Technical Report
CMU/SEI-95-TR-008
ESC-TR-95-008

Moving On Up: Data and Experience Doing CMM-Based Process Improvement

Will Hayes
Dave Zubrow

August 1995

Technical Report

CMU/SEI-95-TR-008
ESC-TR-96-008
August 1995

Moving on Up: Data and Experience Doing CMM-Based Process Improvement

Will Hayes
Dave Zubrow

Empirical Methods

Unlimited distribution subject to the copyright.

Software Engineering Institute
Carnegie Mellon University
Pittsburgh, Pennsylvania 15213

This report was prepared for the

SEI Joint Program Office
HQ ESC/AXS
5 Eglin Street
Hanscom AFB, MA 01731-2116

The ideas and findings in this report should not be construed as an official DoD position. It is published in the interest of scientific and technical information exchange.

FOR THE COMMANDER

(signature on file)

Thomas R. Miller, Lt Col, USAF
SEI Joint Program Office

This work is sponsored by the U.S. Department of Defense.

Copyright © 1996 by Carnegie Mellon University.

Permission to reproduce this document and to prepare derivative works from this document for internal use is granted, provided the copyright and “No Warranty” statements are included with all reproductions and derivative works.

Requests for permission to reproduce this document or to prepare derivative works of this document for external and commercial use should be addressed to the SEI Licensing Agent.

NO WARRANTY

THIS CARNEGIE MELLON UNIVERSITY AND SOFTWARE ENGINEERING INSTITUTE MATERIAL IS FURNISHED ON AN “AS-IS” BASIS. CARNEGIE MELLON UNIVERSITY MAKES NO WARRANTIES OF ANY KIND, EITHER EXPRESSED OR IMPLIED, AS TO ANY MATTER INCLUDING, BUT NOT LIMITED TO, WARRANTY OF FITNESS FOR PURPOSE OR MERCHANTIBILITY, EXCLUSIVITY, OR RESULTS OBTAINED FROM USE OF THE MATERIAL. CARNEGIE MELLON UNIVERSITY DOES NOT MAKE ANY WARRANTY OF ANY KIND WITH RESPECT TO FREEDOM FROM PATENT, TRADEMARK, OR COPYRIGHT INFRINGEMENT.

This work was created in the performance of Federal Government Contract Number F19628-95-C-0003 with Carnegie Mellon University for the operation of the Software Engineering Institute, a federally funded research and development center. The Government of the United States has a royalty-free government-purpose license to use, duplicate, or disclose the work, in whole or in part and in any manner, and to have or permit others to do so, for government purposes pursuant to the copyright license under the clause at 52.227-7013.

This document is available through Research Access, Inc., 800 Vinial Street, Pittsburgh, PA 15212.
Phone: 1-800-685-6510. FAX: (412) 321-2994. RAI also maintains a World Wide Web home page. The URL is http://www.rai.com

Copies of this document are available through the National Technical Information Service (NTIS). For information on ordering, please contact NTIS directly: National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161. Phone: (703) 487-4600.

This document is also available through the Defense Technical Information Center (DTIC). DTIC provides access to and transfer of scientific and technical information for DoD personnel, DoD contractors and potential contractors, and other U.S. Government agency personnel and their contractors. To obtain a copy, please contact DTIC directly: Defense Technical Information Center / 8725 John J. Kingman Road / Suite 0944 / Ft. Belvoir, VA 22060-6218. Phone: (703) 767-8222 or 1-800 225-3842.]

Use of any trademarks in this report is not intended in any way to infringe on the rights of the trademark holder.

Table of Contents

List of Figures iii
List of Tables v
Acknowledgments vii

1 Background 1
2 Data Used in the Study 4
3 Time to Move Up a Maturity Level 7
  3.1 Measuring Time to Move Up 8
  3.2 Findings of the Study 8

4 Analysis of Software Process Assessment Findings 11
  4.1 Methodology 11
  4.1.1 Definition of a “Finding” as the Unit of Analysis 11
  4.1.2 Mapping Findings to the CMM 12
  4.1.3 Analytical Approach 12
  4.2 Prevalence of Findings by KPA 13
  4.3 Differences Between Level 1 and Level 2 Organizations 14

5 Conclusions 18
  5.1 Time to Move Up a Maturity Level 18
  5.2 Differences Between Level 1 and Level 2 Organizations 19
  5.3 Future Focus for Research 20

Appendix A A Word About Box Plots 23
Appendix B Reliability Study for Mapping Findings 25
References 27

List of Figures

Figure 1: Key Process Areas of the CMM 1
Figure 2: Year of First Assessment 4
Figure 3: Organization Type... 5
Figure 4: Relative Maturity Profile 6
Figure 5: Group Differences in Time to Move Up 8
Figure 6: Moving From Level 1 to Level 2 Versus Remaining 14
Figure 7: First Assessment Findings for Level 1 Organizations 15
Figure 8: Second Assessment Findings for Level 1 and Level 2 Organizations 16
Figure 9: Second Assessment Findings for Level 1 and Level 2 Organizations 17
Figure 10: Pattern of Maturity Level Changes.. 20

List of Tables

Table 1: Summary Statistics for Time to Move up a Maturity Level 9
Table 2: Comparison to the 1992 Baseline 13

Acknowledgments

We wish to acknowledge the efforts of the many people who made this study possible.

Michael Zuccher, David White, and Bernadette Harris maintain the Process Appraisal Information System. Their diligence allows the SEI to maintain the “safe haven” for industry data, and their patience in helping to construct the large data set used here is much appreciated.

Mark Paulk, Mary Beth Chrissis, Suzanne Garcia and Mike Konrad provided the content expertise we needed to establish a reliable method for analyzing the data. Their efforts and insights are gratefully acknowledged.

Two of our reviewers: Steve Masters and Dennis Goldenson, helped us to make significant improvements to earlier drafts of this report. Credit for the value added is due to them. Any remaining oversights should be attributed to the authors.

Finally, to the 48 un-named organizations whose data made this report possible, we extend our most heartfelt gratitude. Their trust in the SEI, and willingness to share proprietary information for the good of the software industry is much appreciated.

Moving On Up: Data and Experience Doing CMM-Based Software Process Improvement

Abstract: An analysis of Software Process Assessment results from 48 organizations undertaking 2 or more assessments is presented in this report. The analysis focuses on the time required to increase process maturity, as well as the most prevalent process issues faced by the 48 organizations. Results of the analysis are used to provide guidance to organizations embarking on a software process improvement effort.

1 Background

Ever since the late 1980s, software organizations have been striving to improve their software process maturity as a way to improve productivity and quality. The Capability Maturity Model^{SM} for software (CMM^{SM}) defines the relationship between software process maturity and software project performance [Paulk 93a] [Paulk 93b]. In general, software process maturity serves as an indicator of the likely range of cost, schedule and quality results to be achieved by projects within a software organization. Specifically, the CMM defines 5 levels of process maturity that represent distinct plateaus of organizational performance.

[SM] CMM and Capability Maturity Model are service marks of Carnegie Mellon University.

To achieve these levels of software process maturity, organizations must overcome a series of challenges by addressing sets of Key Process Areas (KPAs). The KPAs at each level together provide a capability within the organization to realize the improvements in performance characteristic of the specific maturity level. The KPAs of the CMM are depicted in Figure 1 below.

