Software Measurement Body of Knowledge – Overview of Empirical Support

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Abstract

The "Guide to the Software Engineering Body of Knowledge – SWEBOK" (2004 version) – contains ten distinct Knowledge Areas (KAs) and three common themes: Quality, Tools and Measurement. Since measurement is present in all the KAs, an initial taxonomy for measurement had been proposed as a foundation for the addition of a new specific KA on Software Measurement. To verify the feasibility of such a proposal, this paper presents an overview of the level of empirical support for each measurement topic identified. The types of empirical support adopted are from the Zelkowitz & Wallace taxonomy.

Key words – SWEBOK, ISO TR 19759, Software Measurement, Knowledge Area, Empirical support

1. Introduction

One of the key projects specifically designed to contribute to the recognition of software engineering as a *bona fide* engineering discipline is the *Guide to the Software Engineering Body of Knowledge* (**SWEBOK**) [ABRA01, 05, ISO05]. This project has been sponsored by the IEEE Computer Society and supported by a consortium of industrial sponsors. The main goal of the SWEBOK was to develop an international consensus on the "generally accepted knowledge" in the software engineering domain. The relevance of the SWEBOK has been recently enhanced by its acceptance as an ISO technical report (ISO/IEC TR 19759:2005) [ISO05]. This Guide to the SWEBOK was developed in a three-phase approach:

- 1st release: *Straw Man* version – 1997,
- 2nd release: *Stone Man* version (also referred to as the Trial Version – 2001) [ABRA01],
- 3rd release: *Iron Man* version – 2004 [ABRA05][1]

The Guide to the SWEBOK documents the consensus on the structure of the software engineering knowledge, which consists of ten (10) Knowledge Areas (KAs): the first five representing what the ISO calls the *primary* processes in the 12207 standard [ISO95], and the other five the *support* and *organizational* processes (see Table 1). The 10 KAs have a common architecture, as illustrated in Fig. 1.

SWEBOK Knowledge Areas (KA)	ISO 12207 Process Types
1. Software Requirements	Primary processes
2. Software Design	
3. Software Construction	
4. Software Testing	
5. Software Maintenance	
6. Software Configuration	Support and Organizational processes
7. Software Engineering Management	
8. Software Engineering Process	
9. Software Engineering Tools & Methods	
10. Software Quality	

Table 1 - *Guide to the SWEBOK: KA [ABRA05]*

[1] Freely available on the SWEBOK website at: www.swebok.org

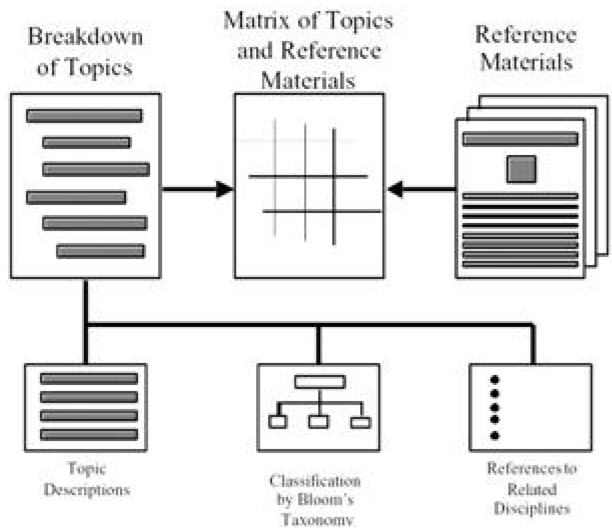

Figure 1 – *Organization of a Knowledge Area (KA) description in the SWEBOK [ABRA05]*

In the Guide to the SWEBOK, there are *common themes* that cut across most KAs, such as *Quality*, *Tools* and *Measurement.* Two of these have been recognized as distinct KAs, that is, Quality and Tools. Measurement, however, did not achieve recognition as a distinct KA. In this paper, we explore the reasons for this and propose contributions that we hope will lead to software measurement being recognized as a KA in its own right.

Measurement is, of course, fundamental to the engineering disciplines, and, at the inception of the SWEBOK, it had been given to all the KA associate editors as a criterion for identifying relevant measurement-related knowledge in their respective KAs.

Individual associate editors initially developed each of the 10 KAs on their own, which led to different levels of breadth and depth of treatment of subtopics like measurement. This is also an indication that measurement-related knowledge has not been developed equally across KAs over the recent history of software engineering. Subsequently, an initial, unified view of the measurement knowledge in software engineering was proposed in [BUGL04] in the form of a proposal for a distinct KA on Software Measurement, taking into account all the measurement-related items from the existing KAs in the 2001 edition of the Guide to the SWEBOK and organizing them into an initial breakdown, refined subsequently in the 2004 update to the SWEBOK [ABRA05].

