Less is More in Software Process Improvement

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Abstract. Many software process improvement (SPI) programs fail to deliver the benefits they promise. This is usually due not to bad new processes being created, but to a lack of adoption of the new processes. Many articles have been written about reasons for lack of adoption. One element that is missing in these articles is the capacity of organizations to adopt more changes. Often organizations implement many changes in parallel, hoping to achieve an accumulated benefit. We conjecture that in many cases less is more – concentrating on implementing a few changes well yields more benefits than implementing a lot of changes less well. This article presents a model to analyze and measure adoption of processes and some practical techniques to support adoption of processes.

1 Short description / Stage setting

Many software process improvement (SPI) programs fail. Practitioners in the field of SPI claim that about 80% of those programs fail to achieve their promised benefits. Unfortunately there is no published data to support this statement, for an obvious reason: people do not publish failures. Studies show that 67% of SPI managers want guidance on *how* to implement SPI activities, rather than *which* SPI activities to implement [10], which can be taken as some evidence confirming the high failure rate claim. Even programs that do not fail as such often fail to deliver the promised returns. It appears to be very difficult to truly change the behavior of managers and engineers involved in software or systems development. Failure can be complete, where nothing of what was planned is achieved. But mostly, failure is much more subtle—some new processes are adopted to some extent, but not to the extent needed to achieve any real benefits. Improved processes do not bring any benefits if they aren't used. We conjecture that the lack of adoption is often caused by the desire to do too much at the same time. The support activities needed for successful adoption are too diluted over all changes and lose their effectiveness.
There are many consequences of failed adoptions:

- Organizations still do not achieve their development project goals, and projects often are too late, over budget, deliver lower quality than planned
- The investment in the improvement program is fully or partially wasted

- The improvement model (e.g., CMMI, Six Sigma, ISO 9000) is perceived by the affected organization as a bad model that does not deliver what is promised

It is currently difficult to analyze if improved processes have been fully adopted. For SPI programs based on the CMMI model [19] there is a well-defined appraisal method [20]. However, even with this rigorous method it is almost impossible to gauge if the processes have really changed the hearts and the minds of the practitioners.
This paper attempts to address these issues and indicate directions for future research, focusing on understanding adoption to the level that we can influence and measure it, and on the absorptive capacity of an organization, the extent to which it can adopt more changes. This paper first elaborates on the research questions, and then reviews the most applicable prior literature, derives methods and models for adoption and concludes with suggestions for further research.

2 Key Questions / challenges that we address

To support SPI programs to achieve better results one not only needs to introduce the right technologies and processes but the following topics need to be addressed as well: transition mechanisms, adoption measurement and absorptive capacity. When current SPI programs fall short in achieving adoption of processes, we need to offer systematic mechanisms to achieve adoption. We call these transition mechanisms, as they support an organization transition along the stages of the adoption curve: contact, awareness, understanding, trial use, adoption, institutionalization and internalization [5], [9]. Taking an organization step by step through these phases strongly enhances the likeliness of full adoption. Measurements of adoption make the effectiveness of these transition mechanisms transparent, allowing corrective action in cases where progress stalls. As–in our view–absorptive capacity is one of the most prominent limiting factors in achieving full adoption, we devote special attention to this topic.

2.1 Transition Mechanisms

It is widely recognized that process change or technology change occurs through several distinct stages [5], [15], [7, 8]. Prospective users of new processes first get in *contact* with the new process, become *aware* of what this process could do for them and obtain a deeper *understanding* of the technology itself. When these stages leave a positive impression users will perform a *trial usage* of the process before deciding on full *adoption*. The new processes become *institutionalized*, embedded in the culture, and after sufficient passage of time they become *internalized*; users cannot think they would ever perform the process in the old way again. Recognizing these stages, we could use them actively to support adoption in an SPI program. The design of the SPI program should identify and plan mechanisms to support the process users to proceed along these stages. This paper gives suggestions for identification of transition mechanisms and relates these mechanisms to adoption measurement.

