

Understanding Maturity Models Results of a Structured Content Analysis

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Abstract: Maturity models are popular instruments used, e.g., to rate capabilities of maturing elements and select appropriate actions to take the elements to a higher level of maturity. Their application areas are wide spread and range from cognitive science to business applications and engineering. Although there are many maturity models reported in scientific and non-scientific literature, the act of how to develop a maturity model is for the most part unexplored. Many maturity models simply – and vaguely – build on their, often well-known, predecessors without critical discourse about how appropriate the assumptions are that form the basis of these models. This research sheds some light on the construction of maturity models by analysing 16 representative maturity models with the help of a structured content analysis. The results are transformed into a set of questions which can be used for the (re-)creation of maturity models and are answered with the help of the case example of a knowledge maturity model. Furthermore, a definition of the term maturity model is developed from the study's results.

Keywords: capability, maturity model, knowledge maturing, structured content analysis

Categories: H.1.0, H.3.1, M.9

1 Maturity modelling and knowledge maturing

Maturing has been used as an analytic, explanatory or normative concept in several domains, the most well-known of which is software engineering, e.g., Nolan's stage theory [Nolan 1973], the capability maturity model integration (CMMI, <http://www.sei.cmu.edu/cmmi/>) or the Software Process Improvement and Capability Determination model (SPICE, <http://www.isospice.com/>). The identification of 74 different maturity models from domains within the spectrum of (business) information systems and computer science shows the great variety and widespread use of maturity models available in the literature. However, this list only provides the tip of an iceberg due to the fact that there are many more maturity models in other domains, e.g., biology, sociology or psychology [Greenberg, et al. 1974, 331pp].

An analysis of a sample of maturity models has shown that many models differ with respect to their characteristics. But at the same time also several similarities within these models have been found which in part can be explained by the fact that many authors of maturity models simply build on their predecessors without much thinking about the appropriateness of their design decisions. This suggests that the concept of maturity modelling should be reflected and reassessed.

As a deeper understanding of maturing and maturity models is necessary for the creation of a new or revised maturity model, goals of this paper are to give an overview of the different conceptions of maturing and fundamental principles of maturity models and show the applicability of the results with the help of the case

example of a knowledge maturity model. The paper presents the results of an in-depth analysis of 16 maturity models for their individual characteristics in order to gain information about the nature of maturing and maturity modelling. The results are then used to inform future development of maturity models in the domains of (business) information systems and computer science with a special emphasis on the field of knowledge management, i.e. knowledge maturing. Aspects of how these findings could be used to inform the creation of new or the revision of existing maturity models are discussed with the help of the example of a knowledge maturity model. Section 2 gives an overview of the procedure taken for the analysis of maturity models. Section 3 presents and discusses the results of the structured content analysis of 16 maturity models. Beyond that, section 4 proposes a definition for the term maturity model, before section 5 concludes this paper.

2 A study design for the analysis of maturity models

The investigation into the nature of maturity and the act of maturity modelling was performed with the help of the structured content analysis method. This section presents the applied study design for the investigation of 16 maturity models.

Analysis in the scientific world is often distinguished into qualitative and quantitative approaches. Quantitative research strategies are based on the model of the natural sciences and therefore facilitate the testing of hypotheses. Qualitative research strategies are based on the model of the social sciences and follow an inductive approach of research. This approach could also be described as an understanding approach which is often used to build hypotheses. [Schambach-Hardtke 2005, 18].

The aim of the current research is to explore and analyze existing models and to investigate characteristics and not to test hypotheses which would require a prior investigation. This procedure of identifying characteristics demands a qualitative approach. We decided to rely on textual descriptions of maturity models as sources for our investigation rather than empirical evidence in order to be able to cover more models and compare them. A suitable method focusing on the analysis of contents and the identification of criteria is the structured content analysis [Mayring 2008, 82pp]; its general procedure is depicted in [Figure 1].