This paper presents an analysis of the experimental support for this proposed additional KA. Such an analysis can contribute to highlighting current strengths and weaknesses that need to be addressed to meet the criteria for the addition of a new KA, as specified in the evolution strategy defined in the 2004 version of the SWEBOK Guide ([ABRA05] – Appendix B: *Evolution of the Guide*).

The paper is organized as follows: Section 2 introduces prior work on a proposed Software Measurement KA. Section 3 refers to a taxonomy for classifying empirical in software engineering and an illustrative use in the analysis of the 2001 version of the Software Construction KA. Section 4 applies the classification to the current measurement KA proposal. Finally, section 5 presents some suggestions for the next steps.

2. Software Measurement topics in SWEBOK – Prior work

The SWEBOK 2001 version presented an interim version of the Guide for the purpose of obtaining feedback for reviewers across the world[2]. This feedback process provided many refinements in most of the 10 KAs, increasing the depth and level of consistency across them; however, comments received did not significantly increase the content on measurement-related issues nor on the positioning of measurement within the overall software engineering taxonomy.

Starting from the observation that in the 2001 version of the Guide to the SWEBOK two of the three "common themes" (e.g. Quality and Tools) had been recognized as distinct KAs, we investigated in 2003 whether or not measurement could be a candidate KA, and we proposed an initial version of a measurement KA [BUGL04].

[2] Refer to the SWEBOK website (http://www.swebok.org) for the complete list of reviewers and related demographics.

In the 2004 revision of the SWEBOK [ABRA05], various contributors added measurement-related knowledge to some KAs where treatment of measurement had initially been fairly weak, such as the Construction KA. Within this 2004 review cycle, a specific proposal for the addition of a new KA was also proposed by two international reviewers; such a proposal, however, was not accepted at that time on the basis that measurement had not yet become generally accepted in the software engineering community, and that no detailed structure had yet been validated by peers in the software engineering measurement community. This proposal also led the SWEBOK editorial team to develop, and publish, criteria for the acceptance of new KAs.

The initial proposal for a measurement KA was updated next by taking into account the SWEBOK 2004 version content and using the Vincenti classification of engineering knowledge types as the preferred analytical tool [ABRA04]. The results of this study are shown in Fig. 2.

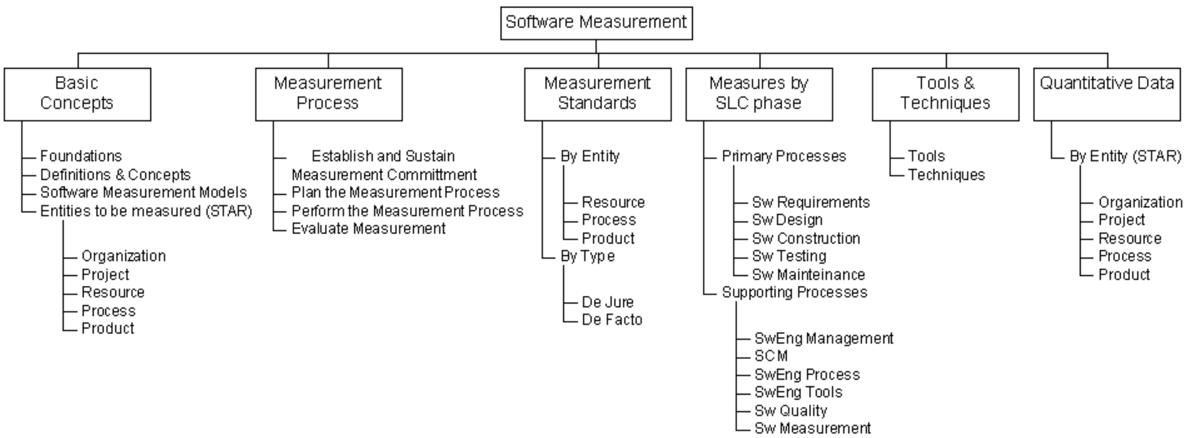

Figure 2 – *The 2004 proposed breakdown for the Software Measurement KA [ABRA04]*

3. Analysis of empirical support for a new KA on measurement

The next step discussed in this paper is the analysis of the empirical support that this proposal of a new measurement KA could bring to the software engineering community.

3.1. The Baseline (Zelkowitz & Wallace)

Zelkowitz & Wallace [ZELK98] have indicated that "*experimentation is one of those terms that is frequently used incorrectly in the computer science community,*" that is, even if researchers proposed new technologies and performed "experiments" to validate them, "*rarely [did] such experimentation involve any collection of data to show that the technology adheres to some underlying model or theory of software development or that the software is effective.*"

Taking into account previous studies in the software engineering domain, Zelkowitz & Wallace proposed a list of 12 empirical support methods[3] grouped into three categories, as summarized in Table 2. Their taxonomy was tested with a list of 612 IEEE software engineering publications covering three different years (1985, 1990 and 1995): their analysis indicated increasing usage of empirical support methods in those publications (the number of papers in the "no experimentation" category decreased during these years, from an initial, roughly 34% (1985) to about 18% (1995). Over the years, the three support methods most often used were, in descending order of frequency: Assertion, Case Study and Lessons Learned, with a predominance of methods from the Observational group.