2.2 Adoption Measurement

To make any founded claims about the lack of adoption of new processes, we should be able to measure adoption. To what extent do people apply a process? And how many people from our target population do apply the new processes. The following example illustrates the difference between partial and full adoption. An organization has developed a new estimation process to improve the accuracy of the development project estimates. The new process includes a spreadsheet which requires several attributes to be given (number of screens, number of interfaces, etc.) and then suggests an estimate for software development effort. The estimator is allowed to differ from this suggestion, but he then needs to document why.
A partial adoption of the new estimation process could have the following indicators:

- People use the new estimation spreadsheet.
- They compare the model outputs with what their gut-feeling estimate tells them.
- They then tune their inputs into the model to make both numbers match.
- When estimates turn out to be wrong, they blame the model.

A full adoption of the new estimation process might look like this:

- People use the new template and estimation model.
- They also compare model results with their gut feeling estimates.
- They document where there are differences between the two and involve the estimation process owner in case of significant deviations.
- During project execution they compare their estimates to the actual numbers for effort and time for each of the tasks performed.
- Based on this the estimation model parameters are tuned to better match reality.

Key differences between real and partial adoption:

- The estimation method is used according to its intentions.
- The estimation results are integrated with the project tracking process. More generally speaking, the results of one new process are integrated with other processes, in ways that the process author may not have foreseen.
- The organization uses feedback to become a learning organization.

2.3 Absorptive capacity

SPI involves change, changes to the work practices of managers and engineers. Is there a limit to the amount of change people and organizations can handle?
If we implement too many changes at the same time the resistance against the changes will increase, the amount of support and coaching for each change will be diluted, leading to a less than optimal implementation. On the other hand, if we change too little we may not achieve the goals we strive for. Can we find an optimal amount of change? There may be synergy between these multiple improvement programs, but the opposite, dysergy, is a definite possibility as well. On top of what an SPI initiative launches as changes, the target group of our SPI program is subject to much more change than that what is initiated by the SPI program: reorganizations, new products, new technology, changes in personnel and management. We expect that absorptive capacity is to process improvement what Brook's law is to project management [3]. Brooks stated that adding more resources to a late project would only make it later.

We conjecture that adding more improvements to a suboptimal organization only makes it more suboptimal. We want to define, measure and analyze the concept of absorptive capacity, and find ways to influence it.

3 Review of Existing Literature

Changes to processes should become changes to work practices, changes to behavior. Ajzen [1] describes in the theory of reasoned action (TRA) how intentions and beliefs may or may not lead to actual changed actions. According to TRA, a person's performance of a specified behavior is determined by his or her behavioral intention (BI) to perform the behavior, and BI is jointly determined by the person's attitude (A) and subjective norm (SN) concerning the behavior in question. As TRA describes behavior in a general sense, this model does also apply to behavior in the context of SPI. TRA is a descriptive model; it describes how behavior is driven by attitudes and subjective norms. We conjecture that absorptive capacity is missing in this model. TRA assumes that when one has the intention to adopt a certain behavior, this behavior will actually be performed. In reality people are typically constrained to adopt a new behavior by lack of time or lack of training.

Gallivan [7] describes many relevant aspects of process adoption. Based on his analysis of core frameworks on innovation adoption from the social psychology [1], [15], [6] he concludes that these models neglect the realities of implementing technology in organizations, especially when adoption decisions are made at the organization, division, or workgroup levels, rather than at the individual level. In these cases adoption follows two decisions: the primary adoption decision by management to adopt a new technology, and a secondary adoption decision by the workforce to use it in their daily work. Following the primary adoption decision, management could proceed by three fundamentally different paths to ensure secondary adoption: (1) they can mandate that the innovation be adopted throughout the organization at once; (2) they can provide the necessary infrastructure and support for employees to adopt the innovation allowing a more voluntary diffusion; or (3) they may target specific pilot projects within the firm, observe the processes and outcomes that unfold, and decide whether to implement the innovation more broadly later on. This confirms our conjecture that if organizations attempt to implement too much, they won't have the time and resources to ensure a thorough secondary adoption takes place.
Gallivan's work focuses mainly on the adoption of 'hard' technologies, for example the adoption of client-server computing. In our work we focus on 'soft' technologies or process technologies, where the adoption decision is not binary (adopt or not adopt), but continuous (to what extent). Gallivan focuses his research on when and how adoption occurs; we are mostly interested in how well adoption occurs. A similar interest is found with Saga and Zmud [17] who identify three different facets of infusion: more extensive use of the innovation (e.g. using more technology features); more integrative use (using technology to create new workflow linkages among tasks); and emergent use (using technology to perform tasks not previously considered possible).