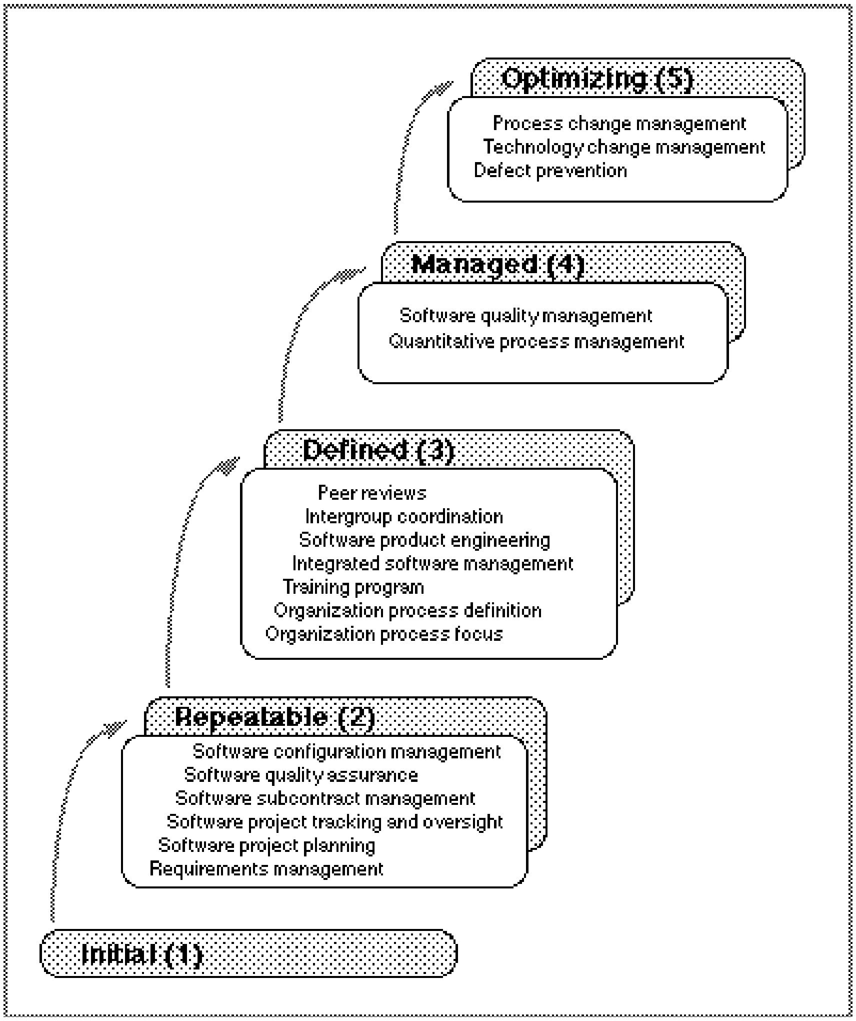

Optimizing (5)
Process change management
Technology change management
Defect prevention
Managed (4)
Software quality management
Quantitative process management
Defined (3)
Peer reviews
Intergroup coordination
Software product engineering
Integrated software management
Training program
Organization process definition
Organization process focus
Repeatable (2)
Software configuration management
Software quality assurance
Software subcontract management
Software project tracking and oversight
Software project planning
Requirements management
Initial (1)

Figure 1 Key Process Areas of the CMM

To assist organizations in their efforts to improve their software process maturity, the SEI developed a diagnostic method that allows organizations to assess their own software process maturity (or have an assessment conducted by a third party). The method[1] identifies strengths and weaknesses in an organization's software process relative to the KPAs of the CMM. The resulting pattern of process strengths and weaknesses determines an organizations level of software process maturity [Humphrey 87a] [Humphrey 87b] [Humphrey 87c] [CBA Project 95].

---

[1] The original assessment method, Software Process Assessment (SPA) was developed prior to the release of the CMM. The SPA method has now been replaced by the new CMM Based Appraisal for Internal Process Improvement (CBA IPI). The original assessment method was based on [Humphrey 87c], and the CBA IPI is based on CMM v1.1.

The software community has been using SEI-developed methodology to improve their software process. As organizations have taken actions and made changes to improve, they have asked the SEI a variety of questions regarding the value of improving software process maturity. These include: What is the return on investment from CMM-based software process improvement? What have been the lessons learned by organizations that have improved? and How long does it take to improve? Previous work by the SEI has addressed some of these questions. Herbsleb et al reported on the return on investment for CMM-based software process improvement and included 5 case studies from organizations that have made improvements in their software processes [Herbsleb 94]. Kitson and Masters described the types of process issues detected by organizations beginning their initiatives with CMM-based software process improvement [Kitson 92]. Finally, the SEI publishes periodic updates of the Community Maturity Profile which shows the distribution of software organizations across the 5 maturity levels of the CMM.[2]

In this report, we investigate the experiences of organizations following the CMM as a model for software process improvement (SPI). Specifically, we address the following questions:

- how long does it take for an organization to move up a maturity level?
- what are the process challenges that distinguish those who move from the initial level (level 1) to the repeatable level (level 2) and those who remain at the initial level?

---

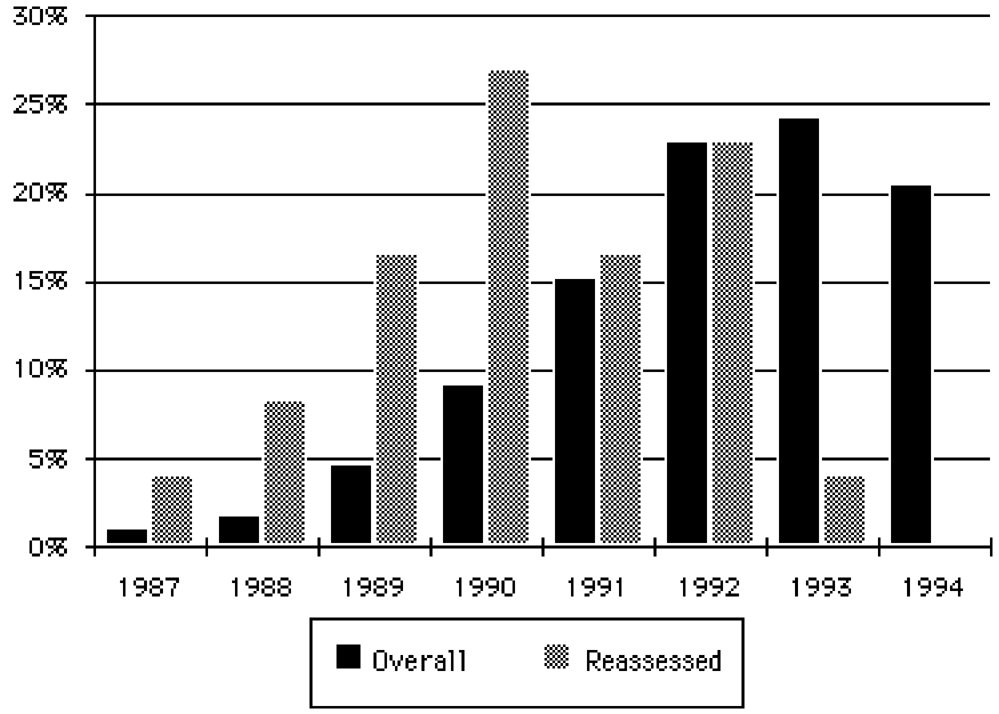
[2] As of this writing, the latest update from April 1995 reports on 379 organizations.

2 Data Used in the Study

Since the SEI developed the SPA method in 1987, it has been collecting assessment results from organizations using the method. The results include the maturity level of the organization, the identified process strengths and weaknesses, the organizational scope of the assessment, and the date the assessment was conducted. To address the questions posed above, we focused on organizations that have undergone multiple assessments. This allowed us to investigate the experiences and changes in individual organizations. From the database housing the assessment results, we extracted the data for 48 organizations that had conducted 2 or more assessments. In fact, as a group these organizations have conducted 104 assessments.

In order to understand whether this set of organizations was similar to the overall software community using CMM-based SPI, we compared it to the overall community on a few dimensions. We compared these reassessed organizations with the overall community in terms of time involved with CMM-based software process improvement, type of organization, and maturity level profile.

The year of first assessment can be taken as an indication of when the organization began its CMM-based software process improvement effort. Figure 2 shows the year in which these (reassessed) organizations did their first assessment compared to the overall community. (note: the reassessed organizations are included in the figures for “overall”).



379 o
48 or

Figure 2 Year of First Assessment

In general, the organizations in this study started their SPI efforts earlier than the organizations in the overall community. For instance, approximately 73% of the reassessed organizations began their SPI efforts in 1991 or earlier compared to approximately 32% in the overall community.

Figure 3 shows the types of organizations included in this study compared to the overall community.

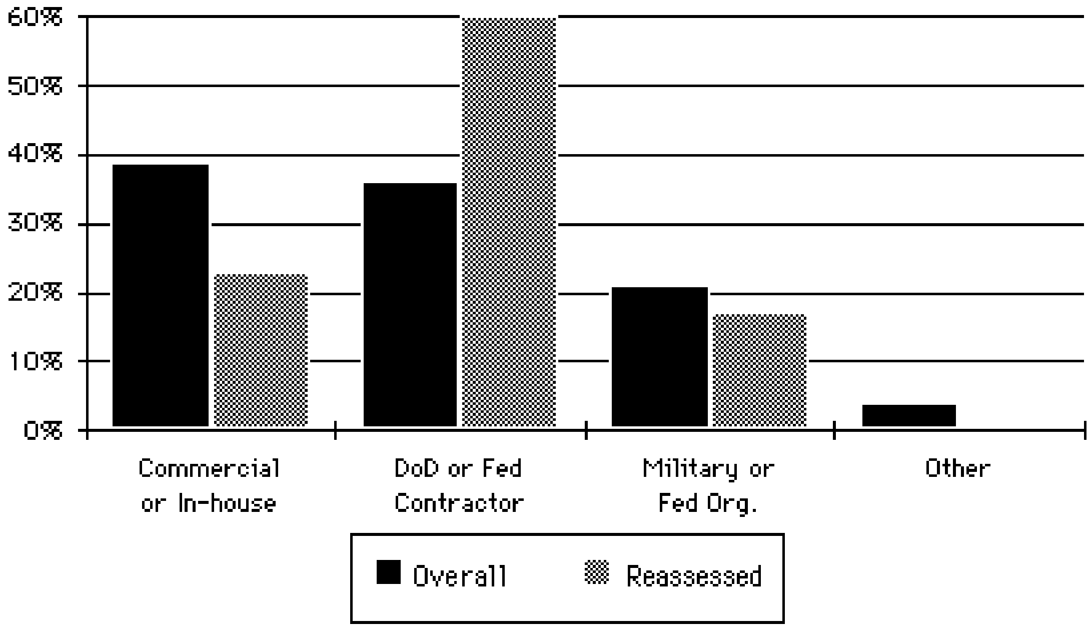


Figure 3 Organization Type

Consistent with the early applications of the CMM and SPA, a majority of the organizations are DoD and federal government contractors. However, since the original development and applications of the CMM and SPA, more commercial and in-house software organizations have initiated programs for CMM-based SPI.

