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The maturity of maturity model research: A systematic mapping study

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ABSTRACT

Context: Maturity models offer organizations a simple but effective possibility to measure the quality of their processes. Emerged out of software engineering, the application fields have widened and maturity model research is becoming more important. During the last two decades the publication amount steadily rose as well. Until today, no studies have been available summarizing the activities and results of the field of maturity model research.

Objective: The objective of this paper is to structure and analyze the available literature of the field of maturity model research to identify the state-of-the-art research as well as research gaps.

Method: A systematic mapping study was conducted. It included relevant publications of journals and IS conferences. Mapping studies are a suitable method for structuring a broad research field concerning research questions about contents, methods, and trends in the available publications.

Results: The mapping of 237 articles showed that current maturity model research is applicable to more than 20 domains, heavily dominated by software development and software engineering. The study revealed that most publications deal with the development of maturity models and empirical studies. Theoretical reflective publications are scarce. Furthermore, the relation between conceptual and design-oriented maturity model development was analyzed, indicating that there is still a gap in evaluating and validating developed maturity models. Finally, a comprehensive research framework was derived from the study results and implications for further research are given.

Conclusion: The mapping study delivers the first systematic summary of maturity model research. The categorization of available publications helps researchers gain an overview of the state-of-the-art research and current research gaps. The proposed research framework supports researchers categorizing their own projects. In addition, practitioners planning to use a maturity model may use the study as starting point to identify which maturity models are suitable for their domain and where limitations exist.

1. Introduction

When talking about maturity models, most people first think of Capability Maturity Model Integration (CMMI). CMMI is a framework that contains best practices for developing products and services. Its roots lie in the software industry with the CMM for Software from 1993. The last installment of the integrated version, CMMI for Development 1.3, was published in 2010 and combined concepts from software development, systems engineering, and product development. Besides this, two additional CMMIs for Acquisition and Services are available, too [35].

Widening the purpose in the evolution of CMM(I) during the last two decades gives a first impression that the applicability of maturity models is not just restricted to software-related domains. In fact, the maturity concept emerged out of quality management. First thoughts were found in the 1930s with the work of Shewhart [33], although they do not have the slightest common ground with today's maturity models. The concept of maturity stages building on each other, and therefore offering a simple but effective tool for analysis and measurement, was introduced by Crosby in 1979. He proposed his so called *quality management process maturity grid*, which categorized best practices along five maturity stages and six measurement categories [7]. Simultaneously, Nolan published an article about the maturation of data processing by defining six stages of growth that have to be achieved until maturity is reached [26].

Since these days, the publication amount of maturity-related topics steadily rose. In 2009 and 2010 alone 62 academic articles were published, which included 34 new maturity model developments. The focus of these publications is still software engineering with topics covering, for instance, data quality, software maintenance, and testing. But other issues, like IT alignment, the use of enterprise resource systems, technology and knowledge management, or collaboration processes are becoming more important, too. This growing diversity and scale of publications makes the field of maturity model research more and more confusing and it

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becomes necessary to analyze and structure the field in a systematic way.

A suitable approach to fulfill this task is a systematic mapping study. A mapping study – as a specific form of literature review – aims at reviewing a relatively broad topic by identifying, analyzing, and structuring the goals, methods, and contents of conducted primary studies. Therefore, the state-of-the-art research, research gaps, or matured sub-areas can be identified and explicated [4,18,29].

To the knowledge of the author, there is no mapping study or similar work about maturity models available. Hence, the aim of this study is to deliver the first comprehensive summary of existing research publications about maturity models. The main answered research questions include *what topics* in maturity model research are prevalent, *what methods* are applied, *how new models are developed*, and *how publication trends changed* over time. The results of the mapping study deliver a comprehensive research framework in maturity model research as well as implications and guidelines for both researchers and practitioners.

The paper is structured as follows: a discussion of the maturity model concept is given in Section 2. Section 3 discovers two fields of related work, available literature reviews with their specific results, and the design science paradigm, which is an important research design in maturity model development and is closely connected to the deduced comprehensive research framework. The design of this mapping study, including research questions, scope, and the search process is illustrated in Section 4. Section 5 explains the applied classification scheme in detail. The results of the mapping and the answers to the research questions are presented in Section 6. In Section 7 the results are discussed, the framework of a comprehensive research cycle is derived and implications for research and practice are given. Finally, Section 8 summarizes the study and gives an outlook for further research.

2. Research background

To get an understanding what maturity models are and what they are used for, the following section discusses the basic concepts of maturity models. Interestingly, a clear definition of the term 'maturity model' is often avoided. Publications of maturity models rather use descriptions of purpose and functioning of the models.

Exemplary definitions are "Maturity models describe the development of an entity over time. This entity can be anything of interest: a human being, an organizational function, etc." [19] or "A maturity model is a structured collection of elements that describe the characteristics of effective processes at different stages of development. It also suggests points of demarcation between stages and methods of transitioning from one stage to another" [30]. Furthermore, many publications simply refer to the CMM(I) as basic definition, which says in its first version: "The CMM is a framework representing a path of improvements recommended for software organizations that want to increase their software process capability" [28].

Although these definitions give a basic understanding of the underlying logic how maturity models work, they do neither clarify the meaning of maturity nor the elements of such a model. In addition, they vary in terms of application (processes vs. organizations vs. humans) and purpose (improvement vs. description). Due to the lack of an accepted general definition, it is necessary to have a closer look at maturity models from three perspectives:

- an understanding of basic terms like 'maturity' and 'capability',
- purpose, application, and benefits,
- structure and components.

Looking up the term 'maturity model' in encyclopedias of software engineering [24] or management information systems [8] unfortunately does not deliver any results. In fact, the only related entry is a description of the Capability Maturity Model (CMM or CMMI) itself, but without discussing the basic concepts of maturity or capability, which are utilized within these models.

Therefore, a closer look to the meaning of these terms is necessary to get a general understanding of maturity models. The Oxford English Dictionary describes 'maturity' as "The state of being mature; fullness or perfection of development or growth". It further details this description for immaterial things as "The state of being complete, perfect or ready" [34]. In the field of IS, maturity is normally measured for so called capabilities. A capability can be described as the "power or ability in general, whether physical or mental" [34] to fulfill specified tasks and goals.

This means from a linguistic perspective that the purpose of models dealing with maturity is to outline the conditions when certain examined objects reach the best (perfect) state for their intended purpose. For instance, these objects can be software development capabilities. In addition, there has to be a "final" state of maturity (fullness of growth) in which no further development is possible.

The question when such a fullness of growth is reached, directly leads to two points of view when developing and using maturity models: a *life cycle perspective* and a *potential performance perspective* [25]. These two perspectives were already existent within the first publications of maturity models. Nolan's model for data processing from 1979 belongs to the life cycle perspective. It measures the state of four process areas through six discrete "stages of growth", whereby only the final (perfect) stage is named "Maturity". An organization evolves over time and therefore automatically has to pass all stages due to improvements and learning effects [26].

The other early model from 1979, Crosby's Quality Management Maturity Grid fits into the potential performance perspective. It defines five maturity stages and the last stage, called "Certainty", is the best or perfect one, too. But in contrast to Nolan's model, Crosby's Maturity Grid is not described in the way of a life cycle. It rather shows the potentials arising of a higher maturity level and the user may decide if it is desirable to proceed to the next stage [7].