3.2. A previous application in the SWEBOK Context: Software Construction – Version 2001

In order to identify some weaknesses and provide further guidance on content improvements, Suryn *et al.* [SURY02] applied the Zelkowitz & Wallace taxonomy to a single SWEBOK KA: Software Construction (2001 version). All the references listed in the SWEBOK *matrix of topics vs. reference material* were reviewed and analyzed, and each specific sub-topic was classified by method used using Table 2.

In this study [SURY02], it was observed that almost every sub-topic was based on assertions by experts, pointing to a possible lack of validated scientific knowledge in the domain of Software Construction, with only three topics based on some form of empirical study. The conclusion was, therefore, that there was a "*need for much stronger and unambiguous empirical evidence to ensure that this Knowledge Area develops progressively into a mature engineering*

[3] Zelkowitz & Wallace have used the expression 'validation methods'; however, the expression we prefer to use here is 'empirical support methods'.

discipline." This analysis contributed to improving the subsequent 2004 version of the Construction KA, in terms of a better KA taxonomy supported by much more empirical evidence.

Category / Empirical support method	Description	Weaknesses	Strengths
A. Observational			
A1. Project Monitoring	Collect development data	No specific goals	Provides baseline for the future; inexpensive
A2. Case Study	Monitor project in depth	Poor controls for later replication	Can constrain one factor at low cost
A3. Assertion	Use ad-hoc validation technique	Insufficient validation	Serves as a basis for future experiments
A4. Field Study	Monitor multiple projects	Treatments differ across projects	Inexpensive form of replication
B. Historical			
B1. Literature Search	Examine previous published studies	Selection bias; treatments differ	Large available database; inexpensive
B2. Legacy	Examine data from completed projects	Cannot constrain factors; data limited	Combines multiple studies; inexpensive
B3. Lessons Learned	Examine qualitative data from completed projects	No quantitative data: cannot constrain factors	Determine trends; inexpensive
B4. Static Analysis	Examine structure of developed product	Not related to development method	Can be automated; applies to tools
C. Controlled			
C1. Replicated	Develop multiple versions of product	Very expensive; Hawthorne effect	Can control factors for all treatments
C2. Synthetic	Replicate one factor in lab setting	Scaling up; interactions among multiple factors	Can control individual factors; moderate cost
C3. Dynamic Analysis	Execute developed product for performance	Not related to development method	Can be automated; applies to tools
C4. Simulation	Execute product with artificial data	Data may not represent reality; Not related to development method	Can be automated; applies to tools; evaluation in safe environment

Table 2 - *Taxonomy of Empirical Support Methods [ZELK98]*

Knowledge Topics	Method Used	
2.0. Definition		
2.1. Software Construction and Software Design	A3	Assertion
2.2. The role of tools in construction	A4	Field Studies
2.3. The role of integrated evaluation in construction	A3	Assertion
2.4. The role of standards in construction	---	N/A
2.5. Manual and automated construction	A3	Assertion
2.6. Construction Languages	A3	Assertion
2.7. Programming Languages	---	N/A
3.0. Breakdown		
3.1. Principle of organization		
3.1.1. Reduction in Complexity	A4	Field Studies
3.1.2. Anticipation of Diversity	A3	Assertion
3.1.3. Structuring for Validation	A2	Case Studies
3.1.4. Use of External Standards	---	N/A
3.2. Style of Construction		
3.2.1. Linguistic	---	N/A
3.2.2. Formal	---	N/A
3.2.3. Visual	---	N/A

Table 3 - *Types of empirical method support for each Construction KA sub-topic – SWEBOK 2001 [SURY02]*

4. Empirical support for the Software Measurement KA

To investigate the credibility of the recommended reference material for our proposal for an additional KA on Software Measurement, the level of empirical support as documented in the references is investigated next. Tables 4a to 4c present the references recommended for the proposed Software Measurement KA: it includes both references from SWEBOK 2004 (see full list in Appendix A) plus the additional ones – in bold – some already recommended in [BUGL04] (see full list in Appendix B). The references have been grouped in three columns:

- **International standards** (ISO, IEEE or other standards organizations): These are based on international consensus by either technical experts or ISO-recognized voting countries, or both.
- **Books**: These often represent only the author's opinions. A book also contains a number of chapters, each of which could be based on a different type or types of empirical support. It is usually difficult to give a single classification to a whole book, while it can be easier to do so for individual chapters.

- **Papers and book chapters**[4]: The most relevant empirical support method is mentioned. When there is not a direct mapping to one of the 12 empirical support methods proposed by [ZELK98], the "N.A." code has been assigned.

