

AN OVERVIEW OF INDUSTRIAL SOFTWARE DOCUMENTATION PRACTICES

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ABSTRACT

A system documentation process maturity model and assessment procedure were developed and used to assess 91 projects at 41 different companies over a seven year period. During this time the original version evolved into a total of four versions based on feedback from industry and the experience gained from the assessments. This paper reports the overall results obtained from the assessments which strongly suggest that the practice of documentation is not getting a *passing grade* in the software industry. The results show a clear maturity gap between documentation practices concerned with defining policy and practices concerned with adherence to those policies. The results further illustrate the need to recognize the importance of improving the documentation process, and to transform the good intentions into explicit policies and actions.

Keywords: system documentation processes, maturity model, key practices, degree of satisfaction, assessment results

1. INTRODUCTION

The purpose of this paper is to report the results after using a system documentation process maturity model and assessment procedure to assess 41 companies involving 91 projects and over 370 software professionals in a period of seven years. The essence of the model remained unchanged throughout its first three versions, but industry feedback as well as the experience gained during the assessments led to modifications of key practices and question

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scoring scheme which are explained elsewhere [11]. Then, a fourth version changed the model structure to one without the maturity levels as an indicator of process maturity that focused on the key practices. This evolution led to the formulation of a process maturity meta-model, further explained in [13].

In this paper we describe the general state of the practice of the system documentation process based on the assessments results. To facilitate comparisons between the results from the different assessments using the distinct versions, only the key practice profiles are used. The maturity levels computed for the first three versions are shown for illustration purposes only. Maturity levels were not part of the fourth version.

The idea behind the Documentation Process Maturity Model is very simple: most defects discovered during software testing are documentation defects (requirements and design defects - defects in documentation that were introduced before any code was written). Empirical studies have shown that poor quality, out of date, or missing documentation is a major cause of defects in software development and maintenance [1,2,8,9]. Thus, documentation is a key component in software quality and improving the documentation process will have considerable impact on improving the quality of software. Our solution scheme has been to design a maturity model that provides the basis for the assessment of current documentation process and guides the identification of key practices and challenges to improve the process [10]. The focus is on the documentation used in software development and maintenance and does not consider end-user documentation. Our approach has been influenced by the Capability Maturity Model (CMMsm) developed by Carnegie Mellon University's Software Engineering Institute (SEI) [4,6,7].

This paper is organized as follows: next section presents the Documentation Process Maturity Model and discusses its foundations and related research that led to its formulation. The following section highlights the major changes performed from the first three versions to the fourth in terms of model structure, and gives a summary of the model evolution. Then, the results obtained from the assessments conducted with each version are shown. The final section discusses the state of the practice of software documentation based on the assessment results, and gives our conclusions and projections for further research work.

2. DOCUMENTATION PROCESS MATURITY MODEL – FRAMEWORK AND EVOLUTION

The Documentation Process Maturity Model (DPMM) is a description of process maturity, capability and practices that characterize an organization that generates high quality documentation. (Recall that documentation refers to the system documentation generated as part of the software development process. It does not include end-user documentation.) A four level software system documentation process maturity model and assessment procedure have been developed. The model represents an ideal process and the assessment determines where the organization stands relative to the model. The model and assessment procedure were influenced by CMM in that key practices, indicators, and challenges are

CMMsm is a service mark of Carnegie Mellon University

defined for each of the four levels of the model; for the assessment procedure a questionnaire, that takes only 30 minutes to complete, is administered to each member of the project team. The tabulated questionnaire responses are used to generate an assessment report that gives the maturity level and a documentation process profile that indicates what practices the organization is doing well, what practices need improvement, and challenges to move to the next higher maturity level. More information about the context framework that was the supporting basis to develop the maturity model and related assessment procedure is given in [10]. The model's overall structure is presented in Table 1.

Table 1. Documentation Process Maturity Model - Summary

	Level 1 Ad-hoc	Level 2 Inconsistent	Level 3 Defined	Level 4 Controlled
Keywords	Chaos, Variability	Standards Check-off list Inconsistency	Product assessment Process definition	Process assessment Measurement Control Feedback Improvement
Succinct Description	Documentation not a high priority	Documentation recognized as important and must be done.	Documentation recognized as important and must be done well.	Documentation recognized as important and must be done well consistently
Key Practices	Ad-hoc process Not important	Inconsistent application of standards	Documentation quality assessment Documentation usefulness assurance Process definition	Process quality assessment and measures
Key Indicators	Documentation missing or out of date	Standards established and use of check-off list	SQA-like practices	Data analysis and improvement mechanisms
Key Challenges	Establish documentation standards	Exercise quality control over content Assess documentation usefulness Specify process	Establish process measurement Incorporate control over process	Automate data collection and analysis Continually striving for optimization

A key to understanding DPMM is the succinct description of each of the four levels in the model, as shown in Table 1. The four succinct descriptions are: Level 1 - all the required documentation may not be done; Level 2 - all the required documentation is done; Level 3 - all the required documentation is done well and attention is paid to the usefulness of the documentation; and Level 4 - an optimizing loop where measurement of the process and usability provide feedback to continually improve the process.