A study has recently been published that applies several social psychology models to the world of SPI. Umarji [21] tries to predict the acceptance of SPI programs on the basis of TRA and the technology acceptance model [1], [6], extending these models because of the fact that SPI is intangible, often more intrusive and judgmental than hard technologies. She suggests adding four groups of factors to the model for SPI:

- Organizational issues: visibility, transparency, and reward structure/incentives.
- Personal issues: fear of adverse consequences, communication, self-efficacy, and degree of control.
- SPI-related issues: amount of learning required, compatibility of work practices, champions/advocates.
- Factors from social psychology: perceived usefulness, attitude, perceived behavioral control, subjective norm, ease-of-use.

We agree with the reasons to adapt the model, however we conjecture that most of the factors she describes are specializations of the attitude and subjective norms in TRA.

A model that has become quite popular to support SPI programs comes from the family therapy domain [18], [22]. Satir describes a process of change as follows: we begin with the *status quo* of the organization (termed *old status quo* by Weinberg), a situation where people have learned to cope with the fallacies in the current system. Then a *foreign element* is introduced, in the context of SPI that would be the SPI initiative. The foreign element causes *chaos*, people who have long worked in the old status quo see all kinds of comfortable practices change, and the people and the system moves into a state of disequilibrium. At some point in time a *transforming idea* is found that drives the system into *integration*, *practice*, and *new status quo*. The description here is sequential, however practice often is not. At each point in the process there is the possibility to fall back to the old status quo. Weinberg [22] suggests that introducing new changes during the chaos phase should be avoided at all times, and mostly during the integration phase as well. Adding new changes during chaos and integration just increases the risk of falling back to old status quo. The optimum time for a new change is during the practice phase, shortly before new status quo. In that phase the chaos is over, so organizations are capable of adopting something new again, but not yet so fixed into a new status quo that new changes will lead to a major chaos again. We suggest using the transition mechanisms as a means to support the organization to find effective transforming ideas quickly. The notion of not adding new changes during transition supports our concept of a limited absorption capability.

4 Approach taken

We are taking the Action Research [14] approach to this investigation and will develop new theory on the basis of observations in both practice and previous literature. We created a theoretical model about adoption based on the literature review and our industrial experience, see Fig. 2.

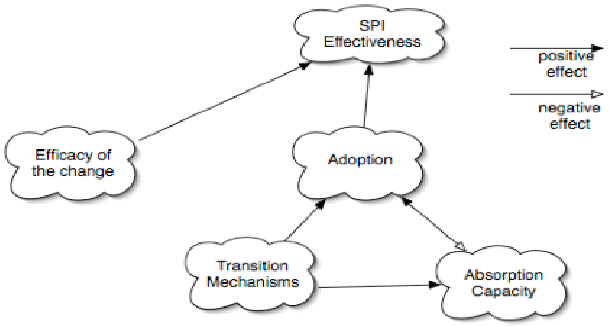

Fig. 1. Modeling the effectiveness of SPI as a function of efficacy and adoption

The model describes how the effectiveness of an SPI program depends on the efficacy of the change and the adoption of the change. Some authors combine efficacy and adoption into one concept; for example Wynekoop as quoted in [7] defines infusion as "the extent to which an innovation is used completely and effectively and improves the organization's performance". However, we claim that separating the orthogonal constructs efficacy–the content of the improvement program–and adoption–the method of change in the improvement program–gives us more analytic power. The efficacy of the change is a key successfactor. Have we implemented the right thing? Do the new processes solve the problems of the old situation? John Rost [16] gives some excellent examples of implementing the wrong set of processes in certain situations. For this study we assume that a useful approach has been taken. Our focus is on the adoption of the change. We contend that this depends on two main factors: the transition mechanisms used, and the absorption capacity of the organization.
Another way to look at the adoption part of the model would be to adopt the TRA model [1], using absorption capacity as a new construct, see Fig. 2.

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Fig. 2. Theory of Reasoned Action model augmented with Absorption Capacity

The absorptive capacity is a new construct that limits the Behavioral Intention of the target group of new processes to adopt it.