Today, most of the available maturity models follow the potential performance perspective instead of life cycle approaches [25]. Nevertheless, it is important to be aware of the difference, because it has implications on the application of the models and the interpretation of stages. Models of the life cycle perspective have a well-defined "final" stage of maturity, which will be reached while evolving over time. Therefore they may serve as tools for management supporting the development of the examined objects. Although the purpose of models belonging to the potential performance perspective is principally the same, there is a fine difference. These models show a development path, too, but the stages focus on the potential improvements which occur by moving along. Every stage holds an inherent effectiveness and self-evident value [21]. The user has to decide by himself which level of maturity (i.e. completeness, perfection) is best for the situation.

Reflecting the purpose of maturity models makes clear that they are no "silver bullets". Nevertheless, the application of maturity models creates useful benefits. First of all, maturity models generate an awareness of the analyzed aspects: their state, importance, potentials, requirements, complexity, and so on. Furthermore, they may serve as reference frame to implement a systematic and well-directed approach for improvements, ensure a certain quality, avoid errors, and assess one's own capabilities on a comparable basis [6,21].

Finally, available maturity models differ in their structure. However, every maturity model should consist of two common components to fulfill its purpose. Looking at the basic definition of maturity, a measure to determine the current state of completion is needed. Therefore, maturity models define a set of levels or stages, describing the development of the examined object in a simplified way [19]. These stages should be sequential in nature and represent a hierarchical progression. Furthermore, they should be closely connected to organizational structures and activities [10].

The second component refers to the measured objects, the capabilities. This means maturity models have to define criteria for measurement like conditions, processes, or application targets. Maturity models that refer to only one criterion are called one-dimensional. Today, however, most of the models are multi-dimensional ones, including affected processes, organizational units, problem domains, etc. [22].

To summarize the considerations above, maturity models describe and determine the state of perfection or completeness (maturity) of certain capabilities. The application of this concept is not limited to any particular domain. The progress in maturity can either be seen as defined evolution path (life cycle perspective) or potential or desired improvements (potential performance perspective). Therefore maturity models define simplified maturity stages or levels which measure the completeness of the analyzed objects via different sets of (multi-dimensional) criteria.

This explanation is well reflected in the definition by Becker et al.: "A maturity model consists of a sequence of maturity levels for a class of objects. It represents an anticipated, desired, or typical evolution path of these objects shaped as discrete stages. Typically, these objects are organizations or processes." [3]. This definition serves as basis for the mapping study, too. On the one hand it includes the relevant aspects regarding basic terms and model structure. On the other hand it is not too restricted with regard to application domain, criteria, and other model elements.

3. Related work

3.1. Available literature reviews

In the run-up to this mapping study, as well as while conducting the study, we searched for already available literature reviews, mapping studies, or similar work. Finally, only five suitable articles could be identified, whereby none of them met the aims of this mapping study. These five articles are shortly introduced and differentiated from the study here conducted.

Hansen et al. [12] conducted a systematic literature review in 2004. They reviewed over 300 articles in the software improvement field and classified them as being prescriptive, descriptive, or reflective. Their main results included that prescriptive approaches are prevalent and that the field is dominated by the CMM approach. They furthermore called upon more theoretical reflective contributions to advance software improvement. Their study did not concentrate on maturity models, although these are one common approach in software improvement. Furthermore, their research question was very specific and therefore their review could not answer the research questions of this mapping study. Nevertheless, the work of Hansen et al. influenced the concepts of the applied classification scheme within the category *research content* (see Section 5).

Another systematic review was conducted by Staples and Niazi in 2008 [36]. They analyzed which organizational factors motivate the adoption of CMM-based software improvement actions. They reviewed more than 40 articles and identified mainly the improvement of project performance and product quality as motivators. This work focused on CMM-based approaches and not on the field of maturity models as a whole. Furthermore, it specifically asked for motivators for adoption and therefore did not cover the research questions of this mapping study, too.

The other three articles were not systematic literature reviews in a narrow sense. Jokela et al. [14] conducted a survey about usability capability maturity models in 2006. They identified and compared several maturity models, especially for the domain of software and product usability in a structured approach. Becker et al. [3] presented a process model for the development of maturity models in 2009. For that purpose they conducted a review of several maturity models with a focus on their development processes. Finally, in 2010, Khatibian et al. [15] reviewed maturity models for knowledge management in order to discover how much they could contribute to the measurement of knowledge management capabilities. Again, these studies only covered one special kind of maturity model, or had a narrow focus and thus were unsuitable for a broad mapping of the maturity model research field.

Besides the named studies, many articles identified during the mapping study included smaller literature reviews to support the purpose of the respective research questions or to explain the research context. These reviews could not be used, either, because they always showed a narrow part of the whole field of maturity model research. These findings again support the need of a comprehensive mapping study.

3.2. Design science

When new maturity models are developed, it is normally not sufficient to construct them in terms of content and structure. To ensure their applicability and benefits, they have to be tested, for instance, by proof of concept or by real life applications. The results of these tests or evaluations may have influence on the model again. This "logical" procedure is to be found in the design science paradigm. In fact, design-oriented research designs are often used when maturity models are developed (see Section 6.3). Therefore, it is important to introduce the basic concepts of design science research, which also have great influence on the following research questions.

Table 1
Design science research guidelines [13].

Nr.	Guideline	Description
1	Design as an artifact	Design-science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation
2	Problem relevance	The objective of design-science research is to develop technology-based solutions to important and relevant business problems
3	Design evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods
4	Research contributions	Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies
5	Research rigor	Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact
6	Design as a search process	The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment
7	Communication of research	Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences

The key aspect of design science is to develop useful IS solutions by creating and evaluating so-called artifacts. In context of maturity models, the model itself is such an artifact and hence, the applicability of the design science paradigm is suitable. To guide researchers, some frameworks for conducting design-oriented research are available. One of the most cited frameworks is the *Design Science Research Framework* by Hevner et al. [13], which builds on the work of March and Smith [23]. The authors' objective was to describe the design-oriented paradigm by using a conceptual framework with clear guidelines to evaluate the quality of the research. These guidelines address artifact construction, evaluation, and presentation and can be used to examine scientific grounding and practical relevance of an artifact [13]. Table 1 lists the seven guidelines and their description.

All of these guidelines should be addressed when developing new maturity models. This is supported by Becker et al., who presented a process model for maturity model development that is based on these guidelines [3]. However, guidelines 3 and 5 are of particular importance. They state that a maturity model has to be evaluated to demonstrate its suitability and that this evaluation has to be conducted via rigorous research methods. This is the most differentiating issue between design-oriented and pure conceptual maturity model development.

Thus, the study aimed at answering three specific design-related research questions: *how important design-oriented research designs are* in published research articles, *how developed maturity models are evaluated,* and *what methods are used* for this purpose?

4. Research design

4.1. Research method and research questions

The aim of this study is to obtain an overview about the area of maturity model research. Therefore, systematic literature reviews, as proposed by Kitchenham [16], Kitchenham et al. [17], or Webster and Watson [37], are an appropriate approach for gaining comprehensive insights. Furthermore, to answer questions about the structure of a broad field, relevant topics within this field, and research trends, Kitchenham et al. [18] and Petersen et al. [29] recommend mapping studies, which are a specific form of systematic literature review.

In accordance with the objective of this study, the research questions focus on categorizing and structuring the area of maturity model research. Table 2 shows all research questions of this mapping study.

Table 2
Research questions of the study.