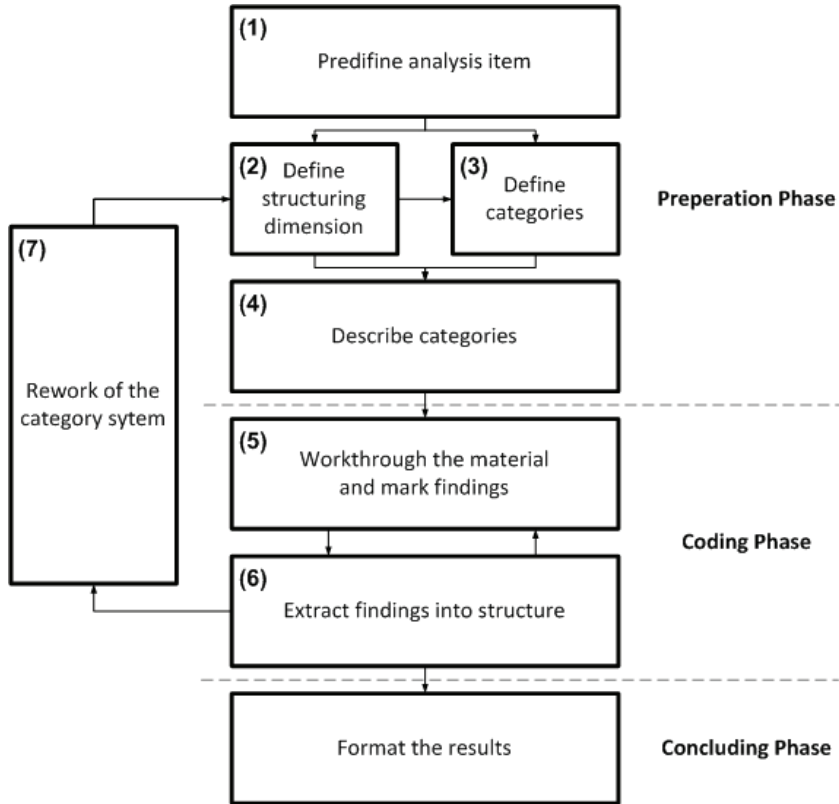


Figure 1: Process flow of a structured content analysis [Mayring 2008, 84]

Structured content analysis starts with the definition of the *analysis items* (1), which are those items that provide descriptions about the model itself. The smallest analysis item can be a single word while the potentially largest item is the entire model description.

In the next step, information associated with an analysis item is extracted from the model context and put into another structure determined by several *structuring dimensions* (2) and its underlying *category system* (3). In this paper, the structure was determined by the analysis question “Which characteristic patterns can be observed by comparing maturity models?” that comprises four sub-questions:

- *What does the term maturing mean?* Aim is to find the underlying concept of maturing employed by the model.
- *Which element is maturing?* Aim is to classify the subject of maturing into person, object or social system and some more detailed categories.
- *What are the main features of a maturity model?* Aim is to find a construction plan for maturity models. Because the authors were not aware of any similar studies, no codes were available, hence an inductive approach was needed to develop these.

- *How is the model used and supported?* Aims to answer the question why some maturity models are applied in practice while others are not. For example for [Krcmar 2005], formal certification is a critical factor.

After the preparation phase which ends with a verbal *definition of the derived categories* (4), the material is *worked through* (5 and 6) for a first time. As new categories may arise during this first run, [Mayring 2008, 83] proposes an iterative approach that allows *rework of the category system* (7). This inductive process is typical for qualitative techniques [Lamnek 2005, 91].

The material was worked through in three phases [see Figure 2] while the number of codes first rapidly increased (phase A), then slowly got more and more stable (phase B) to be finally condensed to a concluding level (phase C). The revision points between the phases were set at 13% (2 models), 50% (8 models) and 100% (16 models) of the models worked through.

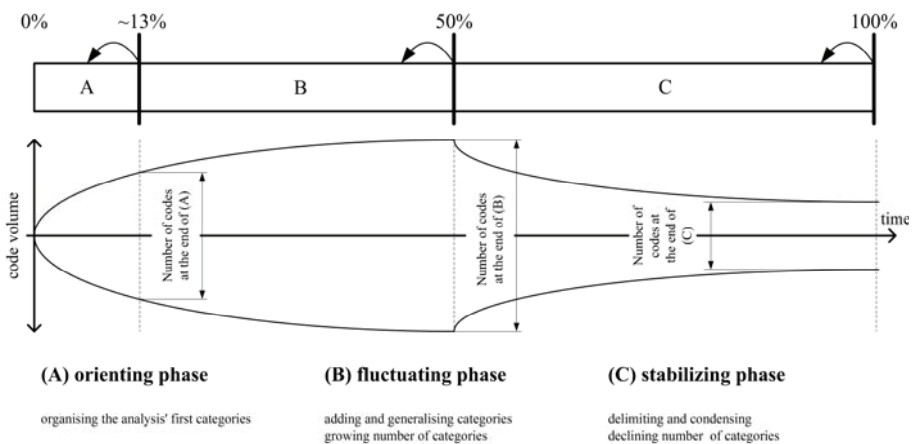


Figure 2: The three steps of the coding process. based on [Hädrich 2008, 222pp]