4.1 Transition Mechanisms

Adoption of change typically follows a seven-phase adoption curve [5]. The phases are contact, awareness, understanding, trial use, adoption, institutionalization, and internalization. When organizations conduct a process improvement program, they should apply mechanisms to help the organization transition from one phase to the other. Mechanisms to bring people into the contact phase could be e-mails or posters about the new technology. Mechanisms to bring people from contact to awareness could be information presentations on the new technology. The more effective the mechanisms are, the more effectively and efficiently will the organizations adopt the new technology. There is not, and cannot be, any single set of transition mechanisms. Organizations have different backgrounds, cultures, and structures, so the set of mechanisms should be defined for each organization. Effective mechanisms from the past are of course a very good source for new efforts. Table 1 gives several examples of transition mechanisms for each phase, obtained from a customer engagement and from work by Garcia [9].

Table 1. Transition Mechanisms

Stage	**Transition Mechanisms**
Contact	Information emails, Posters, Brown bag lunches
Awareness	"Elevator speech" Magazine articles and conference briefings Flash cards with objectives, benefits, URL, etc. Web site, FAQ Successful ROI stories, case studies
Understanding	Training sessions, communication Detailed case studies Identify and authorize champions Identify stakeholder roles and responsibilities
Trial use	Coaching by process experts Small working group to support pilots Special authorities for pilots Documented pilot results
Adoption	Availability of process artefacts Strong set of incentives; rewards and consequences Refined guidance on process usage choices Education - mature courses, modularized for JIT delivery In-Process Aids
Institutionalization	Inclusion in quality audits Integration with other processes Emergent use in unanticipated situations Fully realized curriculum of training for different users New employee training/orientation Continuous improvement to adoption artifacts (guides, etc.)
Internalization	-

4.2 Absorption Capacity

There is no literature on the concept of absorption capacity except from the remarks Weinberg [22] makes about what a good time is to introduce new change.
Independent of how good the transition mechanisms are, the capacity of the organization to absorb change is a limits the adoption of new changes. Organizations trying to adopt many changes at the same time are likely to fail in several of them. Both individuals and organizations have a limited capacity for change and will resist more changes once their limit is reached. What determines this adoption capacity? At what point do people and organizations reach their limits? Can we identify mechanisms that enlarge absorption capacity? Can we measure absorption capacity and use that measure to predict when limits are likely to be hit? Probable factors that influence the absorption capacity are: the amount of changes at a given point in time, individual personalities and traits [15], [11], passage of time (it makes a difference if the last change was a month or a year ago), top-down or bottom-up changes, group effects, learning organization characteristics. We plan to explore this phenomenon in future research.
Brooks' law [3] states that the efficiency of teams reduces when new team members are added due to increased communication between the team members. By analogy we suggest that the effectiveness of SPI reduces when more change is introduced due to diluted attention to each of the SPI initiatives. Effective SPI requires that sufficient support be given to the target group [2], [12], [13], training, coaching, motivation. This support should be given both my management and by a process group. The generic practices in the CMMI model [19] are included in the model to ensure the new processes are institutionalized. The generic practices include: training, resources, measurement, and verification by quality assurance and management. These support activities should be performed for each process in the organization, with specific attention to new processes that still need to be institutionalized. The more changes we have, the more diluted the support activities will be, leading eventually to a level of support that falls below a threshold where it has any effect.
If the number of process improvement activities is P, and the total capacity to support process improvement is S, then the average support given to each improvement activity is S / P. If the effective contribution to an organization's effectiveness for each improvement is $e_{i,}$, then the overall effectiveness E of all improvements is:

$$E = \sum_{1}^{P} \frac{e_i}{P} \tag{1}$$

Formula 1 does not account for synergies or dysergies between improvement activities, nor for a threshold value for support. The total effectiveness E is the return we get on process improvement. This is strongly reduced by conducting many improvements; the investment increases with every process improvement, making the return on investment (ROI) very negative when many improvements are carried out.