Nr.	Research question	Rationale
RQ1	What is the main focus of maturity model research and what research topics are relevant besides developing and using maturity models?	The answer delivers an overview of main fields of interest as well as side topics in maturity model research
RQ2	How can the field of maturity model research be structured?	RQ2 builds on the results of RQ1 and intends to identify a framework to structure relevant topics in maturity model research
RQ3	What are the most common research designs and methods applied?	This question discovers the most important designs and methods as well as gaps and under-represented approaches
RQ4	How important are design-oriented vs. conceptual designs for the development of maturity models?	Maturity models should undergo a well-founded development and a sufficient (empirical) validation to be useful for other researchers and suitable for practice (see Section 3.2). This question discovers to what extent current research follows this principle
RQ5	How are developed maturity models validated?	Strongly connected to RQ4, both questions (RQ5, RQ6) reveal how maturity models are validated to fit their purpose
RQ6	How important are qualitative vs. quantitative methods for validation?	
RQ7	What are the most common maturity models addressed in research? How important are maturity models developed by industrial consortia, practitioners, or standardization organizations for research?	The answer to this question intends to identify what models are developed within and used for research and how much research is influenced by well-known "standard" maturity models
RQ8	In what domains are maturity model research applied?	This question reveals to what extent the concept of maturity models is applicable to other domains
RQ9	How have publication amount, frequency, and research topics changed over time?	The answer to this question shows research trends, a timeline of publications, and emerging or abandoned topics
RQ10	What are relevant search terms and what are the main publication forums?	RQ10 relates to the methodology of this mapping study. The question intends to identify the most important databases, journals, and conferences for maturity model research and the most appropriate search strategies

4.2. Scope of the study

For conducting the study a concept-centric approach was chosen. So, the development of the classification framework (see Section 5) was concept-driven. This is necessary because author-centric approaches cannot synthesize the literature of a broad research topic [37].

Additionally, mapping studies (or literature reviews in general) are of a different nature. Fettke [9] provides a framework to explicate the nature of a literature review. This framework helps to clarify the focus, goals, procedures, and limitations of a conducted literature review. The nature of this mapping study is characterized in Table 3.

Furthermore, the term 'maturity model' is used in many different meanings and contexts and clear definitions are avoided (see Section 2). Hence, it is necessary to limit the range of considered meanings. Saleh and Alshawi [31] differentiate between product-based (assessment of features of products) and process-based (measurement of effectiveness of processes) approaches. The scope of this study focuses on the latter approach. Additionally, considered literature has to deal with maturity models defining levels or stages of maturity, which are used to assess defined requirements of the process. Mostly, these stages build on each other to pursue process improvements [1,20] and support the aim of improving and standardizing processes [5] (for a further discussion of basic concepts see Section 2). Other models, describing and assessing process structures (for instance, Total Quality approaches as the European Foundation of Quality Management (EFQM) Model) are not considered.

4.3. Search process

To enhance the rigor of systematic literature reviews, and mapping studies in particular, the process of searching and analyzing the literature has to be made as transparent as possible. Hence, the following paragraphs describe the conducted steps of searching, selecting, and analyzing the literature in the mapping study. The complete systematic mapping process is shown in Fig. 1.

Table 3
Scope and nature of the mapping study (following [9]).

Characteristic	Scope of mapping study	Rationale
Type	Natural language, statistical	In the mapping study descriptions, explanations and arguments in natural language, as well as descriptive statistics are used to analyze the literature
Focus	Topics, methods	The mapping study aims at structuring and providing an overview over the research field. Hence, the focus is not to discuss specific research results, but rather to identify broader topics and methods used
Goal	Subject areas, critics	The main goal of the review is to identify central subject areas and to critically analyze if there are untreated areas
Perspective	Neutral	The author of the mapping study holds a neutral position regarding the analyzed literature
Literature	Selective	The mapping study cannot analyze the complete literature of the field. Therefore, some literature is excluded in form of unconsidered data sources or excluded material. Nevertheless, the exclusion criteria are chosen in a way that ensures a nearly complete selection regarding subject matter (see Section 4.3)
Structure	Conceptual, methodical	The mapping study analyzes and compares relevant literature on the basis of concepts and used methods
Target group	Researchers	The main target groups of the mapping study are specialized researchers (Information Systems) and researchers in general who have an interest in maturity model research. Nevertheless, practitioners may find the study results useful, too
Future research	Explicated	The mapping study aims to identify research gaps and therefore explicate potential future research areas

4.3.1. Selection of data sources and search strategy

The conducted mapping study was based on electronic databases and conference websites. An extensive selection of databases was the first step in fulfilling the research aim of a comprehensive overview about research in maturity models. The databases selected were Business Source Complete and Academic Search Complete of EBSCO, ScienceDirect, Emerald Management, SpringerLink, and WISO wirtschaftswissenschaften (wiso-net). These databases assured that publications of the most important research domains – like Information Systems, Software Development, or Business and Management – were covered. Additionally, the proceedings of five important international conferences on the field of IS were selected for the study, too. These were International Conference on Information Systems (ICIS), European Conference on Information Systems (ECIS), Americas Conference on Information Systems (AMCIS), Hawaii International Conference on System Sciences (HICSS), and International Conference on Wirtschaftsinformatik (WI).

The search strings used were influenced by the aim of a comprehensive overview. Synonyms for the term "maturity model" were identified by using dictionaries, test searches, and references in sample papers. The search terms used were "maturity model", "capability model", "process improvement model", "maturity grid", "competency model", "excellence model", and the respective German translations. Two of the search terms had to be excluded afterwards in the phase of scanning the abstracts because the results were irrelevant for this study. These were "competency model", where the articles covered only topics of human resources, and "excellence model", where the articles dealt with quality measurement, but not in the context of maturity models. Furthermore, most of the German translations proved irrelevant except the term "Reifegradmodell" as direct translation of maturity model.

For all terms the search strategy was to find the single words, for example (maturity AND model) in the title, abstract, or keywords. This strategy made sure to include other phrases also, such as "model of maturity". In the case of too many initial results, the complete phrase ("maturity model") was added for searching within the full text. As for the conferences and in some databases, available search strategies were sometimes limited and had to be adjusted appropriately. Therefore, a list containing all data sources with the respective search strategies and the number of results is available online as Supplementary material.

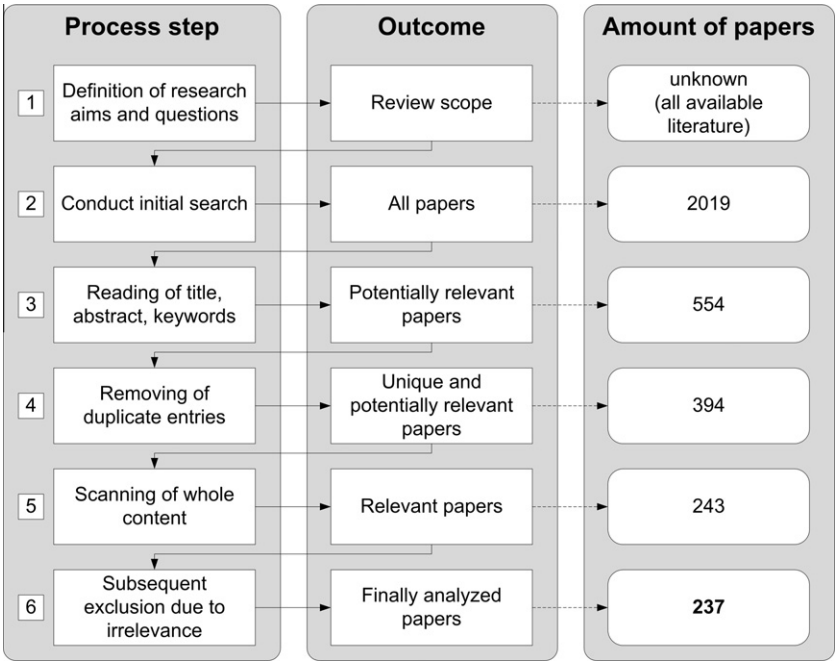

Fig. 1. Search process (following [29]).