As suggested by [Dey 1993, 120], the analysed models were selected randomly in order to avoid a coding bias which might have arisen from how the models were selected and would have strained the development of the category system.

An Internet search was carried out in order to get an approximation of the basic population of maturity models as basis to draw a sample resulting in a list of 76 maturity models, further subdivided into three categories:

- maturing of *persons* (8 models found)
- maturing of *objects* (22 models found)
- maturing of *social systems* (46 models found)

The classification into these three categories is in line with knowledge as maturing element that can either be connected to a person, an object or a social system [Maier 2007, 198pp]. In order to equally imply all knowledge media into the

content analysis, identical numbers of models were drawn from each subset. The sample based on this trisection finally contained 16¹ models [Table 1].

Model Subset	Acronym	Approximated Diversification	Source of information ²
Person	PSP	2120	[Humphrey, et al. 2005]
	PCMM	561	[Curtis, et al. 1995]
	SFIA	70	[SFIA 2007]
	Dreyfus Model	31	[Dreyfus, et al. 1988]
	Cross Model	0	[Cross 2007]
Object	SPICE	971	[Coletta 1995]
	UMM	138	[Earthy 1999]
	EMM	77	[Marshall, et al. 2004]
	SMMM	40	[April, et al. 2005]
	bIMM [*]	19	[Chamoni, et al. 2004]
Social System	CMM	13600	[Paulk, et al. 1993]
	COBIT	830	[ITGI 2007]
	Nolan Model	602	[Nolan 1979]
	TMM	184	[Burnstein, et al. 1998]
	CM3	84	[Kajko-Mattsson 2002]
	OIMM	37	[Clark, et al. 2001]

^{*} Model was added to the list subsequently

Table 1: The sixteen selected maturity models to be analysed

In order to maximise meaningfulness of the gained results, only the five most cited models in each category were used as input for the content analysis. The ranking was based on the number of search results returned by Google Scholar using the model's name as search term.

3 Study Results

On the basis of the structured content analysis applied to 16 selected maturity models the following model characteristics could be found which are illustrated with the help of a number of questions. Some characteristics show similarities, others show differences between the analysed models.

A model characteristic was categorised as similar among the analysed models, if the relative frequency of appearance of one code of the sub question was at least 65%. Those sub questions that complied with this criterion are subsumed in [Table 2].

¹ Initially, the sample contained five models from each category. During the analysis, one model, suggested to describe the process of object maturing, was found wrongly classified. As the model was already analysed, it had not been rejected from the analysis table. Instead, the next model from the list of object maturing models was analysed.

² Each model was analysed on the basis of two textual sources. Here, only the most recent of these two sources is listed.