Finally, Figure 4 shows that these organizations have achieved a higher maturity profile distribution than that of the overall community.

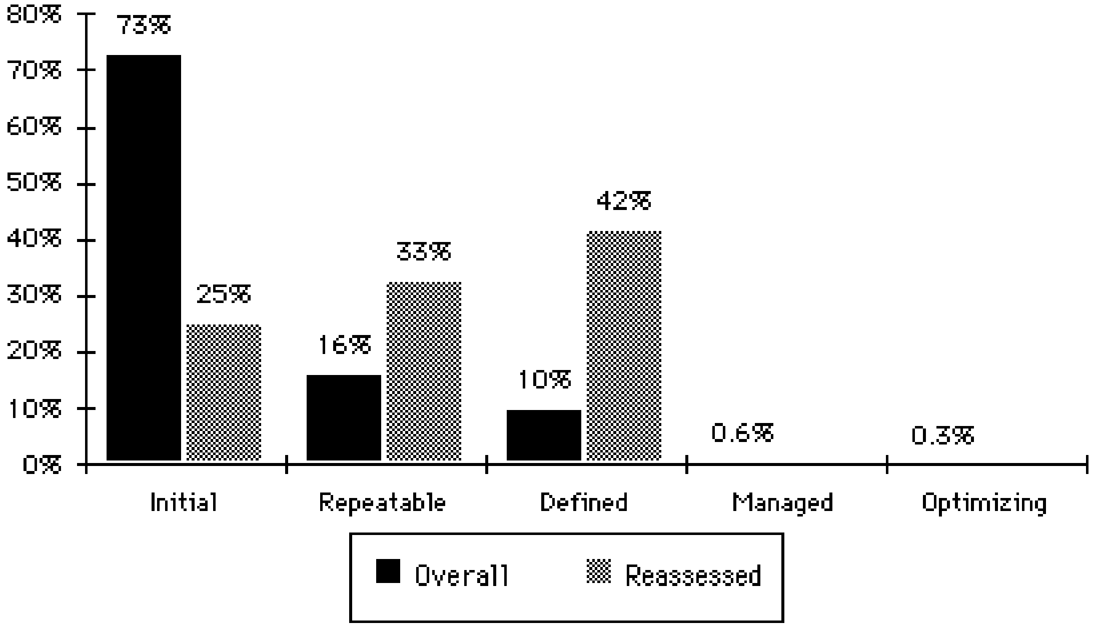


Figure 4 Relative Maturity Profile

For instance, 42% of the organizations that have been reassessed have achieved the Defined Level of process maturity (level 3) as of the most recent assessment, while only 10% of the overall community have reached the Defined Level. Similarly, 73% of the overall community is at the Initial Level while only 25% of the reassessed organizations are currently at the Initial Level.

In summary, the reassessed organizations differ from the overall software community. As a group, they adopted CMM-based SPI earlier, tend to include relatively more DoD and federal government contractors, and have progressed to a relatively higher software process maturity profile. In the following sections of the report, we analyze a subset of these reassessed organizations to answer some of the questions posed by those organizations involved with and considering the adoption of CMM-based SPI.

3 Time to Move Up a Maturity Level

This part of the study was motivated by the customer-expressed need to have credible information about how long it takes for CMM-based SPI to have a noticeable impact on organizations. The most prevalent “conventional wisdom” has been that it takes 18 to 30 months to improve a full maturity level but depending on the situation it could take much longer than this. The purpose of this analysis is to supplement conventional wisdom with empirical data. The uses for such data include

- developing feasible SPI plans
- setting sponsor expectations
- setting expectations among the staff participating in a SPI effort

In order to plan process improvement activities, it is important to understand how long it will take for noticeable differences to appear. Estimates for time required to achieve the next maturity level have been based on the judgment and experience of the decision maker. Furthermore, in a recent survey by Goldenson and Herbsleb, 86% of the process improvement champions surveyed agreed with the statement “process improvement is taking longer than we expected” [Goldenson 95].

Setting and maintaining the sponsorship of management has been recognized as an important contributor to the success of SPI programs [Humphrey 87a] [Daskalantonakis 94]. For senior managers, the level number has historically been the most widely recognized indicator. When goals like “Level 5 in ‘95” are set by senior managers, process improvement champions sometimes lack substantive information with which to suggest more feasible targets.

While management sponsorship is vital, the ‘buy-in’ of technical staff is also crucial.[3] The synergy developed during the assessment process is just as important as the sponsorship discussed above. Setting unrealistic expectations for the technical staff can squelch their motivation and create a backlash of cynicism that will be counterproductive in the end. Champions of SPI programs will benefit from providing technical staff with credible information about anticipated progress.

To summarize, our goal in this section of the study is to report on the experience of early adopters of the CMM in order to provide input for better planning and to set expectations of management and practitioners alike.

---

[3] Sudlow, Bill, *From Chaos to SEI Level 2 in 18 Months,* Unpublished white paper, 1994.

3.1 Measuring Time to Move Up

Change in an organization's process maturity is a gradual transition. We would be hard pressed to identify a specific event or moment associated with an organization changing from level X to level X+1. But, for the purpose of this study, we use the day an assessment ends as the milestone. Thus, the conclusion of an organization's first assessment is taken to be the time when CMM-based SPI began, and the conclusion of a subsequent assessment where the organization's maturity level increased is taken as the milestone for an increase in the maturity level. This decision seems reasonable because the maturity level of an organization is not known until it is measured, and the final findings presentation is where this measurement is first reported.

3.2 Findings of the Study

On average, organizations moving from level 1 to level 2 did so in approximately 30 months (between the first assessment that found them at level 1 and the subsequent assessment that found them to be at level 2). Organizations moving from level 2 to level 3, on the other hand, did so with an average of 25 months. However, the averages fail to reveal interesting and important information found in the distributions of times to change a maturity level.

Figure 5 is a graphical depiction called a "box plot," which is used to show the distribution of number of months to move up a maturity level for the two groups. Please refer to Appendix A for a brief review of how to read the box plot.

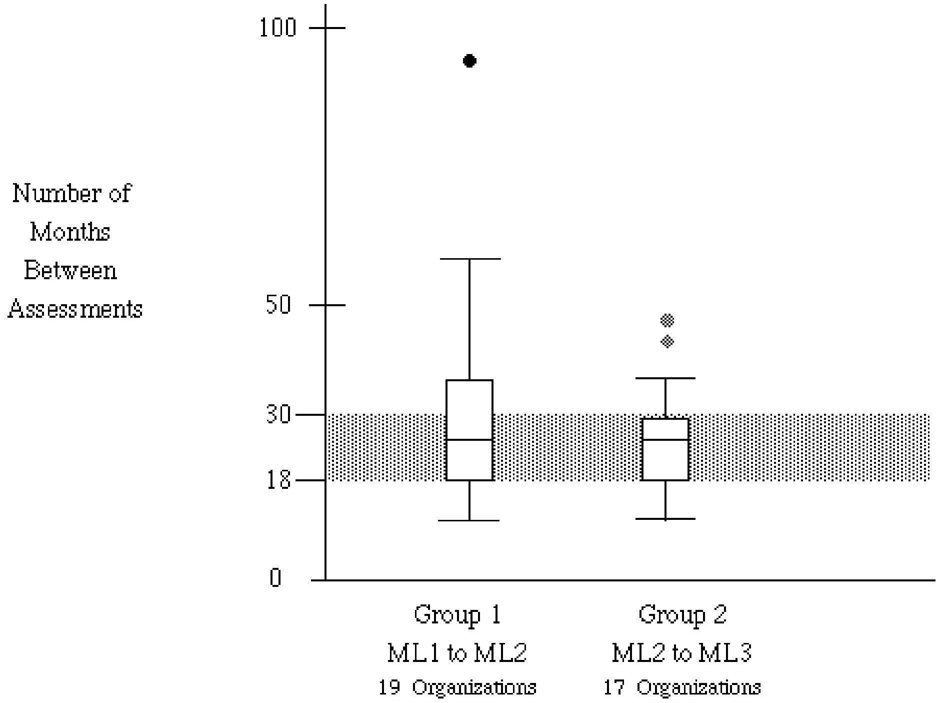


Figure 5 Group Differences in Time to Move Up

The “box plots” shown above represent the distribution of number of months between assessments for the two groups shown on the horizontal axis. The grey horizontal ban represents the conventional wisdom of 18 to 30 months.