4.3.2. Exclusion and inclusion criteria

To ensure that only relevant articles entered the pool of papers to be finally analyzed, irrelevant articles were excluded. The criteria for exclusion were twofold: content based and publication based. Furthermore, only articles in the English or German languages were kept.

As for the content, articles that did not deal with maturity models as a main focus were excluded. These articles mentioned maturity models only in the abstract or incidentally. Furthermore, articles referring to maturity models not in the meaning of the scope of this study (see Section 4.2) were excluded, too. Besides that, articles were not excluded for other content-related aspects, such as research domain, research topic, and specific focus to certain tasks, themes, or date of publication due to the research aim of as broad an overview as possible. Content-related exclusion of articles took place in steps 3 and 5 (see Fig. 1).

Being publication based, only academic journals were included in the study. This is justified, because the study aims at analyzing the research activities in the field of maturity models, and therefore a certain quality of the articles and completeness of research had to be assured. Hence, non-academic, journalistically written articles, opinion and experience papers, as well as simple success stories were excluded. Furthermore, dissertations and industrial, technical, and work reports were excluded, because it was assumed that important results of such types were published in academic journals or at conferences. Finally, books were excluded after some sample searches because they did not deliver considerable results and the inclusion of books is regionally very limited due to availability.

Regarding conference proceedings, only articles of the five above named international conferences were analyzed. These conferences deal with a broad range of IS-related topics and therefore support the overall research aim of the study. To avoid an unbalanced emphasis of single topics, other specialized conferences were excluded from this study (see Section 7.5).

To minimize the risk of excluding relevant articles, doubtful articles were included and read in more detail at a later step of the mapping process. This led to step 6, where five papers had to be excluded afterwards.

For excluding duplicate entries (step 4 in Fig. 1), a procedure was determined to answer RQ10. First, if articles were found via different search phrases, the ones found by the term "maturity model" were kept to get an idea of how many articles could be identified via that search strategy. Second, if articles were found within different data sources, articles were kept by a defined order of data sources (see Section 6.6).

5. Classification scheme

For structuring and analyzing the identified articles, a classification scheme was developed. For this, the idea of a "concept matrix" was taken and adapted from Salipante et al. [32] and Webster and Watson [37] for this study. A concept matrix is a logical approach that defines several "concepts" (that may be variables, theories, topics, methods, and so on), where all articles are grouped in and therefore serve as a classification scheme. New concepts could be added during the classification process until the final scheme was developed. According to Petersen et al. [29] the process of classifying the articles has to be systematically clear to enhance transparency. Hence, the process is illustrated in Fig. 2.

The first step was an initial development of the classification scheme based on prior literature. The identified articles were read afterwards and classified according to the scheme. If there were any doubts in classifying a specific article, the scheme was refined; i.e., concepts and categories were added, expended, or modified. In this case, prior classified articles had to be checked again to validate their classification within the refined scheme. This procedure proved very helpful, because it lead to a stable classification scheme after approximately 30 articles.

The resulting and final classification scheme as basis for the mapping is shown in Fig. 3. The used concept categories are subsequently explained in detail. They are:

- Research design.
- Research method.
- Research content.
- Application domain.
- Developed/used maturity model.

The concepts are not mutually exclusive in the single categories, except for research design. It is assumed that an article has to have only one or at least one major research design. For the other categories, articles may be classified into more than one concept. For instance, one article may have a design-oriented research design by developing a maturity model and simultaneously contain interviews and focus groups for supporting the development and a survey for validation purposes.

The concepts within the category *research design* were adapted from Alavi and Carlson [2]. They provided a framework, distinguishing between empirical and non-empirical research with additional subcategories for each one. This framework was expanded to fit the research aims. The resulting concepts for the classification scheme are empirical research with a quantitative or qualitative approach, conceptual research, design-oriented research, and others. To be classified as design-oriented, an article had to follow the guidelines of design-oriented research as stated in Table 1, for example, by empirically validating developed maturity models. Articles, developing maturity models, frameworks, and so on, on a theoretical basis out of literature, were classified as conceptual. Others included articles that did not fit into the other research designs or where no design could be identified.

To classify the articles according to *research method*, an initial structure was taken from Palvia et al. [27], which provided an overview about used methods in IS research. While analyzing the

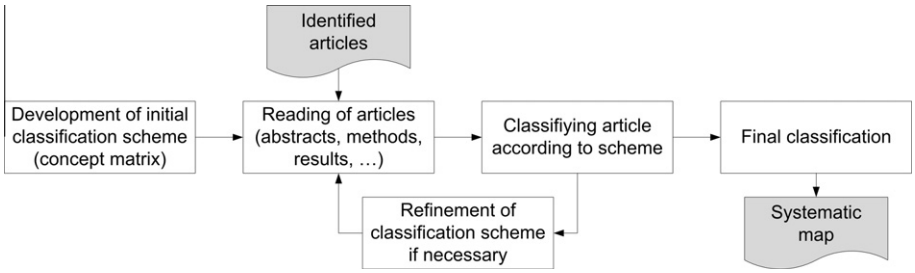

Fig. 2. Systematic classification process (following [29]).

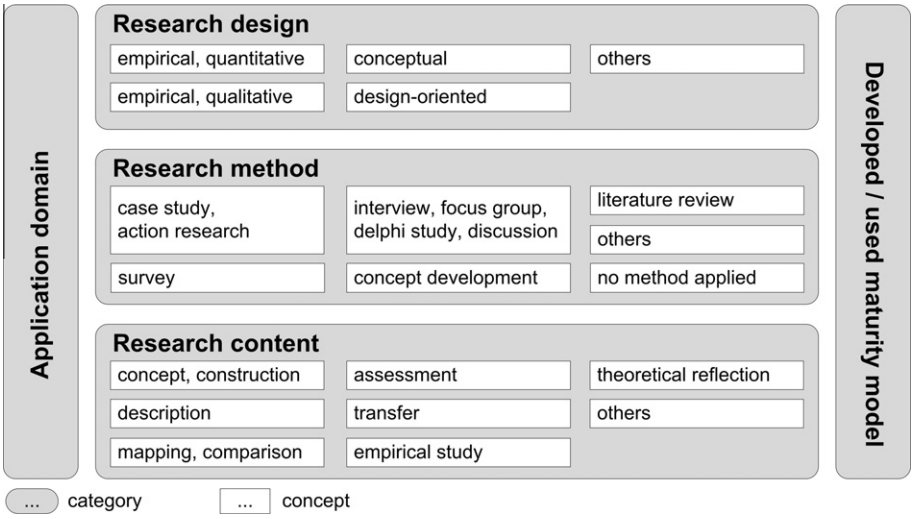

Fig. 3. Classification scheme.

articles, additional methods were added. After classifying all articles, concepts (i.e., methods) with three or less entries were combined (see for example the concept *interview, discussion*, etc. in Fig. 3).

The concepts in the category *research content* emerged gradually by analyzing the articles. Each article was classified with keywords, summarizing the content in a coarse way. During the analysis new keywords emerged and some articles had to be classified again. This procedure was repeated until the concepts remained stable. The final concepts are subsequently shortly explained:

- *concept/construction*: articles where a maturity model is developed (conceptual) or constructed (design-oriented),
- *description*: articles where existent maturity models are described for presentation purposes or as applicable methods or instruments,[2]
- *mapping/comparison*: articles where existent maturity models are compared and mapped to each other or to other maturity-related concepts,
- *assessment*: articles where the maturity of industries, organizations, etc. is assessed (not the assessment, in terms of validation, of the model itself),[3]
- *transfer*: articles where an existing maturity model is applied to another domain or research field without changing the model or developing a new one,
- *empirical study*: articles where an empirical study (qualitative, quantitative, and mixed) has been conducted to develop, apply, or validate maturity models, take out assessments, or other purposes,
- *theoretical reflection*: articles where theoretical implications of maturity models are discussed; for example, applicable theories, measurement approaches, theoretical benefits, and others
- *others*: articles that could not be classified into the before mentioned concepts.