category and code		model name											Frequency (ABS)					
		CMM	COBIT	CM3	Dreyfus model	EMM	Cross Model	Nolan Model	OJMM	PSMM	PSP	SFTA		SMMM	SPICE	TMM	UMM	
How do elements change in time?	change in number	1															3	
	change in nature		1		1		1						1	1			8	
Direction of change	increasing change	1	1	1	1	1	1	1		1	1	1	1	1	1	1	13	
	decreasing change											1					1	
Maturing object	person				1		1				1	1	1				5	
	object	competence																0
		document																1
		infrastructure															1	2
	social System	product					1											1
		service											1					1
		group																0
		team																0
	social System	community																0
		process	1	1	1											1		5
routine																	0	
structure																	1	
Complemented Model	no model is complemented	1	1	1	1	1	1	1	1					1	1	1	10	
	CMM									1	1	1	1	1	1	1	4	
Model design	iterative (one path)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	
	cyclical (many turns)																0	
How do levels built on other levels	upper level comprises lower level	1	1	1				1	1	1			1	1	1	1	10	
	upper level is new concept				1		1					1					3	
How to come from one Level to another?	defined goals have to be fulfilled	1	1	1				1	1	1	1	1	1	1	1	1	11	
	matures implicit				1		1					1					3	
Is there a "not existent" stage?	there is a "not existing" stage		1			1									1		3	
	there is no "not existing" stage						1			1	1						3	
Degree of detail	one trigger per stage																0	
	many triggers per stage	1	1	1				1	1	1	1	1		1	1	1	10	
	no triggers per stage				1							1					2	
Number of Goal Levels	metric values	1	1	1		1		2		1	1	1	1	2	1	1	17	
																	0	
Method of goal benchmarking	metric based		1				1			1		1	1	1	1	1	4	
	non-metric based	1	1	1	1		1		1	1	1	1	1	1	1	1	12	
Model use	conceptual model				1		1	1									5	
	applied model	1	1	1		1			1		1	1	1	1	1	1	10	
What is the model description based on	experience from praxis	1		1			1					1	1		1		6	
	standards												1			1	2	
Certification available?	literature (e.g., other models)		1	1	1	1		1	1		1	1		1	1	1	10	
	certification is available										1			1			2	
Certification available?	no certification available		1		1		1	1					1		1	1	7	
	available																0	

Table 2: Similarities among maturity models

If the relative frequency of appearance of one code within a sub question was smaller than 65% the sub question was added to the differences list [Table 3]. The purpose of this analysis is to inform the design of maturing models. In the following, the main results are presented in the form of questions that can be posed when designing maturity models which are answered on the basis of the example of the knowledge maturity model presented by [Maier, et al. 2007]. The analysis increases modelling precision and shows avenues for further development.

category and code		model name													Frequency (ABS)		
		CMM	COBIT	CM3	Dreyfus model	EMM	Cross Model	Nolans Model	OMMM	PSMM	PSP	SFTA	SMMM	SPICE		TMM	UMM
What means maturing?	change in quality	1		1													4
	change in capability		1			1	1							1	1		7
	change in risk				1												2
	other change	1						1	1				1				3
Conceptual Mother Model	has no conceptual mother model	1			1		1	1			1	1		1			7
	CMM		1	1		1				1			1		1		6
	SPICE					1										1	2
	Other model							1								1	2
Model User	Organisation internal assessment team	1	1	1		1			1	1	1	1	1	1	1	1	12
	Organisation external assessment team	1									1	1	1	1			5
	model is not used practically				1		1	1									3
Complemented Model	no model is complemented	1	1	1	1	1	1	1	1				1	1	1	1	10
	CMM									1	1		1		1		4
Number of stages	metric value	5	6	3	5	6	3	6	5	5	4	7	5	6	5	6	5.5
Is there a "not existent" stage?	there is a "not existing" stage		1			1								1			3
	there is no "not existing" stage						1			1	1						3
What do level descriptions include?	trigger descriptions	1	1	1		1				1	1			1	1	1	9
	activity descriptions (tasks, processes)	1	1			1				1	1		1	1	1	1	9
	conceptual level description	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	13
Level skipping	explicitly allowed											1				1	2
	not recommended	1						1		1							3
Are there parallel maturing processes possible for one unit	parallel maturing is possible	1	1		1	1	1	1	1			1	1				8
	parallel maturing is not possible	1		1									1		1	1	5
Where do assessment data come from	interviews													1	1	1	3
	documents													1			1
	questionnaire	1													1		2
	data						1										1
Tool support	supported by assessment model	1	1									1		1	1	1	6
	supported by software tool														1		1
	not supported by tool				1		1	1	1								4

Table 3: Differences among maturity models

What is the nature of maturing?

- How do elements change in time? *Knowledge elements change in nature while they advance through the knowledge maturing process.*
- What does maturing mean? *Maturing means change in formality, distribution, commitment, legitimation, understandability and teachability of the maturing subject, i.e. of socially constructed knowledge in an organisation.*
- What is the direction of change? *Maturing means an increase of formality, distribution, commitment, legitimation, understandability and teachability.*
- What is the maturing subject? *The maturing subject is a knowledge domain in the sense of knowledge about a topic in a socially distributed activity system.*

How is the model designed?