We can see from Figure 5 that the conventional wisdom is consistent with the experience of many of the organizations in this study. Among the organizations moving from level 1 to level 2 (group 1), 37% of them did so within the 18 to 30 month interval. Among organizations moving from level 2 to level 3 (group 2), fully 50% of them did so within the 18 to 30 month interval.

However, this reflects the experience of a minority of organizations studied here. Among the organizations in group 1, nearly 25% of them moved to level 2 in less than 18 months. In addition, many organizations in this group took significantly longer than 30 months to reach level 2. Table 1 (below) presents some summary statistics for the data reflected in Figure 5. As illustrated in Table 1, 25% of this group took more than 35 months to reach level 2, with the most extreme case being 94 months.[4] The distribution of times for group 2 is not as wide as group 1, but approximately 50% of organizations in this group moved to level 3 in more or less than the interval reflecting conventional wisdom (with 25% moving faster, and 25% moving slower).

As reported earlier, the average number of months for these two groups differs by 5 months. However, the median number of months for the groups is equal (approximately 25 months). It is apparent that the differences in the means are due to the fact that many more organizations moving from level 1 to level 2 took longer to do so than their ‘higher maturity’ counterparts.

Table 1 Summary Statistics for Time to Move up a Maturity Level

Statistic	Group 1	Group 2
Extreme Values or Outliers	94 months	48 months
Largest Non-outlier Value	58 months	36 months
75th Percentile	35 months	28 months
Mean	30 months	25 months
Median	25 months	25 months
25th Percentile	19 months	18 months
Smallest Value	11 months	12 months

---

[4] For clarification, the 75th percentile is the point on the distribution that divides the upper 25% and the lower 75% of the organizations.

The most important finding of this particular analysis is that there is much more variability in the amount of time organizations take to move from level 1 to level 2 than there is in the time it takes to move from level 2 to level 3. Organizations planning their SPI programs will do well to keep this in mind as they set their goals. The change from level 1 to level 2 has the potential to take much longer than the conventional wisdom of “18 to 30 months.” Based on the experience of the 19 organizations studied here, 1 in 4 organizations that move from level 1 to level 2 will take 3 years or more to do so. Fully half of the organizations studied here took more than 2 years to move up a maturity level, regardless of which level they were moving to. Finally, the wide variation in time to move up a maturity level suggests other factors should be considered and that predicting the time it takes to improve an organization is complex.

It would seem reasonable to conclude that the experience of moving from level 1 to level 2 has an impact when the organization continues its progress by reaching level 3. The foundation for improvement, and lessons learned, from the first transition to the repeatable level may very well contribute to attaining the defined level more quickly.

4 Analysis of Software Process Assessment Findings

The first SEI analysis of assessment findings was published by Kitson and Masters in 1992 [Kitson 92]. These authors summarized the findings from 59 early applications of the SPA method. Kitson and Masters, in the abstract of their technical report, describe their study in the following way:

> *It characterizes the software processes used by software managers and practitioners at the assessed sites and classifies issues identified during the assessments. The basis for the characterization and classification is a software process maturity model developed by the SEI.*

Now that the practice of Software Process Assessments, and the prevalence of CMM-based SPI has expanded considerably, the SEI has a larger pool of data upon which to draw. This enables additional analyses and the pursuit of more detailed research questions than was possible in 1992 when Kitson and Masters published their report. In the analysis presented below we will add to the information reported by Kitson and Masters, and focus on a comparison of organizations moving from level 1 to level 2 versus organizations remaining at level 1 for two successive assessments.

4.1 Methodology

This section of the report describes the methodology employed in the study. It covers how the assessment results were coded for analysis and the analytical approach used to produce the results.

4.1.1 Definition of a “Finding” as the Unit of Analysis

This study focuses on findings from software process assessments. The definition below was taken directly from the Lead Assessor’s Guide for CBA IPI:

> *finding — An observation or collection of observations that have been accepted by the team as valid. A finding includes strengths, weaknesses, evidence of alternative practices, and evidence of non-applicable practices. A set of findings should be accurate, corroborated, and consistent within itself [Masters 95].*

The word “finding” is usually assumed to include strengths and weaknesses that are presented in the final presentation at the conclusion of an assessment. For the purpose of this study, we examined only those findings identified as weaknesses (or areas where process improvement was deemed necessary), any reference to “finding” in this report should be interpreted as “process weakness.”

Based on this definition for the unit of analysis employed in this study, we were forced to exclude one of the 48 reassessed organizations from the remainder of the study.[5]

4.1.2 Mapping Findings to the CMM

The lion's share of the effort for this study was devoted to coding the CMM content identified in the 1485 findings under consideration. Our experience, and the experience of Kitson and Masters, told us that mapping findings to the CMM would not be a simple task. In order to identify issues and propose remedies for them, we conducted a reliability study of the mapping process. A description of the reliability study and our conclusions are presented in Appendix B. In the end, each finding was identified with respect to which KPA the finding addressed. In a small number of cases (29), a single finding was mapped to two KPAs.

4.1.3 Analytical Approach

We decided to analyze the data by identifying the presence or absence of findings related to specific KPAs, rather than counting the number of findings associated with each KPA for each organization in the data set. In our early analyses, we discovered that there were significant differences between assessments with respect to how many findings they reported. The number of findings per assessment ranged from 2 to 87 in our sample.

While we would expect that within a given organization (using comparable assessment teams) variation in the number of findings would indicate variation in the number of significant process weaknesses, this is not likely to be true across organizations (and more importantly, across assessors). The grouping of process weaknesses (or the listing of more specific weaknesses by themselves) is determined by a trained team that has the goal of helping the organization to look objectively at their process and improve it. One assessment team might elect to group many detailed findings together into a single statement, while another assessment team might choose to present a 'laundry-list' of findings. These decisions made by the assessment team are based on their understanding of the needs of the organization, and how they expect the audience to respond at the final findings presentation.

For these reasons, we decided to examine the presence or absence of findings mapped to each KPA, rather than counting the number of findings in each KPA for each assessment. As a result, when multiple findings address the same KPA, the occurrence of that KPA in the findings is counted only once for that set of findings. The percentages we report reflect percentages of organizations with one or more finding in each KPA, not the percentage of findings associated with each KPA.

---

[5] This organization had conducted three assessments, and their data were used in the analysis for time to move up a maturity level. The rest of their data were excluded from the remaining analyses because none of the findings reported could be construed as "process weaknesses" without substantial inferences on our part. The findings of these three assessments could best be described as "proposed solutions" rather than "process strengths" or "process weaknesses."

4.2 Prevalence of Findings by KPA

In this part of the report we present a brief comparison of our findings with those reported by Kitson and Masters [Kitson 92]. In general, the prevalence of issues associated with KPAs has not changed significantly since the Kitson and Masters report. The table below shows how the KPAs were rank-ordered in terms of prevalence in both studies. The lower ranks imply that more organizations had one or more finding in the associated KPA. Higher ranks imply the opposite — that fewer organizations reported weaknesses associated with the KPA. Therefore, we can see from the table that the most frequently occurring KPA in the findings of organizations included in both studies is Software Product Engineering (SPE). Conversely, the least frequently occurring KPA in both studies is Process Change Management (PCM).

Table 2 Comparison to the 1992 Baseline

Kitson & Masters				Hayes & Zubrow			
Rank	KPA	**Rank**	KPA	**Rank**	KPA	**Rank**	KPA
1	SPE	**10**	SCM	**1**	SPE	**10**	RM
2	SPP	**11**	ISM	**2**	SPP	**11**	ISM
3	OPD	**12**	QPM	**3**	TP	**12**	PR
4	SPTO	**13**	TCM	**4**	SPTO	**13**	TCM
5	TP	**14**	PR	**5**	OPD	**14**	QPM
6	IC	**15**	SQM	**6**	SQA	**15**	SQM
7	OPF	**16**	SSM	**7**	IC	**16**	SSM
8	SQA	**17**	DP	**8**	SCM	**17**	DP
9	RM	**18**	PCM	**9**	OPF	**18**	PCM

Of the 18 key process areas in the CMM, 9 of them received the exact same ranking in the table above, while 7 differed by one rank, and only 2 differed by two ranks across both studies.