4.3 Adoption Measurement

Process adoption is generally characterized as consisting of two orthogonal dimensions [9], [7]: infusion and diffusion. Infusion or depth of adoption describes how well the new process has been adopted by the target population. Is there a full or a partial adoption of the new processes? Diffusion or breadth of adoption describes how broadly the target population has adopted the new process. Do they all apply the new processes? It has been suggested by Kaputo and Garcia [4], [9] to use these dimensions as measurements for adoptions. An additional benefit of measuring adoption is that it provides a leading indicator for the return on investment (ROI) of process improvement. Assuming the right new processes have been developed, a high adoption measure tells us that a return on investment is to be expected.
An example of how an adoption measurement could be presented is given in Fig. 3. This shows a hypothetical organization that has introduced three process improvements. The inspections are performed very well by a small group of people; most people perform estimations poorly and testing is performed well by most.

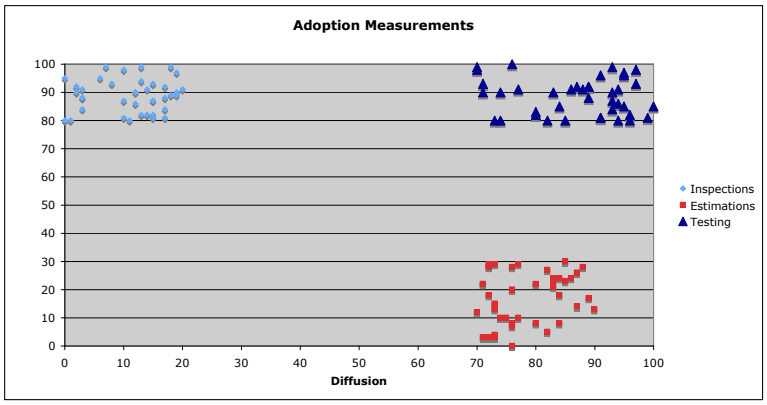

Fig. 3. Graph of adoption as measured by diffusion and infusion

4.3.1 Measuring Diffusion

To measure diffusion, we should measure how far the target population has come along the stages of the commitment curve [5]. When transition mechanisms have been defined in an improvement project, these mechanisms can be used as proxies for adoption commitment. Transition mechanisms are the means that have been used to get the target population through the stages of contact, awareness, understanding, trial use, adoption, institutionalization and internalization. Examples of transition mechanisms from some recent customer engagements can be found in **Table 2.** Suggested measurements for each stage in the adoption curve**Table 2**

Table 2. Suggested measurements for each stage in the adoption curve

Stage	Measurement

Contact	
Awareness	Number of attendees
Understanding	Number of attendees, course completion tests
Trial Use	Number of pilot projects, number of people reporting usage
Adoption	Number of projects/people reporting usage, practice implementation indicators, training attendees
Institutionalization	Process change requests
Internalization	

Table 3. Transition Measurements

To compute a composite diffusion measurement D, we count the number of people P_s who are in a certain stage S of the adoption curve, and give weights to each stage W_s, internalization gets the highest weight, contact the lowest.

$$D = \sum \frac{P_s}{W_s} \quad (2)$$

4.3.2 Measuring Infusion

To measure infusion we need to gauge how well the people within the target population use the new processes. The process developer should identify all roles that should work with this process, and for each role define how well the knowledge of the process should be and what the typical tasks would be when the process is fully carried out. The infusion could be measured along the infusion facets: ordinary use, extensive use, integrative use, and emergent use. The following table uses an inspection process as an example.

Table 4. Using infusion facets as means to measure infusion

Role	**Tasks**	**Ordinary use**	**Extensive use**	**Integrative use**	**Emergent use**
Meeting moderator	Send invitations, moderate the meeting, follow-up that rework is performed	Inspection form with indication that rework has been checked	Not just asking for rework completeness but go through all changes together	Using checklists from the producing process (e.g. design)	Using inspection data as input to predictive failure models
Author	Inform mod-	Time spent	Having	Using the	Use in-

	erator that work is ready for inspection. Perform re-work	on rework after the meeting	criteria defined to determine when a document is ready for inspection	inspection status of documents as progress indicators in project tracking	spection effort as cost driver in a Cost of Quality model
Reviewer	Review material in advance of the meeting. Comment during the meeting	Preparation time	Using a checklist in review preparation	Ensure all stakeholders are involved in the review	Use inspection outcomes in risk management

5 Expected or achieved Results

This paper describes a model around adoption of software process improvement based on literature and on the experience of the author. Some elements have already been applied in practice: we have identified transition mechanisms, infusion and diffusion measures with several customers in an engagement to start an improvement program. The program is currently too young to see any practical results; it is too early to gather data based on the measurements defined.
So, the model will be further validated using action research. Some initial ideas on further work include:

- Study an improved process that has already been well adopted according to an organization, retrospectively define the infusion and diffusion measurements, and measure whether the intuitive understanding of adoption matches with measurement data, thus validating the concepts of measuring infusion and diffusion.
- Refine the methods to establish infusion and diffusion measurements, allowing taking accurate measurements at low cost.
- Perform a controlled experiment in a university setting to validate the absorption capacity construct in the adapted theory of reasoned action model.
- Validate absorption capacity comparing companies with many changes against companies with few changes.