[2] The development of maturity models normally requires a description of this model, too. In this case, these were not counted as descriptions. Conversely, when this model was referred to in a later or in another study and its structure, etc. was described (for example, for the purpose of empirical validation or assessments), this counted as description.

[3] Most articles dealing with assessments were simultaneously empirical studies. However, when no information about the (empirical) method was given, the article was only classified into assessment and NOT into empirical study.

Additionally, the categories *application domain* and *developed/used maturity model* were analyzed throughout the articles to get an overview about model usage.

6. Results

In the following sections the mapping results are presented and described according to the research questions. Selected articles are stated as examples. The full list of articles is given in Appendix A and their mapping and classification are available online as Supplementary material.

6.1. Focus and objectives in maturity model research (RQ1)

As for RQ1, the classification of the 237 articles per research content revealed eight recurring concepts (see Fig. 3). The distribution of these concepts is shown in Fig. 4. The total amount of all articles adds up to more than 237 because one article could contain more than one of the named concepts.

Two of the concepts proved dominant: first, construction of maturity models and development of concepts with 128 articles; and second, empirical studies with 130 articles. These contained 61 articles where both concepts were included. Hence, the development of maturity models and their empirical application and validation had the most attention in maturity model research. In comparison, only seven articles focused a transfer of an existent maturity model to another domain without changing its structure. For instance, Veldman and Klingenberg [A222] transferred CMMI to the context of engineer-to-order firms, and Drinka and Yen [A46] used CMM for redesigning student curricula. Mostly, existing maturity models were changed and adjusted in their processes, actions, maturity levels, etc. and were thus counted as concept or construction.

Sixty-six articles contained descriptions of maturity models for presentation purposes or as explanations for other research aims. This took place mostly in combination with other content, for example empirical validation or comparisons. Out of them, nine articles contained pure descriptions of maturity models [for instance A17, A25, and A55].

Furthermore, 23 articles compared different maturity models regarding structure, applicability, or covered processes and tasks; they also mapped maturity models to other concepts. Most of these studies compared CMM(I) with other maturity models, but only a

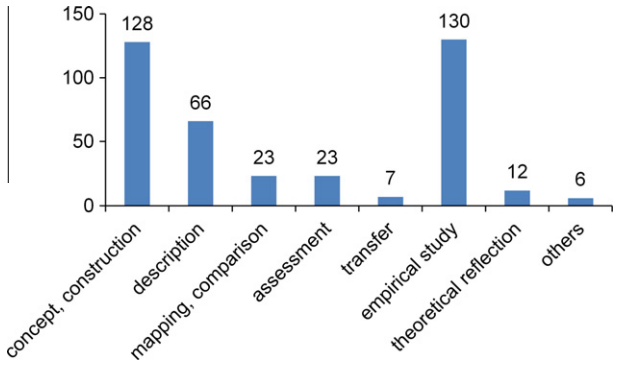

Fig. 4. Number of articles per research content.

few provided an overview about more maturity models for a specific domain or task. Examples are usability of software [A100], software development [A77], and hybrid value creation [A19].

Interestingly, only 12 articles paid attention to theoretical issues. For instance, Jugdev and Thomas [A102] examined whether maturity models are able to deliver competitive advantage or not. Urwiler and Frolick [A219] discussed Maslow's Hierarchy of needs as an underlying theory of maturity models. Others investigate the impact of organizational theories to maturity models and vice versa [A141, A153, and A205]. Out of these 12 articles, three delivered (systematic) literature reviews. These were [A79], where software process improvement approaches were divided into descriptive, prescriptive, or reflective; [A100], where maturity models for usability in software engineering were investigated; and [A205], which examined why organizations use CMMI (see Section 3.1).

Pure assessment of maturity was the content of 23 articles. This low number stems from the overall exclusion criteria of the study (see Section 4.3.2) because most of the assessment literature was either not published in academic journals or was written in the form of success stories.

Finally, there were six articles that could not be classified into the other concepts. Two of these developed process models and criteria for developing maturity models [A18, A70]. In [A34] a framework for the classification of maturity models was provided. The remaining three articles dealt with other content (short analysis of some past studies [A61], trend forecast [A196], and a short research project overview [A33]).

6.2. Structure of research topics (RQ2)

As mentioned above, the articles could be classified into one or more content-related concepts to answer RQ1. Nevertheless, to develop a general structure of research topics in maturity model research, we scrutinized the research objectives of every article in more detail. In this way it was possible to derive four main topic areas in which every article could be classified mutually exclusive:

- *Maturity model development*: articles within this topic area have the main objective of developing or constructing a new maturity model. This may contain conceptual as well as design-oriented models or descriptions of models, if the purpose is the introduction of a new model.
- *Maturity model application*: articles within this topic area aim principally at the application of maturity models in several contexts or specific domains. They also contain maturity assessments and transfers of models.
- *Maturity model validation*: articles within this topic area have the main purpose of validating existing maturity models. This includes empirical as well as conceptual validation, comparisons of maturity models, simulations, and so on.
- *Meta-articles*: the main objective of articles within this topic area is not research "with", but research "about" maturity models. These are, for instance, literature reviews, process models for the development of maturity models, or other theoretical considerations.

Fig. 5 shows the distribution of the four topic areas among the articles. In analogy to RQ1, the development of maturity models (108 articles, 46%) was the most followed research objective. Interestingly, the proportion of articles dealing with model validation was relatively small (32 articles, 14%). One reason for this was the fact that many articles developing new maturity models already included empirical methods like case studies to validate their models. The main objective of these articles was still model development. However, the low number of articles aiming at the validation of maturity models was also an indicator that larger (quantitative) studies about the applicability of maturity models are scarce. Finally, the number of meta-articles dealing with theoretical issues of maturity models was very low (15 articles, 6%).

The above structure into four topic areas that reflect the main research objectives of the analyzed articles proved useful for other research questions, too. Therefore, the structure was used to answer research questions RQ4 to RQ9 and the conducted analysis referred to the identified structure.

6.3. Research design and method (RQ3)

The analysis regarding RQ3 revealed a wide set of applied research designs and methods (see Fig. 6). All in all, 76 articles were based on an empirical research design (40 qualitative, 36 quantitative). Furthermore, 89 articles were based on a conceptual design, and 48 articles had a design-oriented research design. Finally, 24 articles could not be classified into the other research design concepts.

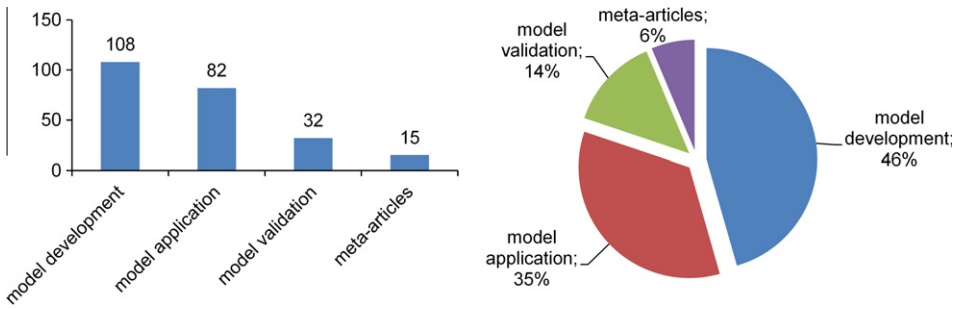

Fig. 5. Number of articles and percentages per topic area.