SWEBOK Measurement Topics Breakdown	Source[5] / Item	International Standards	Books	Papers & Book chapters: Empirical Method Used
1.0. Basic Concepts	New			
1.1. Foundations	SEP, §8.4.3	[ISO93]	**[Zus97]** **[Shep95]**	**[Abr03]:** Legacy (B2)
1.2. Definitions and concepts	SEP, §8.4.3 SEM, §7.6	 [ISO15939-02] [ISO93]	[Kan02]	[Abr96]: Legacy (B2) [Fen98: c2]: Literature Search (B1) [Pfl01: c11]: Literature search (B1) **[Abr02]**: Literature Search (B1)
1.3. Software Measurement Models	SEM, §7.2.6	[ISO15939-02]		
1.4. Entities to be measured (STAR)	New			**[Bug02]**: Literature search (B1)
1.4.1. Organization				---
1.4.2. Project				---
1.4.1. Resource				---
1.4.1. Process				---
1.4.1. Product				---
2.0. Measurement Process				**[Jac97]**: Static Analysis (B4)
2.1. Establish and Sustain Measurement Commitment	SEM, §2.6.1	[ISO15939-02]	**[PSM03]**	[Fen98: c3,c13]: Literature Search (B1) [Pre04: c22]: Literature Search (B1)
2.2. Plan the Measurement Process	SEM, §2.6.2	[ISO15939-02]	**[PSM03]**	
2.3. Perform the Measurement Process	SEM, §2.6.3	[ISO15939-02]	**[PSM03]**	
2.4. Evaluate Measurement	SEM, §2.6.4	[ISO15939-02]	**[PSM03]**	
3.0. Measurement Standards	New			
3.1. By Entity				
3.1.1. Resource		**[IEEE830-98]**		
3.1.2. Process	 SEP, App.B	[ISO15939-02] [IEEE1219-98] **[IEEE12207.0-96]** **[ISO15288-02]** **[ISO95]** **[IEEE1045-92]**		
3.1.3. Product	SEP, §8.4.2 SEP, App.B	[ISO9126-01] [IEEE14143.1-00] [ISO19761-03] [ISO20926-03] [ISO20968-02] **[ISO14598]** **[ISO9241]** **[ISO24570]** **[IEEE1061-98]**	[Jon96]	
3.2. By Type				
3.2.1. De Jure	All the IEEE/ISO std on SwMeas previously listed in Section 3.1			
3.2.2. De Facto	GQM		**[PSM03]** **[Sol99]**	**[Bas94]:** Assertion (A3)

Table 4a - *Empirical support for the Software Measurement KA sub-topics (1 of 3)*

[4] This is an interim classification.

[5] The KAs are introduced by their initial letters: e.g. Software Engineering Management = SEM; Software Quality = SQ; and so on.

SWEBOK Measurement Topics Breakdown	Source / Item	International Standards	Books	Papers & Book chapters: Empirical Method Used
4.0. Measures by SLC phase				
4.1. Primary Processes				
4.1.1. Software Requirements	SR, §1.7.5	[IEEE14143.1-00] **[ISO19761-03]** **[ISO20926-03]** **[ISO20968-02]**		
4.1.2. Software Design	SD, §2.4.3			[Jal97: c5,c6,c7] : Literature search (B1) [Pre04: c15]: Literature Search (B1)
4.1.3. Software Construction	SC, §3.2.3		[McC04]	**[McCA76]**: Static Analysis (B4)
4.1.4. Software Testing	ST, §4.4.1.1 ST, §4.4.1.3 ST, §4.4.1.4 ST, §4.4.1.5 ST, §4.4.2.1 ST, §4.4.2.2 ST, §4.4.2.3 ST, §4.5.1.6 ST, §4.5.1.7			[Bei90:c7s4.2] : Literature search (B1) [Jor02:c9] : Literature search (B1) [Per95:c20] : Literature search (B1) [Pfl01:c9] : Literature search (B1) [Lyu96:c7] : Literature search (B1) [Pfl01:c9] : Literature search (B1) [Jor02:c9] : Literature search (B1) [Pfl01:c8] : Literature search (B1) [Pfl01:c8] : Literature search (B1) [Zhu97:s3.2-s3.3]: Literat. Search (B1) [Per95:c4,c21] : Literature search (B1) [Bei90:c2s2.4] : Literature search (B1) [Per95:c2] : Literature search (B1)
4.1.5. Software Maintenance	SM, §5.2.4.1	[IEEE1219-98:Tab3] [IEEE1219-98] [ISO9126-01] **[ISO19761-03]**		[Abr93]: Case Study (A3) [Car90:s2-s3] : Literature search (B1) [Sta94: 239-249]: Field Study (A4)
4.2. Supporting Processes				
4.2.1. Software Engineering Management	SEM, §7.6.4	[ISO15939-02: s5.4.1, s5.4.2 +App.D]		**[Stri00]**: Legacy (B2)
4.2.2. Software Configuration Management	SCM, §6.1.5.1			[Buc96: c3] : Literature search (B1) [Roy98: 188-202, 283-298]
4.2.3. Software Engineering Process	SEP, §8.4.1	[ISO15939-02]		[Fen98: c3,c11]: Literature Search (B1) [Som05: c25] : Literature search (B1)
4.2.4. Software Engineering Tools	**New**			
4.2.5. Software Quality	SQ, §10.3.4		[Gra92] [Fen97] [Jon96] [Kan02] [Lyu96] [Mus99] [Pfl01]	[Rak97: pp39-50]: Literature Search (B1)
4.2.6. Software Measurement	SEM, §7.6.4	[ISO15939-02: s5.4.1 +App.D]		
5.0. Tools & Techniques				
5.1. Tools	SETM, §9.1.7		[Dor02]	
5.2. Techniques	SEP, §8.4.5 SEP, §8.4.5.1 SEP, §8.4.5.2	 [IEEE12207.0-96]	[Gol99] [Fen98] [SEL96] [Mus99] [Hum95]	