It is important to notice that for the fourth and last version of the model we have dropped the maturity level idea and have only concentrated on key practices. The reason is that in our experience maturity levels seemed to draw attention away from what is really the key issue in software process improvement: the key practices. We have extended this idea and have proposed a meta-model to identify key practices that also considers a product dimension (in terms of quality assurance and usability) when assessing a particular process

during the diagnosis phase. This shows to be especially important when the process produces tangible deliverables, as is the case of the documentation process. Further details are available in [13].

DPMM has evolved over four versions. In the first three versions, each of the four levels has a number of key practices associated with it. Version 4 of DPMM only has a set of associated key practices and no maturity levels. In versions 3 and 4, a number of subpractices were associated with each key practice. Table 2 shows a summary to illustrate the evolution the model has undergone over the four versions. These changes are the result of documentation process assessments performed in the industry, assessing over 90 projects at more than 40 organizations. Full details of the evolution over the first three versions are available in [11].

Table 2. Summary - Evolution of DPMM

Version	Maturity Levels	Key Practices	Sub Practices	Questions	Assessed Companies	Assessed Projects
1	4	18	n/a	56	7	26
2	4	19	n/a	68	13	34
3	4	9	26	67	9	19
4	n/a	11	32	75	12	12

Table 3 shows a list of all key practices identified for each version, indicating which ones have remained unmodified, which have been dropped and which have been added. It is important to note that in Table 3 a key practice that was rewritten or modified appears as a dropped key practice and later as an added key practice. For example the key practice *Use of a check-off list of required documents* in version 1 was modified to *Mechanism to check that required documentation is done* in versions 2 and 3. In other cases, some dropped key practices became subpractices of later versions, so they were not actually dropped either. Subpractices are not shown in Table 3. Only one key practice remained unmodified for all four versions: *Process improvement feedback loop*.

To carry out the assessments we have used an assessment questionnaire, whose purpose is to determine where an organization's documentation process stands relative to the model. The assessment questions are derived directly from the model and its key practices. There are one or more questions for each key practice. The process maturity level (for the first three versions) and the degree of key practice satisfaction are determined from the questionnaire responses. For version 1 the key practices were rated as *Not Satisfied*, *Partially Satisfied*, or *Fully Satisfied*. This rating system seemed ambiguous and too coarse as there was a wide latitude in the degree of key practice satisfaction especially when a practice was classified as *Partially Satisfied*. For example, does *Partially Satisfied* mean the key practice is satisfied seldom or often or half of the time? *Not Satisfied* and *Fully Satisfied* were also ambiguous. Does *Not Satisfied* mean never or most of the time it is not satisfied? Does *Fully Satisfied* mean always or most of the time? To eliminate these ambiguities, from version 2 on there was a change from three to five degrees of satisfaction as follows: *Very High*, *High*, *Medium*, *Low* and *Very Low*.

Each person on a project team completed the assessment questionnaire. The degree of satisfaction of a key practice was generally determined by the average of the responses to the questions associated with that key practice.

Table 3. Summary – Evolution of Key Practices of DPMM

Key Practices of DPMM	Version 1	Version 2	Version 3	Version 4
Consistent creation of basic software development documents	X	X		
Creation of basic software documents				X
Documentation generally recognized as important	X	X		
Written statement or policy about importance of documentation	X	X		
Management recognition of importance of documentation				X
Adequate time and resources for documentation	X			
Adequate time for documentation		X		
Existence of documentation policy or standards		X	X	X
Monitor implementation of policy or standards				X
Adherence to documentation standards	X			
Adherence to documentation policy or standards		X	X	
Use of check-off list of required documentation	X			
Mechanism to check that required documentation is done		X	X	
Use of simple documentation tools	X	X		
Accuracy and reliability of documentation	X	X		
Mechanisms to update documentation	X	X		
Existence of a defined process for creation of documents			X	X
Mechanisms to monitor quality of documentation	X	X	X	
Methods to assure quality of documentation				X
Methods to assess usefulness of documentation	X	X		
Assessment of usefulness of documentation			X	
Assessment of usability of documentation				X
Use of common sets of documentation tools	X	X		
Use of advanced documentation tools	X	X		
Documentation-related technology and training	X	X		
Documentation is traceable to previous documents		X		
Definition of software documentation quality and usability measures				X
Measures of documentation process quality	X	X		
Measures of documentation process quality and usefulness			X	
Collection and analysis of documentation quality measures				X
Analysis of documentation usage and usefulness	X	X		
Analysis of documentation process quality and usefulness			X	
Collection and analysis of documentation usability measures				X
Process improvement feedback loop	X	X	X	X
Integrate CASE and documentation tools	X			