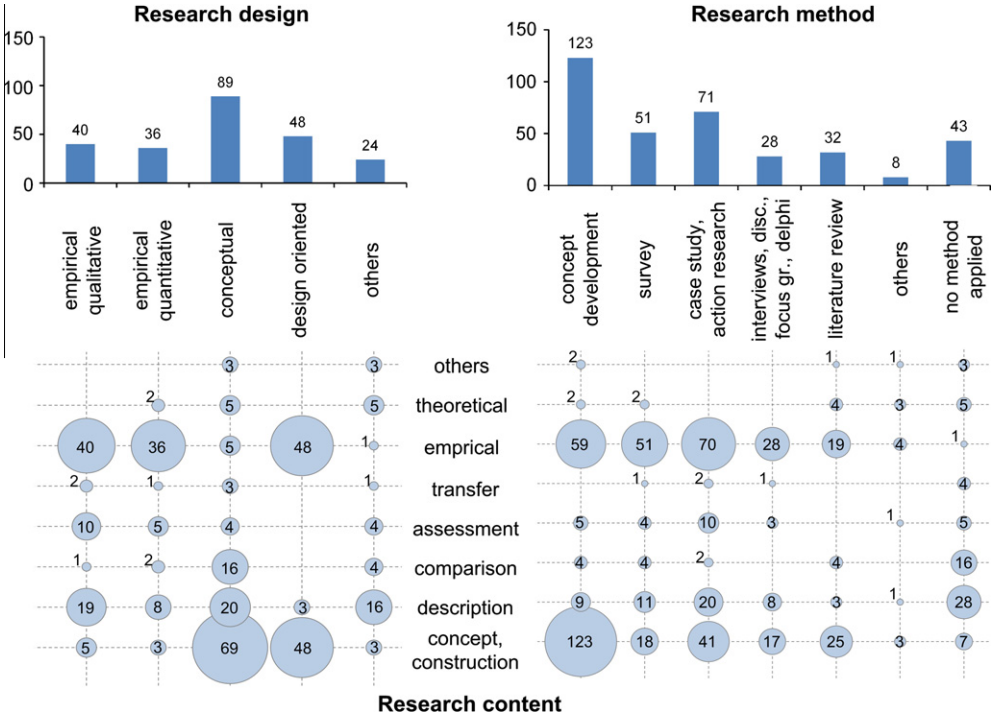

Fig. 6. Number of articles per research method and research design combined with research content. (The numbers in the bubble charts add up to higher numbers than shown in the bar charts because one article may contain more than one concept of research content.)

Accordingly, the most used research methods were concept development (123) and empirical ones (150), such as surveys, case studies, or interviews. Only 32 articles contained a literature review. To be classified into literature review, articles had to contain a comprehensive literature review section. Most articles contained a short topic-specific "literature review", of course, but that is not considered here. Surprisingly, only three articles were systematic literature reviews [A79, A100, and A205] (see Sections 3.1 and 6.1). Furthermore, eight articles used other methods and 43 articles had no recognizable method applied at all.

Derived from a variety of research designs and methods, the bubble charts in Fig. 6 disclose many combinations with research content. Nevertheless, some combinations show a concentration of articles. As expected, the majority of articles dealing with concept development and maturity model construction were either based on a conceptual (69) or design-oriented (48) design. Empirical studies, the second most concerned content, were nearly equally distributed over quantitative (36) and qualitative (40) designs. However, within design-oriented research, qualitative empirical methods were predominant (see Fig. 7). Thirty-five articles used case studies for validating the maturity models or as an empirical basis for their development. For instance, Essmann and du Preez [A50] validated their maturity model with five case studies regarding content and structure. In contrast, Mortensen et al. [A148] conducted two exploratory case studies within companies to deduce their supply chain maturity model from the results.

Some articles described mixed methods approaches. Case studies and action research projects report the usage of multiple sources of data (qualitative and/or quantitative) [e.g., A29, A85, and A108], while quantitative studies contained qualitative aspects in the form of pretests or validation of responses [e.g., A3, A146, and A197]. Only a few articles used mixed methods for different research steps or aims [e.g., A32, A186, and A201]. Filho et al. [A56] combined survey instruments with interview sessions and Sukhoo et al. [A210] combined surveys for basic assumptions with case studies to validate the developed maturity model. Plomp and Batenburg [A172] used interviews as well as a survey to validate their model in different industries.

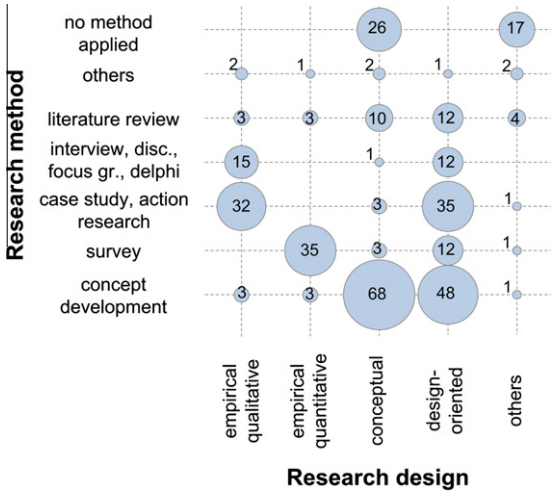

Fig. 7. Number of articles per research method combined with research design.

Other research methods are hardly used. Lee et al. [A119] developed an ontology-based decision support agent to monitor CMMI projects. They used an experiment to test its applicability. A similar approach was chosen by Raffo et al. [A177], who conducted software process simulations to achieve higher CMM levels. Content analysis was conducted by Galin and Avrahami [A61], who investigated past studies about CMM programs; and by Ngwenyama and Nielson [A153], who examined maturity model documentations. Furthermore, Bilotta and McGrew [A26] used Guttman Scaling for data analysis, Davis and Walker [A39] applied Grounded Theory, and Adler [A2] and McBride [A141] deduced results via theory-based considerations.

6.4. Development and validation of maturity models (RQ4, RQ5, RQ6)

In Section 3.2 the design science paradigm was shortly introduced. Normally, maturity models are developed due to problems in practical contexts, for instance within organizations or government institutions. Often, named research objectives are the improvement of processes or a better measurement of the current situation. To take that into account, developed maturity models have to be sufficiently validated to serve their purposes. In Section 6.2 altogether 108 articles were classified into the topic area of model development. These are examined in more detail in the following paragraphs. Every article was specifically checked regarding its research methods for validation as well as for clues in terms of further research in the outlook or summary.

The distribution of research designs within the topic area of maturity model development is shown in Fig. 8. It is clearly dominated by conceptual (56) and design-oriented (42) research designs. Besides, seven articles are empirical and three articles [A10, A47, and A168] are descriptions of maturity models and therefore have no research design applied at all. Fig. 9 gives an overview of how many maturity models are at least initially validated within the different research designs.

More than half of the published articles (52%) show a conceptual research design. That means the authors describe the development and the maturity model, but do not conduct any (empirical) validation. As a typical example for this group of articles, van de Wetering et al. [A228] introduced a maturity model for a picture archiving and communication system in hospitals. They described the model with its structure and contents as well as a strategic planning method underpinning the model. The model was developed by using available literature and the experiences of the authors. Although they stated that it had to be empirically validated via clinical practical application, they did not carry out any validation until the article was published. Surprisingly, only 12 articles out of the 56 conceptual ones reported that the developed maturity models should undergo any (empirical) evaluation.

A minor part of the conceptual articles introduced maturity models only as a byproduct, besides other contributions. For instance, Olson [A161] showed a maturity model for developing a "green strategy" for businesses. The model was described by a graphic and a few sentences, but no information about its construction, rationale, or application were given.