Table 4b - *Empirical support for the Software Measurement KA sub-topics (continued 2 of 3)*

SWEBOK Measurement Topics Breakdown	Source / Item	International Standards	Books	Papers & Book chapters: Empirical Method Used
6.0. Quantitative Data	New			
6.1. By Entity (STAR)				
6.1. Organization	Appraisal CMMI, Sw-CMM, SPICE, … Performance Mgmt Models (MBQA, EFQM, BSC, …)			**[SEMA04a]**: Field Study (A4) **[SEMA04b]**: Field Study (A4)
6.2. Project	Benchmark ISBSG r9			**[ISBSG04]**: Field Study (A4)
6.3. Resource	P-CMM, …			**[PCMM-01]**: Literature Search (B1)
6.4. Process	Appraisal CMMI, Sw-CMM, SPICE, …			**[SEMA04a]**: Field Study (A4) **[SEMA04b]**: Field Study (A4)
6.5. Product	ISO/IEC 9126 profiles, …			**[Fra03]**: Literature Search (B1)

Table 4c - *Empirical support for the Software Measurement KA sub-topics (continued 3 of 3)*

The summary results of the analysis of the references using the Zelkowitz & Wallace taxonomy are presented in Table 5 and can be summarized as:

- References from the 2004 SWEBOK edition: Almost all measurement-related references are either standards or entire books, with a small number being technical papers, reports, manuals and single book chapters.
- Additional references recommended for filling the gaps (in bold in Tables 4a to 4c): 24 additional references distributed across the range of empirical methods, as indicated in Table 5:

	Abs	%	Rank
N.A. – Standards	**9**	37.5	**1**
N.A. – Books	**4**	16.7	**2**
A4. Field Study	**3**	12.5	**3**
B2. Legacy	**3**	12.5	**3**
B1. Literature Search	**2**	8.3	**5**
B4. Static Analysis	**2**	8.3	**5**
A3. Assertion	**1**	4.2	**7**
C4. Simulation	**0**	0.0	**8**
A1. Project Monitoring	**0**	0.0	**8**
A2. Case Study	**0**	0.0	**8**
B3. Lessons Learned	**0**	0.0	**8**
C1. Replicated	**0**	0.0	**8**
C2. Synthetic	**0**	0.0	**8**
C3. Dynamic Analysis	**0**	0.0	**8**
	24	**100.0**	

Table 5 - *Empirical support methods: frequencies for the proposed additional references*

5. Summary and Next Steps

The Guide to the Software Engineering Body of Knowledge – **SWEBOK** – is an IEEE project that was started in 1998. Its purpose is "*to provide a consensually validated characterization of the bounds of the software engineering discipline and to provide a topical access to the Body of Knowledge supporting that discipline.*" It contains ten distinct KAs and three common themes: one of the three common themes in the current SWEBOK Guide is Measurement, which has not yet been recognized as a distinct KA. Two years ago, an analysis was initiated to investigate the feasibility of proposing a new KA on Measurement. The second step, presented here, was to analyze the type of empirical support for the measurement-related references in the 2004 version and to evaluate them in terms of coverage (*is any section in a chapter covered with an appropriate number of references?*) and using the Zelkowitz & Wallace taxonomy of empirical support methods (*does the new KA have an appropriate number of empirical methods represented through its references?*).

After analyzing the references in the proposed measurement KA breakdown, it was noted that a large number of references are of the standards and book types, with a limited number of references to technical papers, reports and guides. Twenty four (24) additional references were added to the breakdown, in order to cover the "gaps" in the measurement references. Some of the next steps will include analyzing the distribution of the reference type, and the identification of further seminal references, which would have better empirical support, that is, the missing types in the lower part of Table 7. Other steps will also be required to get this measurement taxonomy validated by peers in the software engineering measurement community and eventually to reach a point where it would be recognized as generally accepted in the broaded software engineering community.