4.3 Differences Between Level 1 and Level 2 Organizations

As depicted below in Figure 6, this section of the report focuses on 29 of the 47 organizations in the sample. Of these 29 organizations (that were all assessed at level 1 on their first assessment), 18 were assessed at level 2 on their second assessment while 11 were assessed at level 1 for a second time. In order to characterize the differences between level 1 and level 2 organizations, we compare these two subsets of organizations.

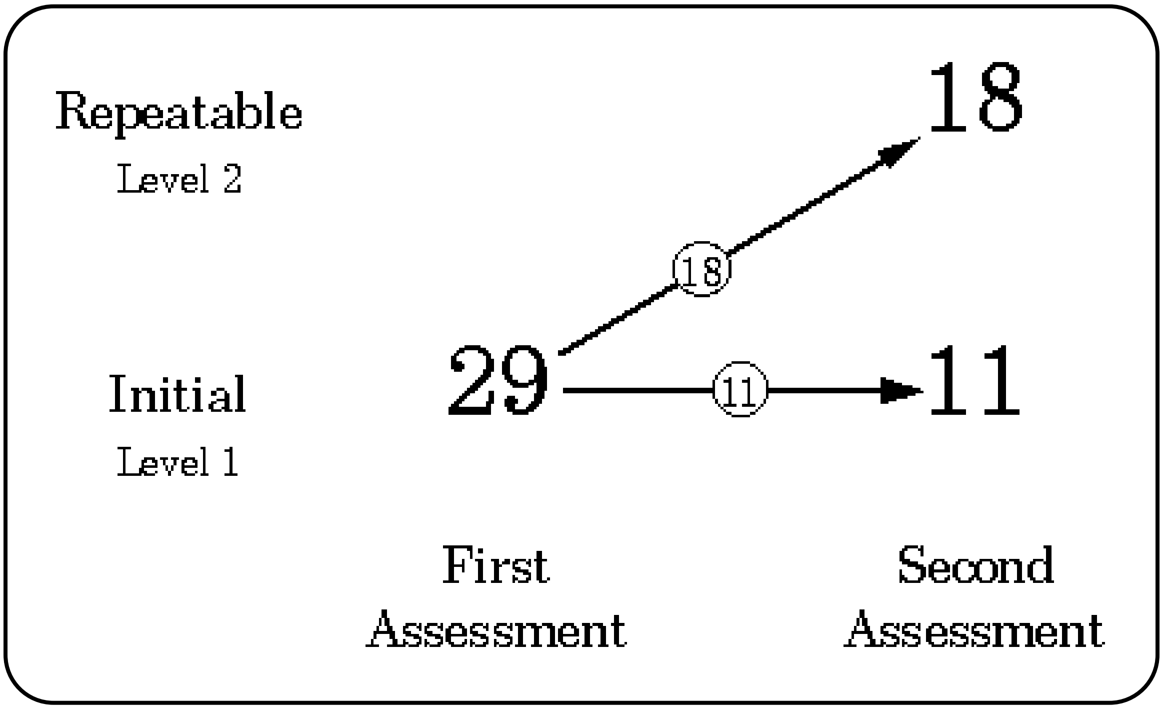


Figure 6 Moving From Level 1 to Level 2 Versus Remaining

By looking at assessment findings from these two sets of organizations, we hope to shed light on what process weaknesses most clearly distinguish organizations at level 2 from their level 1 counterparts. Knowledge about prevalent software process weaknesses allows organizations to take more effective actions to address SPI issues. Knowing that some areas are likely to be more difficult to address than others enables organizations to focus effort where it is most needed and be alert to those KPAs that have proved to be persistently difficult for others.

We started this analysis with a comparison of those organizations that moved to level 2 with those organizations remaining at level 1 in terms of the prevalence of level 2 findings on the first assessment. The figure below shows the percentage of organizations in each group with one or more finding in each of the level 2 KPAs on their first assessment.

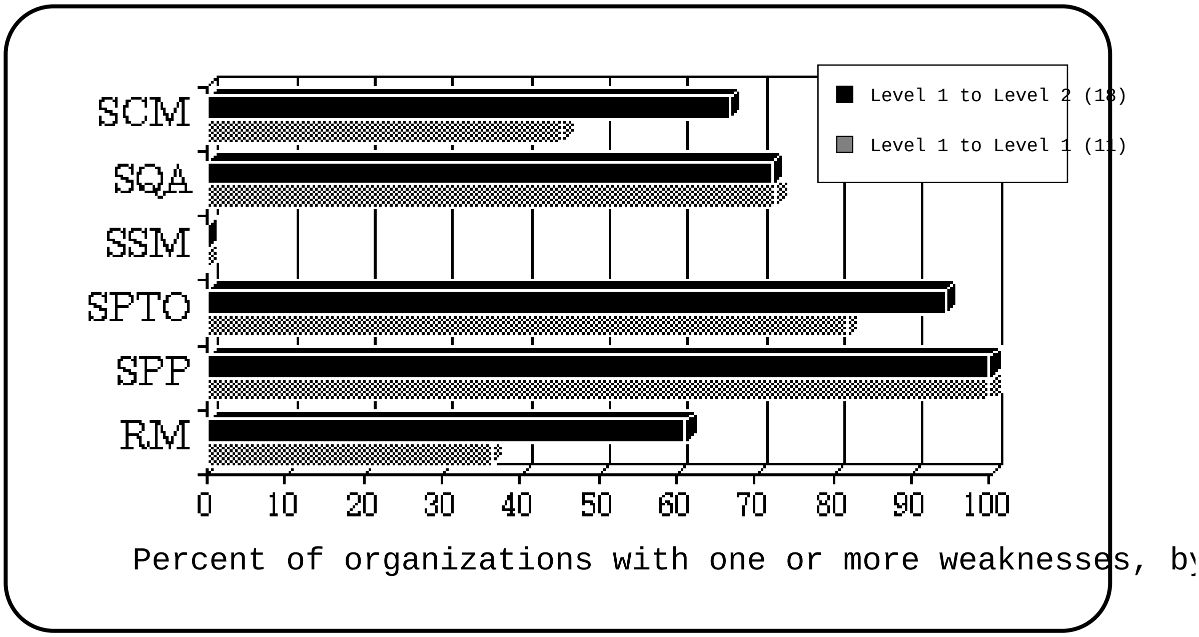


Figure 7 First Assessment Findings for Level 1 Organizations

Several patterns of interest can be seen in the figure above. First, all 29 organizations had one or more weakness in Software Project Planning (SPP), and over 80% had findings in Software Project Tracking and Oversight (SPTO). Second, among organizations that moved to level 2 on the next assessment, Requirements Management (RM) and Software Configuration Management (SCM) findings were more prevalent.

While the lack of statistical significance for these differences prevents us from making reasonable generalizations, the trends may suggest that the two “project management-related” KPAs at level 2 present a similar level of difficulty for process improvement, while the others differ in their level of difficulty. Our conjecture is that SCM and SQA can be thought of as “support functions” and RM as “managing the customer input.” This will be addressed further in the discussion that follows.

Next, we examined the differences between these two groups of organizations with respect to prevalence of level 2 KPA findings on the second assessment.