- Has the model a conceptual mother model? *The knowledge maturing model is not related to any other maturity model.*
- What is the model used for? *The model can be used as an analytic model to help structure the analysis of existing organisational and technical infrastructures in support of goal-directed learning on a collective level.*

- Who uses the model? *The model can be used by people taking on the role of guides helping to foster and reduce barriers for knowledge maturing.*
- Does the model complement other models? *The model does not complement another model.*
- How is the model designed? *The model is designed as a sequence of phases which do not necessarily build on each other. Each phase can use outputs provided by all other phases as inputs for knowledge maturing activities in this phase.*
- How do the stages build on each other? *The stages of the model are independent from each other as the upper stage cannot be traced back to the lower stage.*
- How does the subject proceed from one level to the next? *The maturing element matures implicitly between the stages. However, there can be explicit decisions to take a knowledge domain from one phase to the next one.*
- What is the number of stages? *The knowledge maturing model has five stages.*
- Is there a „not-existing“-stage? *The model has no “not existing“-stage.*
- What do the level descriptions include? *The level descriptions of the knowledge maturing model include conceptual descriptions of the stages.*
- What is the degree of detail of the trigger description? *The model has no triggers between its stages.*
- Is level-skipping allowed? *The model does not mention level skipping.*
- Are there parallel maturing processes possible for one unit? *Within one organisational unit, there might be different knowledge domains which are in different knowledge maturing stages.*
- What is the number of goal levels? *The model has no goals assigned to its stages.*
- What is the method of goal benchmarking? *The model uses a non-metric way of goal benchmarking.*
- Where do assessment data come from? *The model is not practically used yet, so assessment has not been specified yet.*

How is the model used and supported?

- What is the model used as? *The model is used as a conceptual model.*
- Is tool support available? *The model is not supported by a tool.*
- What is the model description based on? *The model is based on practical experience.*
- Is certification available? *There is no certification available for the model.*

4 Implications for maturity modelling

Aside from a first definition proposal given by [Ahlemann, et al. 2005, 15], the nature of maturity models has not been theorised well in literature until now. Maturity models are seen as models that reflect certain aspects of reality, often called capabilities, and define qualitative attributes which are used to classify a competence object into one of several clearly defined classes. These classes are typically brought

into a sequential order [Ahlemann, et al. 2005, 13p]. Although several institutions developing maturity models (e.g., SEI, PMI) have tried to close this gap, the foundation of their contributions has often not been based on the richness of maturity models available, but only focused on their own models.

This work intended to define maturity models on the basis of the empirical data that was gained in the structured content analysis. Therefore, a sample of 16 maturity models was investigated. The characteristics and patterns of the observed models were extracted from the model description and put into a well arranged structure through a content analysis. From this, the following definition of maturity model has been developed:

A maturity model conceptually represents phases of increasing quantitative or qualitative capability changes of a maturing element in order to assess its advances with respect to defined focus areas.

Typically, the maturing element is a person, an object or a social system. The focus area determines which indicators for maturity can be used to assess a maturing element. Examples of focus areas are maturity of processes, of digital resources or of people's competencies. The model structures the maturing elements' developments into a suitable number of phases which are commonly separated by non-metric based trigger conditions and brought into a sequential order. A maturing element can develop into any phase of the model, if it fulfils all trigger conditions of the lower phases plus the ones of the actual phase. It is also important to understand that maturity models can be either used in a descriptive way explaining changes observed in reality or in a normative way. In the latter sense, the maturity model is intended to guide owners', managers' or other committed individuals' interventions into making changes in maturity of maturing elements more effective or efficient.

5 Conclusion

This paper targets a striking gap in theory building about maturity models and can be understood as a first step into the investigation of the nature of maturity and maturity modelling. The coding table, containing the questions to this analysis shows how many aspects have to be accounted in connection with the creation of a maturity model. These aspects can be used as checklist for selecting a maturing model, for comparing maturity models or for designing maturity models.

Besides the already mentioned coding bias, especially a model selection bias challenges the findings of this work, as the analysed sample of models determines the codes that have been found during the analytical process. If the size or the composition of the sample would be changed, the codes might also change. Thus, the results of the structured content analysis, although already considered useful, e.g., for designing maturity models for the domains of knowledge, knowledge-intensive processes or knowledge infrastructures., can be used as input for a quantitative study with a larger sample of maturity models. Propositions that can guide such a quantitative research can build on the basis of the findings presented here.

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