REFERENCES

[ABRA01] ABRAN A., MOORE J.W., BOURQUE P., DUPUIS R., TRIPP L., *Guide to the Software Engineering Body of Knowledge – Trial Version*, IEEE Computer Society, Los Alamos, 2001, URL: http://www.swebok.org/stoneman/trial_1_00.html

[ABRA04] ABRAN A., BUGLIONE L. & SELLAMI A.., *Software Measurement Body of Knowledge - Initial Validation using Vincenti's Classification of Engineering Knowledge types*, in "Software Measurement - Research and Application", Proceedings of the IWSM 2004 / MetriKon 2004 Software Metrik Kongress, 14th International Workshop on Software Measurement and Metrik Kongress, November 2-5, 2004, Konigs Wusterhausen (Germany), Shaker Verlag, ISBN 3-8322-3383-0, pp. 255-270

[ABRA05] ABRAN A., MOORE J.W., BOURQUE P., DUPUIS R. & TRIPP L., *Guide to the Software Engineering Body of Knowledge – 2004 Version*, IEEE Computer Society, Los Alamos, 2005, also ISO/IEC TR 19759: 2005; also available as a free web version at: URL: http://www.swebok.org/ironman/pdf/Swebok_Ironman_June_23_%202004.pdf

[BUGL04] BUGLIONE L. & ABRAN A., *The Software Measurement Body of Knowledge*, Proceedings of 1st Software Measurement European Forum (SMEF2004), 28-30 January 2004, Rome (Italy), ISBN 88-86674-33-3, pp.84-94, URL: http://www.lrgl.uqam.ca/publications/pdf/795.pdf

[ISO95] ISO/IEC 12207: 1995 *Information Technology: Software Life Cycle Processes*, International Organization for Standardization, Geneva, 1995.

[ISO05] ISO/IEC TR 19759:2005 *SOFTWARE ENGINEERING – GUIDE TO THE SOFTWARE ENGINEERING BODY OF KNOWLEDGE*, International Organization for Standardization, Geneva, 1995.

[SURY02] SURYN W., ROBERT F., ABRAN A., BOURQUE P. & CHAMPAGNE R., *Experimental Support Analysis of the Software Construction Knowledge Area in the SWEBOK Guide (Trial Version 1.0)*, Proceedings of the 10th International Workshop on Software Technology and Engineering Practice (STEP2002), 6-8 October 2002, Montréal (Canada), URL: http://www.lrgl.uqam.ca/publications/pdf/764.pdf

[ZELK98] ZELKOWITZ M.V. & WALLACE D.R., *Experimental Models for validating Technology*, IEEE Computer, May 1998, pp. 23-31, URL: http://www2.umassd.edu/SWPI/science/r5023.pdf

Appendix A – References for the Software Measurement KA (SWEBOK[6] - 2004)

[Abr93] A. ABRAN & H. NGUYENKIM, "Measurement of the Maintenance Process from a Demand-Based Perspective," *Journal of Software Maintenance: Research and Practice*, vol. 5, iss. 2, 63-90, 1993, URL: http://www.lrgl.uqam.ca/publications/pdf/7.pdf

[Abr96] A. ABRAN AND P. N. ROBILLARD, "Function Points Analysis: An Empirical Study of its Measurement Processes," *IEEE Transactions on Software Engineering*, vol. 22, 895-909, 1996, URL: http://www.lrgl.uqam.ca/publications/pdf/64.pdf

[Bei90] B. BEIZER, "Software Testing Techniques," International Thomson Press, 1990

[Buc96] F. J. BUCKLEY, *Implementing Configuration Management: Hardware, Software, and Firmware*, Second ed. Los Alamitos, CA: IEEE Computer Society Press, 1996

[Car90] D. N. CARD & R. L. GLASS, *Measuring Software Design Quality*: Prentice Hall, 1990

[Dor02] M. DORFMAN & R. H. THAYER, Eds., "Software Engineering." (Vol. 1 & vol. 2), IEEE Computer Society Press, 2002

[Fen98] N. E. FENTON AND S. L. PFLEEGER, *Software Metrics:A Rigorous & Practical Approach*, Second ed: International Thomson Computer Press, 1998

[Gol99] D. GOLDENSON, K. EL-EMAM, J. HERBSLEB & C. DEEPHOUSE, "Empirical Studies of Software Process Assessment Methods," presented at Elements of Software Process Assessment and Improvement, 1999, URL: http://www2.umassd.edu/SWPI/McGill/spai.pdf

[Gra92] R. B. GRADY, *Practical Software Metrics for project Management and Process Management*: Prentice Hall, Englewood Cliffs, NJ 07632, 1992

[Hum95] W. HUMPHREY, *A Discipline for Software Engineering*: Addison Wesley, 1995

[IEEE1219-98] IEEE Std 1219-1998, *IEEE Standard for Software Maintenance*: IEEE, 1998

