
Formal	Formal 01	2	*43*	*2.529*	*8.903*
	Formal 02	0			
	Formal 03	0			
	Formal 04	0			
	Formal 05	0			
	Formal 06	0			
	Formal 07	0			
	Formal 08	0			
	Formal 09	1			
	Formal 10	0			
	Formal 11	1			
	Formal 12	1			
	Formal 13	0			
	Formal 14	37			
	Formal 15	0			
	Formal 16	0			
	Formal 17	1			
Informal	Informal 01	0	*167*	*15.182*	*19.323*
	Informal 02	6			
	Informal 03	0			
	Informal 04	11			
	Informal 05	56			
	Informal 06	17			
	Informal 07	3			
	Informal 08	4			
	Informal 09	6			
	Informal 10	15			
	Informal 11	49			

Discussion and Conclusion

This study shows that re-invention by users of the requirements inspection process may have had mixed effects. Re-invention, while perhaps positive in improving process institutionalization (the subject of another study), had negative consequences for the proper completion of defect sheets and (presumably) in their usefulness in allocating resources for defect correction. Whether the informal process improved serious defect detection effectiveness is unclear, as is the overall effect of the process change.

There are a number of limitations to this study.

The data are such that parametric statistical techniques are not appropriate, and the number of projects/subprojects is too small to allow H1 to be rejected using nonparametric approaches. It is recommended that documentation for additional projects/subprojects be made available by the organization so that more meaningful statistical analysis is possible.

The study examines one set of projects for one organization. While conversations with organization representatives give no reason to believe these projects are atypical, without random sampling, generalization to the organization is problematical. Whether the results can be generalized beyond the organization is even more problematical. These are, of course, usual problems with any case-type research.

If the informal process is actually more effective (as *suggested* by the results) in detecting serious defects, this may be due to greater "buy in" by reviewers. An alternative explanation would be that there were more defects to be found during the informal process period due to other changes in development processes; conversations with organization representatives indicate this explanation is improbable, but it cannot be excluded at this time. As actual defects are found in the various systems studied, it may be possible to calculate defect densities and exclude this possibility. Of course, the apparent change in effectiveness may be a statistical artifact.

Finally, this study should be understood as being the first in what is hoped will be a series of case-type studies using a variety of methods. The second study is currently in process.

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