Thirty-nine percent of the articles used a design-oriented research design, so the construction process of maturity models was described and the models had to be at least initially validated. Ahmed and Capretz [A5] developed a maturity model to evaluate the business needs of the software product line process. They gave a comprehensive description and conducted two case studies to validate the applicability of their model. Sen et al. [A197], as another example, used another method for validation. After describing the construction process of their data warehousing processes maturity model, they carried out a questionnaire-based field study to examine if their propositions were valid. In addition, 12 articles stated that even further validations were planned.

As Fig. 9 shows, one design-oriented article did not include any validation [A21]. Beecham et al. [A20, A21] clearly developed their

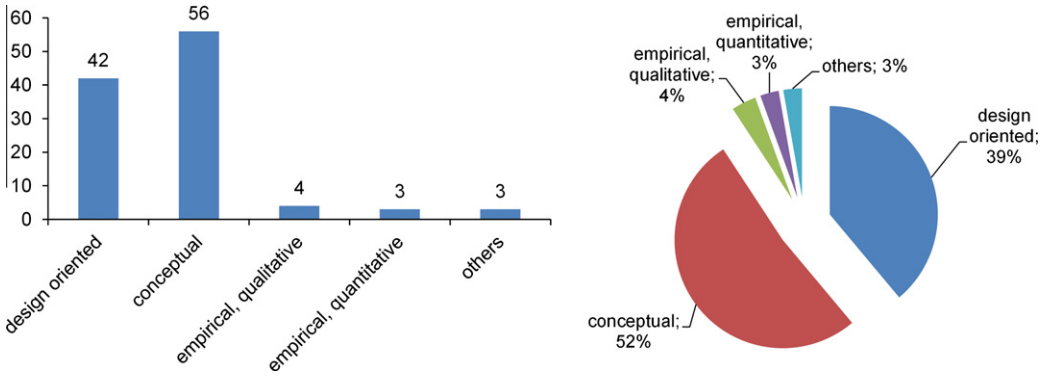

Fig. 8. Distribution of model development articles per research design.

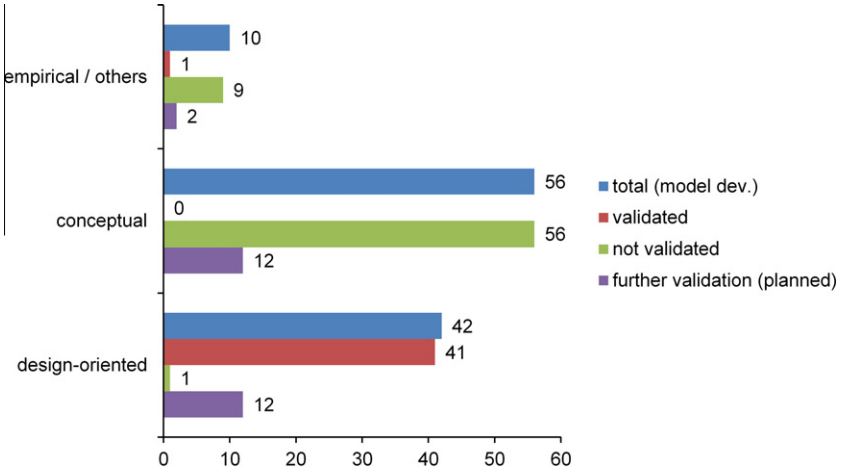

Fig. 9. Validation in maturity model development articles (number of articles).

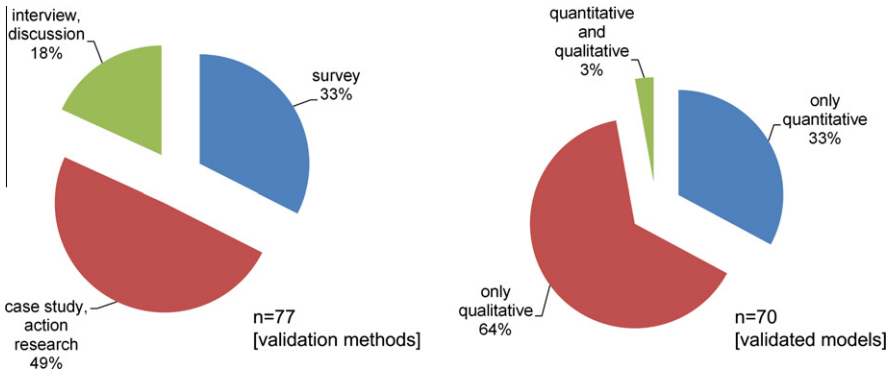

Fig. 10. Validation methods and their combination.

maturity model for the requirements of an engineering process in a design-oriented way, but split it up into two publications. In [A21] they described the development and stated a planned survey for evaluation, which was provided in [A20]. For the purpose of a rigorous analysis, the validation article [A20] was classified into model validation with an empirical quantitative design within this mapping study.

A similar procedure can be observed for the Risk Management Capability Maturity Model, introduced in [A131]. Although the authors conducted the first validation via a piloting workshop and expert interviews [A131], they used an additional case study to detail their validation 1 year later [A130].

Surprisingly, these two examples were the only ones in the complete mapping study where one maturity model was validated at a later time. None of the other articles classified into the model validation topic area matched one of the models introduced within the articles of model development (see Section 7.5 for further details).

The seven empirical articles [A14, A39, A59, A87, A233, A234, and A237] can be seen as exceptions in cases of maturity model development. Although the authors were developing a model within their articles, the model itself was not the focus of research. In [A14, A87, and A237] an empirical design was used and the maturity models arose from the conducted surveys, case studies, or interviews in addition to other, mainly focused, results. Although in [A39], as well as in [A234], maturity models were developed from scratch, an empirical design was used because the intention was to use the models as measurement tools for following surveys or case studies. Finally, in [A233] a maturity model was developed and validated in a case study design. The cases also served as a source for the development and validation of the model.

To get an overview of the relationship of quantitative vs. qualitative validation, all applied methods were analyzed independently from the underlying research design. Articles of both topic areas, model development and model validation, were considered. Fig. 10 shows the distribution and a comparison of the used validation methods. Obviously, qualitative methods (64%), mainly case studies, were predominant for validating maturity models. One third (33%) used surveys as a quantitative method. Furthermore, mixed method approaches were very rarely used. Only two articles (3%) combined qualitative and quantitative methods to validate their developed maturity models [A172, A184]. Plomp and Batenburg [A172] developed a maturity model to measure interorganizational collaboration through information and communication technology and tested their approach in the Dutch retail sector. Therefore, the authors simultaneously sent a questionnaire to 23 organizations and conducted face-to-face interviews in another 12 organizations out of that branch. Similarly, Rosemann and DeBruin [A184] validated their Business Process Management Maturity Model via two case studies. Additionally, they designed a questionnaire-based approach, which was sent to another organization, referring to several individuals of the affected business units. Other articles containing mixed method approaches did not use both qualitative and quantitative parts for validation purposes.

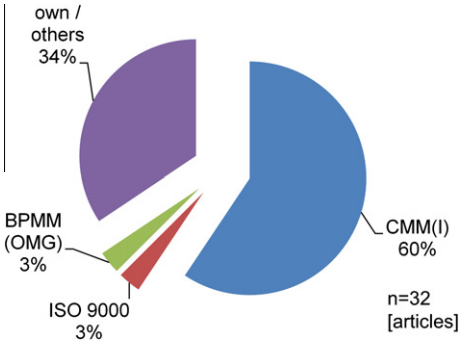

Fig. 11. Used maturity models in model validation [$n = 32$ articles].