[IEEE12207.0-96] IEEE/EIA 12207.0-1996//ISO/IEC12207:1995, *Industry Implementation of Int.Std. ISO/IEC 12207:95, Standard for Information Technology -Software Life Cycle Processes*, vol. IEEE, 1996

[IEEE14143.1-00] IEEE Std 14143.1-2000//ISO/IEC14143-1:1998, *Information Technology-Software Measurement-Functional Size Measurement-Part 1: Definitions of Concepts*: IEEE, 2000

[ISO15939-02] ISO/IEC 15939:2002, *Software Engineering-Software Measurement Process*: ISO and IEC, 2002

[ISO19761-03] ISO/IEC 19761:2003, *Software Engineering-Cosmic FPP-A functional Size Measurement Method*: ISO and IEC, 2003

[ISO20926-03] ISO/IEC 20926:2003, *Software Engineering-IFPUG 4.1 Unadjusted functional Size measurement method-Counting practices manual*: ISO and IEC, 2003

[ISO20968-02] ISO/IEC 20968:2002, *Software Engineering-MK II Function Point Analysis- Counting Practices Manual*: ISO and IEC, 2002

[ISO9126-01] ISO/IEC 9126-1:2001, *Software Engineering-Product Quality-Part 1: Quality Model*: ISO and IEC, 2001

[ISO93] ISO VIM, *International Vocabulary of Basic and General Terms in Metrology*. Geneva, Switzerland: ISO, 1993

[Jal97] P. JALOTE, *An Integrated Approach to Software Engineering*, Second ed. New York: Springer-Verlag, 1997

[Jon96] C. JONES, *Applied Software Measurement: Assuring Productivity and Quality*, Second ed: McGraw-Hill, 1996

[Jor02] P. C. JORGENSEN, "Software Testing: A Craftsman's Approach," Second Edition, CRC Press, 2004

[Kan02] S. H. KAN, *Metrics and Models in Software Quality Engineering*, Second ed: Addison-Wesley, 2002

[Lyu96] M. R. LYU, "Handbook of Software Reliability Engineering," Mc-Graw-Hill/IEEE, 1996

[McC04] S. MCCONNELL, "Code Complete: A Practical Handbook of Software Construction," Microsoft Press, 1993

[Mus99] J. MUSA, *Software Reliability Engineering: More Reliable Software, Faster Development and Testing*: McGraw Hill, 1999

[Per95] W. PERRY, "Effective Methods for Software Testing," Wiley, 1995

[Pfl01] S. L. PFLEEGER, *Software Engineering: Theory and Practice*, Second ed: Prentice-Hall, 2001

[Pre04] R. S. PRESSMAN, "Software Engineering: A Practitioner's Approach" Sixth ed: McGraw-Hill, 2004

[Rak97] S. R. RAKITIN, *Software Verification and Validation: A Practitioner's Guide*: Artech House, Inc., 1997

[Roy98] W. ROYCE, *Software Project Management, A United Framework*: Addison-Wesley, 1998

[SEL96] SOFTWARE ENGINEERING LABORATORY, "Software Process Improvement Guidebook," NASA/GSFC, Technical Report SEL-95-102, April, 1996, URL: http://sel.gsfc.nasa.gov/website/documents/online-doc/95-102.pdf

[Som05] I. SOMMERVILLE, *Software Engineering*, Seventh ed: Addison-Wesley, 2005

[Sta94] G. E. STARK, L. C. KERN & C. V. VOWELL, "A Software Metric Set for Program Maintenance Management" *Journal of Systems and Software*, vol. 24, iss. 3, March, 1994, URL: http://members.aol.com/geshome/ibelieve/sus.pdf (draft version)

[Zhu97] H. ZHU, P. A. V. Hall and J. H. R. May, "Software Unit Test Coverage and Adequacy," *ACM Computing Surveys*, vol. 29, iss. 4, 366-427, Dec., 1997, URL: http://laser.cs.umass.edu/courses/cs521-621/papers/ZhuHallMay.pdf

[6] Reference style as in SWEBOK KA - URL address added when available

Appendix B – Additional References Recommended for the Software Measurement KA

[Abr02] ABRAN, A. & SELLAMI, A.: *Initial Modeling of the Measurement Concepts in the ISO Vocabulary of Terms in Metrology.* Proc. of the 12th International Workshop on Software Measurement (IWSM 2002), October 7-9, 2002, Magdeburg, Shaker Publ., Aachen, pp. 9-20, URL: http://www.lrgl.uqam.ca/publications/pdf/755.pdf

[Abr03] ABRAN A., SELLAMI A. & SURYN W.: *Metrology, Measurement and Metrics in Software Engineering.* Proc. of the 9th IEEE International Symposium on Software Metrics (METRICS 2003), 3-5 September 2003, Sydney (Australia), pp. 2-11, URL: http://www.lrgl.uqam.ca/publications/pdf/798.pdf