6 Conclusion

Rogers has identified that most research on innovation diffusion has a clear pro-innovation bias, and gives some directions for research in other directions to strengthen the analytic power of the research. This paper, with its critical position towards performing too many improvements in parallel, shows a balanced position to innovation. We regard innovation as not a bad thing in itself, but suggest it should be

treated with care and limits. We contend that 'less is more' in software process improvement.

References

1. Ajzen, I., From Intentions to Action: A Theory of Planned Behavior, Springer-Verlag, New York, 1985
2. Baddo, N. and Hall, T., Motivators of Software Process Improvement: an analysis of practitioners' views, The Journal of Systems and Software, 2001, (85-96)
3. Brooks, F. P., The Mythical Man-Month: Essays on Software Engineering, 20th Anniversary Edition, Addison-Wesley Professional, 1995
4. Caputo, K., CMM Implementation Guide: Choreographing Software Process Improvement, Addison-Wesley Professional, 1998
5. Conner, D., R. and Patterson, R., W., Building Commitment to Organizational Change, Training and Development Journal, 1982, (18-30)
6. Davis, F. D., Bagozzi, R. P. and Warshaw, P. R., User Acceptance of Computer Technology: A Comparison of Two Theoretical Models, Management Science, 1989, (982-1003)
7. Gallivan, M. J., Organizational Adoption and Assimilation of Complex Technological Innovations: Development and Application of a New Framework, Database for Advances in Information Systems, 2001, (51-85)
8. Gallivan, M. J., Strategies for Implementing new Software Processes: an Evaluation of a Contingency Framework, SIGCPR/SIGMIS, 1996, (313-325)
9. Garcia, S., Are you prepared for CMMI? 2002
10. Herbsleb, J. D. and Goldenson, D. R., A systematic survey of CMM experience and results., Proceedings of the 18th International Conference on Software Engineering, 1996, (323-330)
11. Moore, G., Crossing the Chasm: Marketing and Selling Technology Products to Mainstream Customers, Harper Business, New York, NY, 1991
12. Niazi, M., Wilson, D. and Zowghi, D., A maturity model for the implementation of software process improvement: an empirical study, The Journal of Systems and Software, 2003, (155-172)
13. Rainer, A. and Hall, T., Key success factors for implementing software process improvement: a maturity-based analysis, The Journal of Systems and Software, 2002, (71-84)
14. Remenyi, D. et al., Doing Research in Business and Management, Sage Publications, 2000
15. Rogers, E. M., Diffusion of Innovations, The Free Press, 1995
16. Rost, J., Software Engineering Theory in Practice, IEEE Software, 2005, (94-95)
17. Saga, V. L. and Zmud, R. W., The Nature and Determinants of IT Acceptance, Routinization, and Infusion, Diffusion, transfer, and implementation of information technology: proceedings of the IFIP TC8 Working Conference on Diffusion, Transfer and Implementation of Information Technology, Pittsburgh, PA. U.S.A., 11-13 October 1993, 1994,
18. Satir, V., Banmen, J., Gerber, J. and Gomori, M., The Satir Model - Family Therapy and Beyond, Science and Behavior Books, Inc., Palo Alto, CA, 1991
19. SEI, Capability Maturity Model Integration (CMMI), Version 1.1, Software Engineering Institute, 2002
20. SEI, Standard CMMI Appraisal Method for Process Improvement (SCAMPI), Version 1.1: Method Definition Document, Software Engineering Institute, 2001
21. Umarji, M. and Seaman, C., Predicting Acceptance of Software Process Improvement, St. Louis, Missouri, USA, 2005
22. Weinberg, G., Quality Software Management: Anticipating Change, Dorset House, 1997