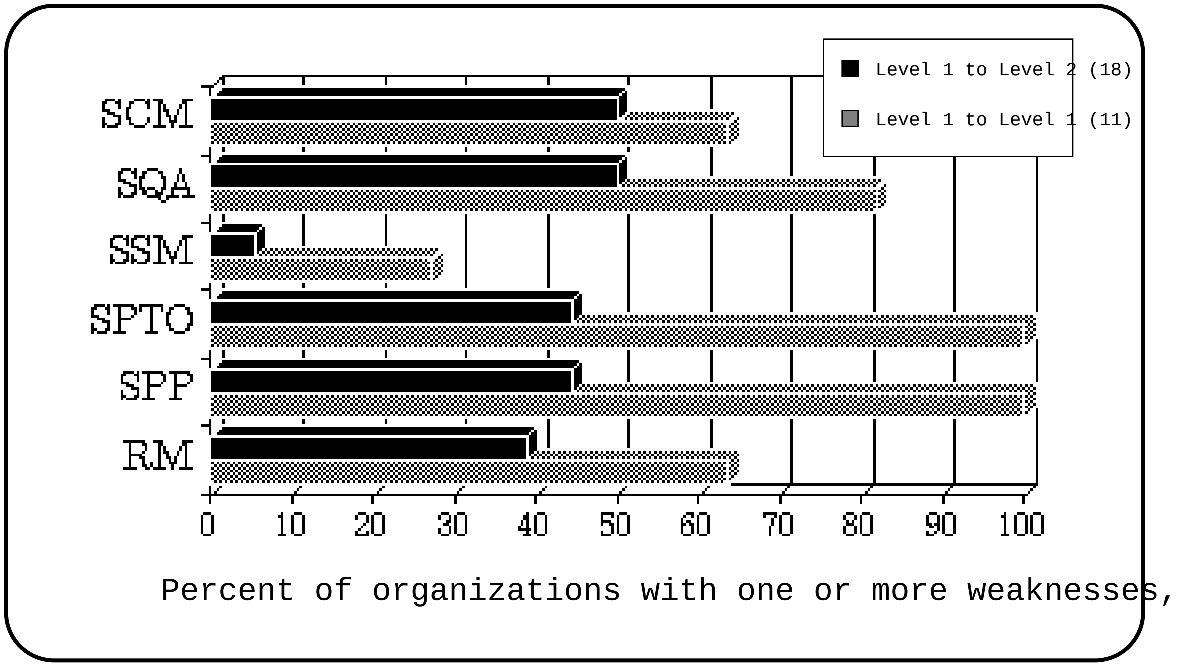


Figure 8 Second Assessment Findings for Level 1 and Level 2 Organizations

The contrast between the two groups is quite stark in the figure above. We see that 100% of the organizations assessed at level 1 on the second assessment had one or more finding in both Software Project Planning (SPP) as well as Software Project Tracking and Oversight (SPTO). Among organizations that moved to level 2 on their second assessment, on the other hand, the prevalence of SPP and SPTO weaknesses is significantly lower. While differences in prevalence of findings in each level 2 KPA exist for these two groups of organizations, the largest differences are found in SPP and SPTO, followed by Software Quality Assurance (SQA).

Note that the prevalence of the non- “project management-related” KPAs among organizations that remained at level 1 is now increased as well. If our conjecture about the grouping of level 2 KPAs is correct, the project management KPAs are the most difficult, followed by the support functions, and finally managing customer input. The data shown in Figure 8 support the hypothesis that SPP and SPTO are much more difficult than any other level 2 KPAs, but the trends associated with the other level 2 KPAs is not sufficient for a conclusive study of this hypothesis.

Finally, the prevalence of findings in level 3 KPAs for these two groups is compared in the figure below.

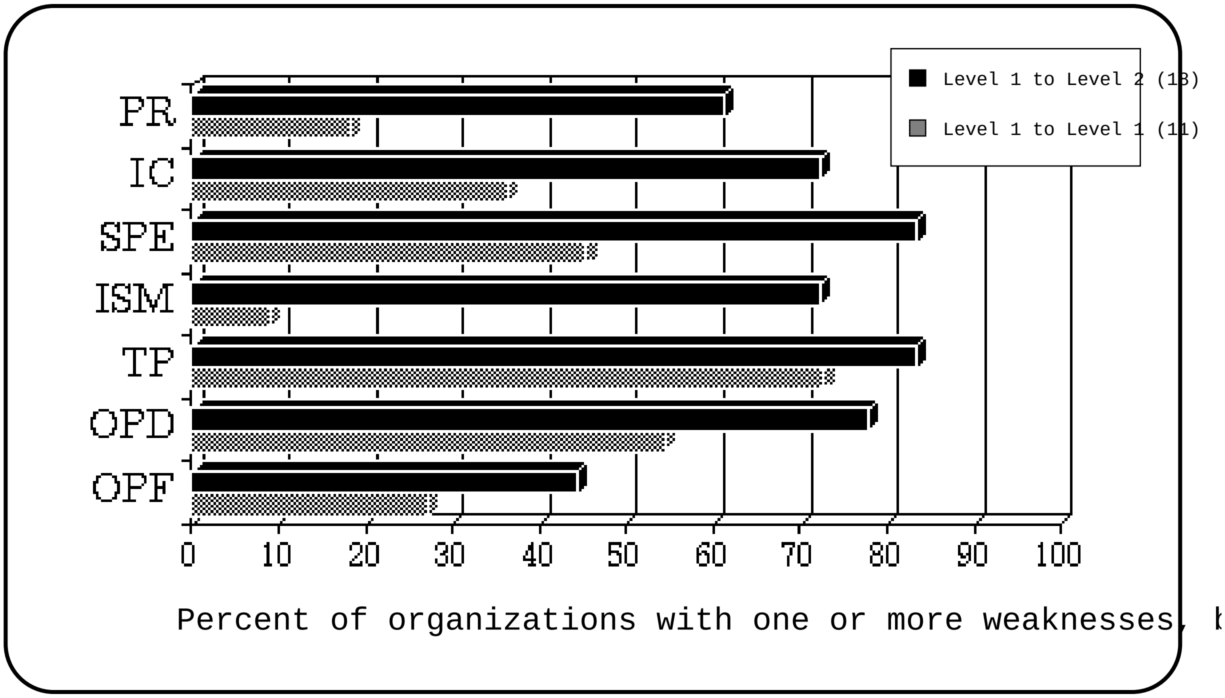


Figure 9 Second Assessment Findings for Level 1 and Level 2 Organizations

The most notable difference between these two groups of organizations (with respect to level 3 findings) can be seen in the prevalence of findings associated with Integrated Software Management (ISM). Less than 10% of the organizations remaining at level 1 on the second assessment reported findings in ISM, whereas over 70% of the organizations that reached level 2 reported findings in this KPA.

ISM is often described as the level 3 version of the level 2 project management KPAs. The data shown in Figure 9 support the theory that organizations at level 1 are focusing on the level 2 project management issues, whereas level 2 organizations are moving into the “higher maturity project management issues.” In addition, we know that much of ISM focuses on the project’s tailoring of the organization’s standard software process, and level 2 organizations are much more likely to be focusing on organization-wide processes than their level 1 counterparts.

Finally, it is interesting to note that the prevalence of findings associated with the Training Program KPA (TP) is high for both subsets depicted above. In fact, Kitson and Masters reported that 73% of the organizations they studied had reported findings in TP. In this study, this figure was 71%. Thus it seems that TP is viewed as an important KPA to focus on regardless of the maturity level of the organization.

5 Conclusions

This final section of the report summarizes the practical lessons to be learned from this study. Interpretations of the results section are presented here for the reader to apply in their CMM-based SPI efforts.

5.1 Time to Move Up a Maturity Level

The experience of early adopters of CMM-based SPI (and assessments) suggest that it takes less time, on average, to move from level 2 to level 3 than it does to move from level 1 to level 2. The data summarized in Figure 5 show that this difference in average time to move up is due mainly to the great variability in the amount of time organizations have taken to move from level 1 to level 2. We do not know at this time whether such marked differences will be observed when we compare these organizations with organizations moving to level 4 or 5.

Improving process maturity by an entire maturity level in less than 18 months is a fairly difficult task. For the two groups studied here, approximately 1 in 4 organizations were able to accomplish this transition in less than 18 months. These conclusions are limited to levels 2 and 3 at this time. When sufficient data from organizations moving to levels 4 and 5 are available we may find that moving to these higher maturity levels happens faster as a result of the foundation provided by the SPI experience at lower levels.

Based on the median time to move up a maturity level for this sample, SPI champions and participants should not be concerned about taking more than 25 months to increase a full maturity level. Fully half of the early adopters studied here took more than 25 months to increase their process maturity by a full level.

Published sources of information regarding the time it takes to improve a maturity level support the findings of this study. Published reports include organizations moving to level 2 in 1 year for Motorola's Cellular Infrastructure Group [Daskalantonakis 94], 18 months for Procase Corporation,[6] approximately 2 years for Motorola's Transmission Products [Johonson 94] and approximately 3 years for the Oklahoma City Air Logistics Center, which was clearly a successful SPI effort [Herbsleb 94].

Published reports of organizations moving to level 3 include: Ratheon, who report moving from level 1 to level 3 in approximately 4 years [Baatz 95]; Grumman Data, who reported moving to level 3 in a little over 2 years (ostensibly starting at level 1) [Nidiffer 95]; Hughes Aircraft: Software Engineering Division, who reported moving from level 2 to level 3 in approximately 3 years [Humphrey 91].

---

[6] Sudlow, 1994.

5.2 Differences Between Level 1 and Level 2 Organizations

The most obvious difference between level 1 and level 2 companies with respect to KPA-related weaknesses is seen in Figure 8. The prevalence of Software Project Planning and Software Project Tracking and Oversight in the process weaknesses of organizations is the most notable distinction between level 1 organizations and level 2 organizations. This observation is very consistent with the basic description of level 2 as “focusing on getting project management under control.”