[Bas94] BASILI, G.CALDIERA & D.ROMBACH, *The Goal-Question-Metric paradigm*, in "Encyclopedia of Software Engineering" - 2 Volume Set, pp 528-532, Copyright by John Wiley & Sons, Inc., 1994, URL: http://www.cs.umd.edu/projects/SoftEng/ESEG/papers/gqm.pdf

[Bug02] BUGLIONE & A.ABRAN, *ICEBERG: a different look at Software Project Management*, IWSM2002 in "Software Measurement and Estimation", Proceedings of the 12th International Workshop on Software Measurement (IWSM2002), October 7-9, 2002, Magdeburg (Germany), Shaker Verlag, ISBN 3-8322-0765-1, pp. 153-167, URL: http://www.lrgl.uqam.ca/publications/pdf/757.pdf

[Fra03] FRANCH X. & CAVALLO J.P, *Using Quality Models in Software Package Selection*, IEEE Software, vol. 20, no. 1, pp. 34-41, January/February 2003

[IEEE1045-92] IEEE, *Standard for Software Productivity Metrics*, Std 1045-1992

[IEEE1061-98] IEEE, *Standard for a Software Quality Metrics Methodology*, Std 1061-1998

[IEEE1074-97] IEEE, "Std 1074-1997: Standard for Developing Software Life Cycle Processes," 1997

[IEEE830-98] IEEE, *Recommended Practice for Software Requirements Specifications*, Std 830-1998

[ISO14598] ISO, ISO/IEC, "14598 - Information technology -- Software product evaluation, Parts 1-6" International Organization for Standardization, 1999-2001

[ISO15288-02] ISO, ISO/IEC, "IS 15288:2002: Systems Engineering – System Life Cycle Processes," International Organization for Standardization, 2002, Geneva

[ISO24570] ISO/IEC, IS "*24570:2005 - Software engineering -- NESMA functional size measurement method version 2.1 -- Definitions and counting guidelines for the application of Function Point Analysis*", International Organization for Standardization, 2005

[ISO9241] ISO/IEC, *Ergonomic requirements for office work with visual display terminals (VDTs) -- Part 11: Guidance on usability*, International Organization for Standardization, 1998

[ISO95] ISO, ISO/IEC JTC1/SC7/WG10, TR 15504-5, *Software Process Assessment - Part 5: An Assessment Model and indicator guidance*, v.3.03, International Organization for Standardization, 1998

[Jacq97] JACQUET J.P. AND ABRAN A., "*From Software Metrics to Software Measurement: A Process Model*" The 3rd IEEE International Software Engineering Standard Symposium, ISESS'97, Walnut Creek, CA, June 2-6, 1997, IEEE Computer Society Press; URL: http://www.lrgl.uqam.ca/publications/pdf/208.pdf

[McCA76] MCCABE T.J., *A complexity measure, IEEE Transactions on Software Engineering*, SE-2(4):308-320, December 1976; URL: http://www.dsi.unive.it/~marzolla/didattica/IngSoftware2005/mccabe.pdf

[PCMM-01] CURTIS B., HEFLEY B. & MILLER S., *People Capability Maturity Model (P-CMM) version 2.0*, Software Engineering Institute, CMU/SEI-2001-MM-001, URL: http://www.sei.cmu.edu/pub/documents/01.reports/pdf/01mm001.pdf

[PSM03] DOD, *Practical Software Measurement: A Foundation for Objective Project Management*, v. 4.0b1, 2003 URL: http://www.psmsc.com/PSMGuide.asp

[SEMA04a] SOFTWARE ENGINEERING INSTITUTE, *Process Maturity Profile Sw-CMM 2004 Mid-Year Update*, Software Engineering Measurement and Analysis Team, Carnegie Mellon University, August 2004; URL: http://www.sei.cmu.edu/sema/pdf/SW-CMM/2004aug.pdf

[SEMA04b] SOFTWARE ENGINEERING INSTITUTE, *Process Maturity Profile CMMI v1.1 SCAMPI v1.1 Class A Appraisal Results 2004 Mid-Year Update*, Software Engineering Measurement and Analysis Team, Carnegie Mellon University, August 2004; URL: http://www.sei.cmu.edu/sema/pdf/CMMI/2004aug.pdf

[Shep95] SHEPPERD M., *Foundations of Software Measurement*, Prentice-Hall, 1995, ISBN 0133361993

[Sol99] VAN SOLINGEN R. & BERGHOUT E., *The Goal/Question/Metric Method: A practical guide for Quality Improvement of Software Development*, Mc-Graw Hill, 1999, ISBN 0-07-709553-7

[Stri00] STRIKE K., EL-EMAM K & MADHAVJI N., *Software Cost Estimation with Incomplete Data*, NCR 43618, Technical Report, National Research Council Canada, January 2000, URL: http://www.software-metrics.org/documents/1071.pdf

[Zus97] ZUSE, H. *A Framework of Software Measurement*, De Gruyter, Berlin, 1997, ISBN 3-11-015587-7