Finally, an assessment report is generated from the questionnaire responses. The report contains an executive summary with the maturity level (only for the first three versions), a documentation process maturity profile and an improvement action plan. Besides the maturity level, the executive summary lists the key practices that were not satisfied, those that need improvement, and those that were missing. The process maturity profile indicates the degree of satisfaction of each key practice. Specific actions to improve existing key practices or to address missing key practices to move to the next higher level are described in the improvement action plan. See [10] for an example of an assessment report. See [12]

for a proposed framework to face the action planning required to move on after conducting the assessments.

3. ASSESSMENT RESULTS

This section reports, for each version, the degree of key practice satisfaction from the assessments conducted for that version.

Using Version 1

The first version was released in March 1993. It was used to assess 26 projects at 7 companies in the time period March 1993 - September 1995, and Tables 4 and 5 show the results in terms of degree of satisfaction for each key practice and the overall results in terms of maturity levels.

Table 4. Key Practices and Degrees of Satisfaction – DPMM Version 1

Level	Key Practices	Not	Partial	Fully
1	1. Consistent creation of basic software development documents	4%	77%	19%
	2. Documentation generally recognized as important	12%	8%	81%
2	3. Written statement or policy about importance of documentation	38%	12%	50%
	4. Adequate time and resources for documentation	27%	54%	19%
	5. Adherence to documentation standards	19%	69%	12%
	6. Use of check-off list of required documentation	31%	27%	42%
	7. Use of simple documentation tools	4%	8%	88%
3	8. Accuracy and reliability of documentation	0%	62%	38%
	9. Mechanisms to update documentation	65%	31%	4%
	10. Mechanisms to monitor quality of documentation	65%	27%	8%
	11. Methods to assess usefulness of documentation	77%	15%	8%
	12. Use of common sets of documentation tools	35%	23%	42%
	13. Use of advanced documentation tools	65%	23%	15%
	14. Documentation-related technology and training	100%	0%	0%
4	15. Measures of documentation process quality	100%	0%	0%
	16. Analysis of documentation usage and usefulness	96%	4%	0%
	17. Process improvement feedback loop	69%	23%	8%
	18. Integrate CASE and documentation tools	73%	12%	15%

Version 1 was used to assess 26 projects. Although only four out of the 26 projects classified defect data by development phase, there was one promising data point that supported the model. Three of the four projects were from the same organization. Two projects were assessed as a level 2 and one a level 1. The defect data indicated that for the one project at level 1, 41% of the defects found during integration testing were design and requirements defects whereas for the two projects at level 2 only 25% of the defects found were design and requirements defects [2]. This strongly suggests that defects are indeed detected earlier in projects with a higher documentation maturity level.

Table 5. Breakdown by Maturity Level - DPMM Version 1

Level	%
1	62%
2	38%
3	0%
4	0%

The results from Table 4 show that most organizations are at level 1. The higher the maturity level the lower the degree of satisfaction for the key practices in that level. It's important to contrast degree of satisfaction of practice 2 (*Documentation generally recognized as important*) with that of practice 4 (*Adequate time and resources for documentation*), or between practices 3 (*Written statement or policy about importance of documentation*) and 5 (*Adherence to documentation standards*). Both cases stress the need to move from good intentions to concrete actions.

Using Version 2

The second version was released in September 1995. It was used to assess 34 projects at 13 companies in 3 countries in the time period September 1995 - September 1996. Tables 6 and 7 show the results in terms of degree of satisfaction for each key practice and the overall results in terms of maturity levels.