Several published case studies of software process improvement also point to the importance of project management. The findings of this study amplify some of the conclusions reached by authors of these case studies [Johnson 94]. In a 1994 survey by KPMG Management Consulting, respondents considering their experience with ‘runaway projects’ sited better project management as the key to preventing the problem [*Computer Weekly 95*]. Finally, the vital role of project management in software process was summarized by Russell H. Dewey in the following way:

> *Though languages and tools are important, the most important software productivity and quality improvements today are management, not technology, driven [Dewey 88].*

5.3 Future Focus for Research

The figure below shows the pattern of changes in maturity level for the set of organizations studied here. There are many interesting patterns of change in maturity level reflected in this figure, of which we chose to study a small part.

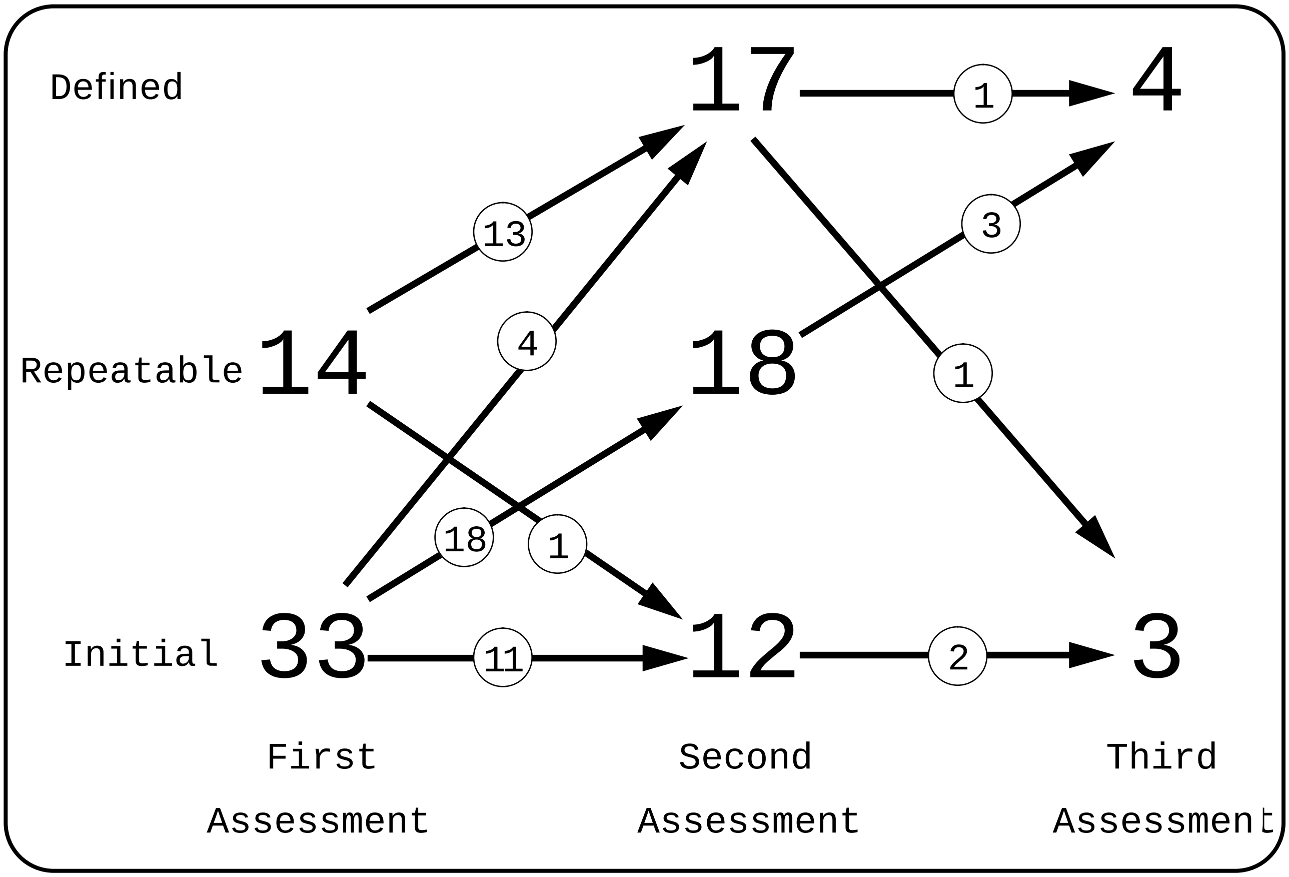


Figure 10 Pattern of Maturity Level Changes

The contrast between moving from level 1 to level 2 and staying at level 1 afforded us the most data for analysis. A similar contrast between organizations moving from level 2 to level 3 and organizations remaining at level 2 was not possible given the pattern above. In addition, the data available to date do not permit analysis of organizations at levels 4 and 5. There are 2 organizations that reported decreases in their maturity level. Given this small sample size, we are unable to make meaningful generalizations about what process weaknesses are associated with this decline.

The incidence of organizations “skipping” maturity levels is also of interest in the figure above. Four of the organizations in the sample moved from level 1 to level 3. One of these organizations, in fact, moved back to level 1 on their third assessment. As more data become available, we may be able to gain valuable insights about how some organizations seem to make such drastic improvements in maturity level. The organizational characteristics associated with fast or slow progress are of interest to many of our customer organizations. Questions like “what is the impact of the size of the organization?” or “how do people and technology contribute to process improvement success?” are two examples we have heard verbalized by SEI customers.

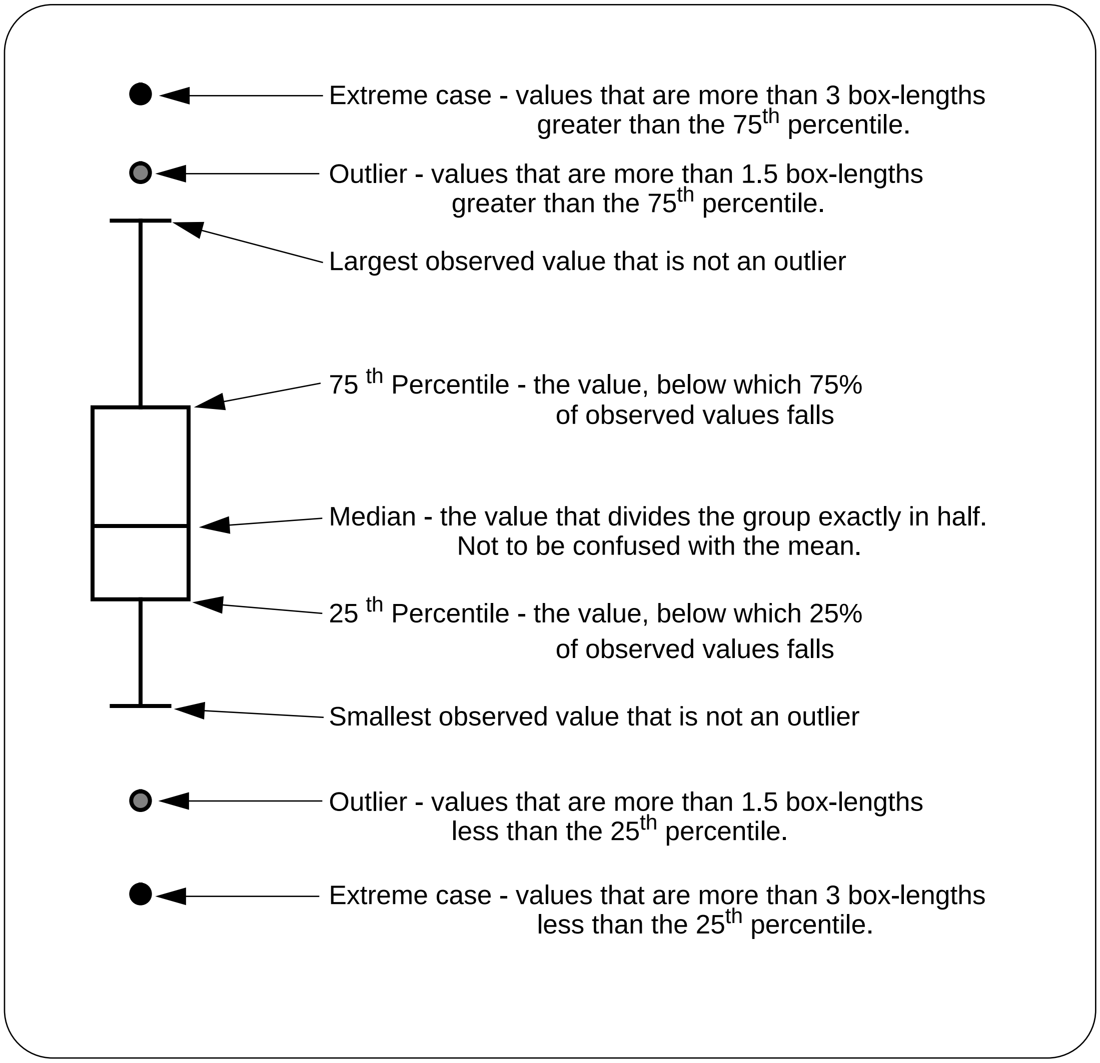
Finally, the three organizations that moved from level 1 to 2 to 3 on three successive assessments reflect ‘steady progress’ which many organizations strive for. Contrasting the process issues of these continuously improving organizations with the weaknesses of others may reveal important insights about ordering process issues to resolve in order to ensure successful SPI upon which organizations can continue to build. Future studies may be able to address this very important issue, if the data reported to the SEI allow.