Table 6. Key Practices and Degrees of Satisfaction - DPMM Version 2

Level	Key Practices	VL	L	M	H	VH
1	1. Consistent creation of basic software development documents	0%	24%	53%	15%	9%
	2. Documentation generally recognized as important	29%	6%	3%	12%	50%
2	3. Written statement or policy about importance of documentation	26%	12%	12%	9%	41%
	4. Adequate time for documentation	18%	24%	26%	32%	0%
	5. Existence of documentation policy or standards	21%	21%	32%	18%	9%
	6. Adherence to documentation policy or standards	65%	26%	3%	6%	0%
	7. Mechanism to check that required documentation is done	15%	26%	24%	15%	21%
	8. Use of simple documentation tools	0%	0%	9%	32%	59%
3	9. Accuracy and reliability of documentation	0%	18%	56%	26%	0%
	10. Mechanisms to update documentation	65%	26%	9%	0%	0%
	11. Methods to monitor quality of documentation	59%	32%	6%	3%	0%
	12. Methods to assess usefulness of documentation	85%	12%	0%	3%	0%
	13. Use of common sets of documentation tools	9%	12%	21%	24%	35%
	14. Use of advanced documentation tools	53%	41%	3%	3%	0%
	15. Documentation-related technology and training	65%	26%	6%	3%	0%
	16. Documentation is traceable to previous documents	53%	29%	15%	3%	0%
4	17. Measures of documentation process quality	71%	26%	3%	0%	0%
	18. Analysis of documentation usage and usefulness	85%	12%	3%	0%	0%
	19. Process improvement feedback loop	56%	41%	0%	3%	0%

Table 7. Breakdown by Maturity Level - DPMM Version 2

Level	%
1	68%
2	29%
3	3%
4	0%

The results from using this version of the model are not substantially different from those obtained with the previous one. As the maturity levels increases the satisfaction of related key practices gets lower; the apparent contradiction between intentions and actions remains, evidenced by the decreasing degrees of satisfaction of practices 2 (*Documentation generally recognized as important*) and 4 (*Adequate time for documentation*), and 3 (*Written statement or policy about importance of documentation*), 5 (*Existence of documentation policy or standards*) and 6 (*Adherence to documentation policy or standards*).

Using Version 3

The third version was released in September 1996. It was used to assess 19 projects at 9 companies in 2 countries in the time period September 1996 – December 1998. See Tables 8 and 9.

Table 8. Key Practices and Degrees of Satisfaction - DPMM Version 3

Level	Key Practices	VL	L	M	H	VH
1	No key practices – in this level there is only a set of basic practices	0%	6%	28%	50%	17%
2	2.1. Existence of documentation policy or standards	6%	11%	33%	17%	33%
	2.2. Mechanism to check that required documentation is done	0%	22%	17%	39%	22%
	2.3. Adherence to documentation policy or standards	33%	39%	0%	17%	11%
3	3.1 Existence of a defined process for creation of documents	17%	39%	17%	28%	0%
	3.2 Methods to assure quality of documentation	6%	56%	22%	17%	0%
	3.3 Assessment of usefulness of documentation	0%	33%	50%	17%	0%
4	4.1. Measures of documentation process quality and usefulness	39%	44%	11%	6%	0%
	4.2. Analysis of documentation process quality and usefulness	67%	28%	6%	0%	0%
	4.3. Process improvement feedback loop	50%	22%	22%	6%	0%

Table 9. Breakdown by Maturity Level - DPMM Version 3

Level	%
1	72%
2	28%
3	0%
4	0%

Again, the results from this version are very similar to those of the previous versions. The degrees of satisfaction of practices 2.1 and 2.3 illustrate the big gap between the existence of the policy and the adherence to it.

Using Version 4

The fourth version was released in December 1998. It has been used to assess 12 projects in the time period December 1998 – present. Table 10 shows the results in terms of degree of satisfaction for each key practice. No maturity levels are computed for this version.

Table 10. Key Practices and Degrees of Satisfaction - DPMM Version 4

Key Practices	VL	L	M	H	VH
1. Creation of basic software documents	0%	8%	25%	17%	50%
2. Management recognition of importance of documentation	0%	8%	25%	0%	67%
3. Existence of documentation policy or standards	17%	8%	25%	0%	67%
4. Monitor implementation of policy or standards	8%	8%	42%	25%	17%
5. Existence of a defined process for creation of documents	25%	0%	33%	33%	8%
6. Methods to assure quality of documentation	8%	25%	42%	25%	0%
7. Assessments of usability of documentation	8%	67%	17%	18%	0%
8. Definition of software documentation quality and usability measures	67%	17%	8%	8%	0%
9. Collection and analysis of documentation quality measures	42%	42%	17%	0%	0%
10. Collection and analysis of documentation usability measures	100%	0%	0%	0%	0%
11. Process improvement feedback loop	42%	33%	17%	0%	8%

The results are not very different from the results provided by the assessments using the previous three versions. Once again there is a considerable gap between the intentions and the actions, as clearly illustrated by the degrees of satisfaction of practices 2 (*Management recognition of importance of documentation*), 3 (*Existence of documentation policy or standards*) and 4 (*Monitor implementation of policy or standards*).

4. SUMMARY AND CONCLUSIONS

Software process maturity models are conceptual frameworks to improve software development and maintenance processes. They do not guarantee success in obtaining higher quality products or more efficient processes. To achieve these goals, there has to be a real commitment and actions to fulfill that commitment from the whole organization.

This paper has presented the results obtained from the assessments of 91 projects at 41 companies using a documentation process maturity model. Its purpose is to profile the key components of the system documentation process, and an assessment procedure whose goal is to determine how well an organization's documentation process matches that of the model. We developed a simple assessment questionnaire that takes a short time to complete and whose responses provide information for an assessment report that describes how the organization's process stands relative to the model and suggests changes to improve the process.

Our results show a clear picture of process immaturity and general software documentation process practice non-satisfaction. Not surprisingly, this is reflected in a steady decrease in key practice satisfaction expected in less mature organizations. The key practices are listed in a natural maturity order (e.g. practices of more mature organizations appear later in the list) that clearly show the trend. Assessed organizations mostly satisfy key practices linked to assuring the existence of policies or standards, but they fail for higher maturity key practices related to assuring the actual monitoring of compliance to these policies or standards. There is an acknowledgement of the problem but little action to back it up. The results also highlight the low satisfaction for key practices related to assuring the quality and usability of the actual documents produced. The main challenge is to make a serious effort to enhance the software documentation process, by adopting and carrying out explicit policies aimed at process improvement.

One crucial point that our experience has made very clear is the importance and fundamental role of the key practices. They drive the generation of the assessment questionnaire. When an organization's process is assessed relative to the model, the assessment is actually measuring the organization's degree of satisfaction of the key practices. That is, how well is the organization carrying out the key practices. In spite of this, the maturity level has been the most commonly used indicator of the organization's process maturity. The maturity level is such a broad indicator that it is of limited value as it provides incomplete information about which key practices are satisfied and which are not.

The results and analysis reported in this paper are part of a broad on-going research effort aimed at improving the whole software process.

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REFERENCES

1. D. Card, F. McGarry and G. Page. Evaluating software engineering technologies. *IEEE Transactions on Software Engineering*, **13(7)** (1987) 845-851.
2. C. Cook and M. Visconti. Documentation is important. *CrossTalk*, **7(11)** (1994) 26-30.
3. C. Cook and M. Visconti. New and improved documentation process model, in *Proceedings of the 14th Pacific Northwest Software Quality Conference*, Portland, Oregon, October 1996 (PNSQC, Portland, 1996), pp. 364-380.
4. W. Humphrey. *Managing the software process* (Addison-Wesley, Reading, 1989).
5. B. Lientz and E. Swanson. Problems in applications software maintenance. *Communications of the ACM*, **24(11)** (1981) 763-769.
6. M. Paulk, B. Curtis, M. Chrissis and C. Weber. *The Capability Maturity Model guidelines for improving the software process* (Addison-Wesley, Reading, 1995).
7. M. Paulk, B. Curtis, M. Chrissis and C. Weber. Capability Maturity Model, version 1.1. *IEEE Software*, **10(4)** (1993) 18-27.
8. J. Pence and S. Hon III. Building software quality into telecommunications network systems. *Quality Progress*, (October 1993) 95-97.
9. H. Rombach and V. Basili. Quantitative assessment of maintenance: an industrial case study, in *Proceedings of the IEEE Conference on Software Maintenance*, Austin, Texas, September 1987 (IEEE, Washington, 1987), pp. 134-144.
10. M. Visconti and C. Cook. A software system documentation process maturity approach to software quality, in *Proceedings of the 11th Pacific Northwest Software Quality Conference*, Portland, Oregon, October 1993 (PNSQC, Portland, 1993), pp. 257-271.
11. M. Visconti and C. Cook. Evolution of a maturity model – critical evaluation and lessons learned. *Software Quality Journal* (2000) (to appear).
12. C. Cook and M. Visconti. What to do after the assessment report?, in *Proceedings of the 17th Pacific Northwest Software Quality Conference*, Portland, Oregon, October 1999 (PNSQC, Portland, 1999), pp. 214-228.
13. M. Visconti and C. Cook. A meta-model for software process maturity. *Technical Report OSU/CS-00-60-07* (OSU/CS, Corvallis, Oregon, 2000).