Appendix A A Word About Boxplots

The purpose of this appendix is to provide the reader with a brief overview of how to interpret boxplots [Tukey 77].

Boxplots are often the best way to visually compare the dispersion (variability) of multiple data sets. By constructing box plots for several different groups on the same metric (as in Figure 5 on page 8 of this document) one gets an impression of how the GROUPS differ, in a more complete way than a comparison of group MEANS.

The figure below provides definitions for various parts of the boxplot.


Extreme case - values that are more than 3 box-lengths greater than the 75th percentile.
Outlier - values that are more than 1.5 box-lengths greater than the 75th percentile.
Largest observed value that is not an outlier
75 th Percentile - the value, below which 75% of observed values falls
Median - the value that divides the group exactly in half. Not to be confused with the mean.
25 th Percentile - the value, below which 25% of observed values falls
Smallest observed value that is not an outlier
Outlier - values that are more than 1.5 box-lengths less than the 25th percentile.
Extreme case - values that are more than 3 box-lengths less than the 25th percentile.

Appendix B Reliability Study for Mapping Findings

This appendix provides a brief description of the reliability study we conducted. The information provided here, for the most part, does not bear directly on the conclusions we draw in the paper, but helps the reader understand how the data were treated.

Our motivation in conducting the reliability study was to ensure that the CMM content mappings were assigned in a consistent (repeatable) way. In the absence of reliability, it is nearly impossible to draw reasonable conclusions from the analyses.

First, based partly on the earlier study conducted by Kitson and Masters, an initial set of coding rules was drafted and reviewed by the authors of this study. We knew from our assessment experience and conversations with Kitson and Masters that assigning CMM content codes to findings would be a non-trivial task. Our goal was to take advantage of the CMM structure in order to provide more detailed identification of the issues raised in assessment findings.

Based on the initial coding rules, one of the authors assigned codes to each finding. These initial codes identified the

- Key Process Area in which the process issue is discussed
- Goal that would not be satisfied as a result of the process weakness
- Common Feature that contains the process issue
- Key Practice that addresses the process issue
- difficulty in making the mapping (high, medium & low)

If the finding addressed more than one CMM issue we allowed it to be mapped to two different sets of codes. These two sets of codes were identified as “primary mapping” and “secondary mapping.”

Next we enlisted the help of two authors of the CMM to assign codes independent of our judgment. The CMM authors coded a random sample of 100 findings, and their codes were compared with those assigned by the authors of this study.

Our analysis of these codes revealed that there was sufficient agreement at the KPA level, but that codes assigned at lower levels of detail tend to differ both among the CMM authors and with the study author.

While investigating the reliability of the coding process we made the following observations:

- 26% of the assessments were conducted prior to the publication of the CMM.
- 94% of the assessments were carried out using the methodology known as Software Process Assessment.
- 6% of the assessments were carried out using the new CBA-IPI method.
- Discussions with the content experts lead us to conclude that looking at assessment findings without the context of participating in the assessment leaves much room for competing interpretations of a given finding. These competing interpretations seem equally defensible.
- The finding area[1] assigned by the assessment team is the most defensible code for CMM content, if the named finding area matches the name of a Key Process Area in the CMM. We found that 78% of the team-assigned finding area labels suggested (or named explicitly) specific KPAs in the CMM.
- Reliable coding of findings to KPAs was possible. However, codes for goals, common features and key practices tended to differ substantially among the participants in the reliability study.

Given this experience with the reliability study, we revised the coding rules in the following ways:

- Rely on the team-assigned finding area unless there is a defensible reason not to (e.g., there is no obvious link to any of the KPAs in the CMM, based on the finding area alone).
- Code the findings according to KPA only (as we did not expect sufficient reliability at lower levels).
- Code the difficulty of mapping for each finding, and review the high difficulty mappings before proceeding.
- For findings that pertain to more than 1 KPA, split the finding into 2, and identify each KPA. (In the end, this resulted in 29 additional findings for a total of 1514.)

The findings were then coded following the revised rules, and the difficult findings were reviewed and discussed among the two authors of this study.

All of the mapping was accomplished using a database created for this purpose. Each finding was reviewed multiple times before finalization, allowing us to review — for example— all findings that were mapped to a particular KPA or had a given level of mapping difficulty.

Based on our knowledge of current assessment practice, we expect that new data generated by the CBA IPI method will allow more detailed analyses. Because of the more rigorous mapping of findings to CMM content, our hope is that future work in this area will focus on more detailed investigations at the level of Goals or even Key Practices.

---

[1] By "finding area" we mean the process area identified by the team. This is typically the title of the slide on which the findings is presented.

References

[Baatz 95] Baatz, E. B., “Out -of this-World Software,” *CIO* (February 1995): 41-48.

[Computer Weekly 95] “IT projects still fail to deliver, says research,” *Computer Weekly* (March 1995):52.

[Daskalantonakis 94] Daskalantonakis, Michael, K., “Achieving Higher SEI Levels,” *Cross Talk: The Journal of Defense Software Engineering*, Vol. 7 No 9., September 1994.

[Dewey 88] Dewey, Russell, H., *Software Engineering Technology and Management.* SRI International, Business Intelligence Program, Report No 762, 1988.

[Goldenson 95] Goldenson, Dennis & Herbsleb, James. *After the Appraisal A Systematic Survey of Process Improvement, its Benefits, and Factors that Influence Success* (CMU/SEI-95-TR-009). Pittsburgh, Pa.: Software Engineering Institute, Carnegie Mellon University, 1994.

[Herbsleb 94] Herbsleb, James; Carleton, Anita; Rozum, James; Siegel, Jane; & Zubrow, David. *Benefits of CMM-Based Software Process Improvement: Initial Results.* (CMU/SEI-94-TR-13). Pittsburgh, Pa.: Software Engineering Institute, Carnegie Mellon University, 1994.

[Humphrey 87a] Humphrey, Watts, S., *Managing the Software Process.* Addison-Wesley, 1987

[Humphrey 87b] Humphrey, Watts, S. and Sweet, William, L., *A Method for Assessing the Software Engineering Capability of Contractors* (CMU/SEI-87-TR-23, ADA 187230). Pittsburgh, Pa.: Software Engineering Institute, Carnegie Mellon University, 1987.

[Humphrey 87c] Humphrey, Watts, S., *Characterizing the Software Process: A Maturity Framework* (CMU/SEI-87-TR-11). Pittsburgh, Pa.: Software Engineering Institute, Carnegie Mellon University, 1987.

[Humphrey 91] Humphrey, Watts, S.; Snyder, Terry, R.; and Willis, Ronald, R. *Software Process Improvement at Hughes Aircraft.* IEEE Software, July 1991.

[Johnson 94] Johnson, Jed, "How We Climbed to Maturity Level Two", *Application Development Trends* (April 1994).

[Kitson 92] Kitson, D.H. and Masters S. *An Analysis of SEI Software Process Assessment Results: 1987-1991* (CMU/SEI-92-TR-24). Pittsburgh, Pa.: Software Engineering Institute, Carnegie Mellon University, 1992.

[Masters 95] Masters, S. & Bothwell, C., *CMM Appraisal Framework Version 1.0* (CMU/SEI-95-TR-001). Pittsburgh, Pa.: Software Engineering Institute, Carnegie Mellon University, 1995.

[Nidiffer 95] Nidiffer, Kenneth, E, "How Grumman Data Reached Maturity Level 3," *Application Development Trends* (March 1995): 52.

[Paulk 93a] Paulk, Mark, C.; Curtis, Bill; Chrissis, Mary Beth & Weber Charles, V. *Capability Maturity Model for Software, Version 1.1.* (CMU/SEI-93-TR-25, ADA263403). Pittsburgh, Pa.: Software Engineering Institute, Carnegie Mellon University, 1993

[Paulk 93b] Paulk, Mark, C.; Weber Charles, V.; Garcia, Suzanne, M.; Chrissis, Mary Beth; Bush, Marilyn. *Key Practices of the Capability Maturity Model, Version 1.1.* (CMU/SEI-93-TR-25, ADA263432). Pittsburgh, Pa.: Software Engineering Institute, Carnegie Mellon University, 1993

[Tukey 77] Tukey, J.W. *Exploratory Data Analysis.* Reading, Mass.: Addison-Wesley. 1977.