As a final remark to RQ5 and RQ6: only one third (34%) of the articles in the topic area of model validation dealt with the authors "own" models (see Fig. 11). This underlines the observation that many maturity models are developed conceptually and are missing validation. The majority of the validation literature concentrates on CMM and CMMI by conducting case studies and surveys. One article focused the ISO 9000 series [A3] and one on the OMG's Business Process Maturity Model [A179].

6.5. Used maturity models and application domains (RQ7, RQ8)

To answer the question of which maturity models were addressed in research, all used models were counted in total and per topic area. Fig. 12 shows the overall picture of used maturity models. The clear majority was built by the category "own/other" (146). This means that the authors used their own developed models, or relatively unknown models evolved during the research of others. In case of well-known and widespread maturity models, the field was clearly dominated by CMMI (73). Other models developed by standardizing organizations or interest groups, like ISO 9000, SPICE (for software), SPICE (in construction), the OMG's Business Process Maturity Model, or CobiT's Maturity Model were rarely addressed in research contributions. Finally, the Crosby's Maturity Grid, as the origin of maturity models, was used only once.

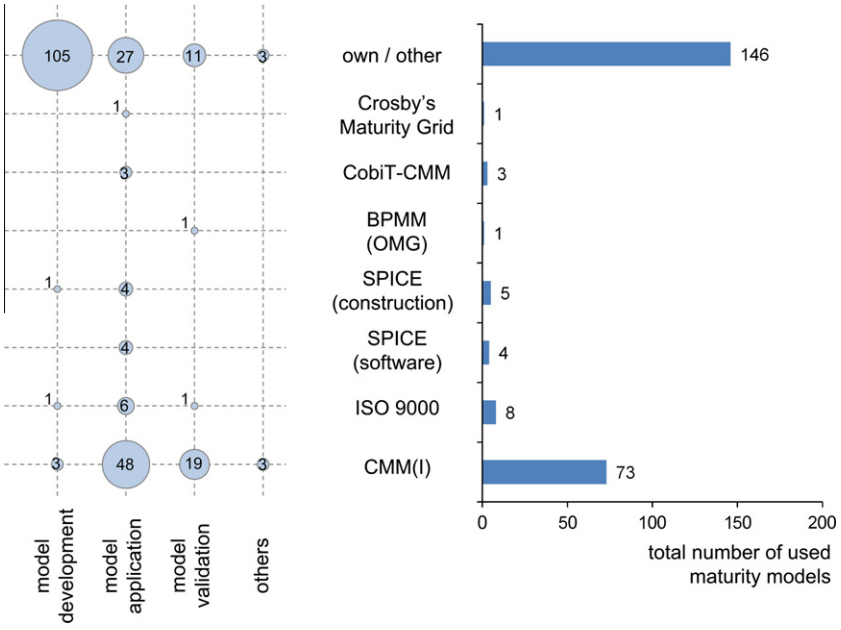

Fig. 12. Number of used/developed maturity models per topic area.

The huge number of researcher's own ("own/other") maturity models is not surprising due to the limitation of research articles and the exclusion of success stories or non-academic application reports. Nevertheless, it is interesting that CMMI is obviously the only "standard" maturity model really noticed within the academic community. The other named maturity models, although widespread in practice, seem to be hardly important for research.

CMMI is mostly used within the area of model application and within case studies [e.g., A38, A163], as a measurement tool within empirical studies [e.g., A26, A45], or as a reference for comparisons and mapping [e.g., A147, A166]. Additionally, it has a great influence on other newly developed maturity models. Some articles adapted the structure and/or transferred the content of CMMI to other research domains by mapping the practices and tasks of CMMI to the new domain [e.g., A14, A140, A220, and A232]. Others were "inspired" by CMMI for the first versions of their maturity models and changed it more and more during their research. Such a process was well described in Heck et al. [A83]. As another example for a relation to CMMI, Niazi et al. [A156] first developed their model independently and often referred to CMMI while explaining and comparing the components of their model.

Interestingly, the Crosby's Maturity Grid [7] seems not to be known to many researchers. Only one article [A115] directly used it within a case study evaluating the quality of contracts in the building industry. Most other articles referred to CMM(I) as the origin of maturity models and did not name the grid at all.

The results and examples of the before mentioned research questions already indicated a wide set of application domains

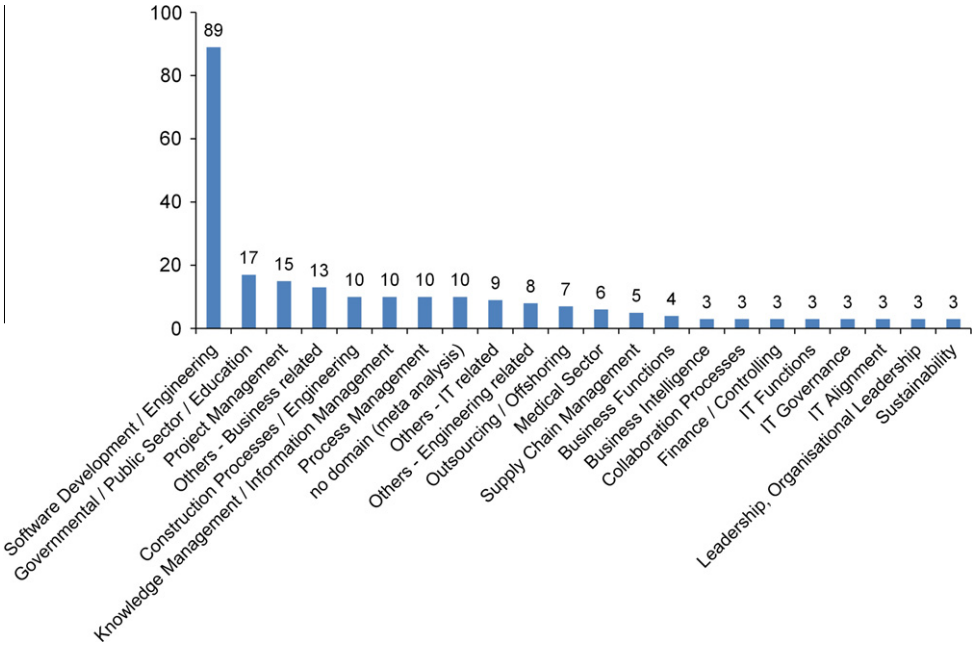

Fig. 13. Application domains throughout the mapping study (number of articles).

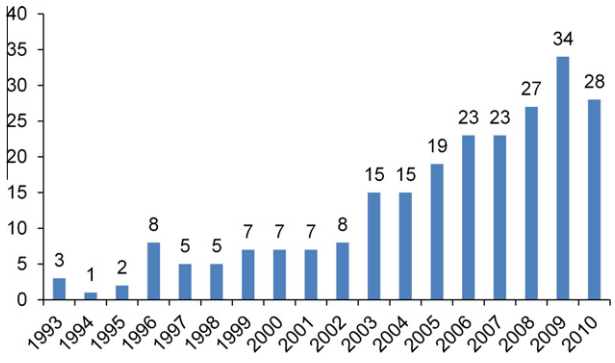

Fig. 14. Timeline of publications in maturity model research (number of articles).

when talking about maturity model research in general. Altogether, 22 application domains could be identified during the mapping study. The procedure for identifying the domains was as follows: first, the domain of every article was named freely, without any predefined classes. Second, the initial domains were combined step by step. For instance, "software development", "software maintenance", "software reuse", and others were combined within the final category "software development/engineering", whereby one final category had to include at least three articles. The results are shown in Fig. 13.

The research field was heavily dominated by the domain software development and software engineering. That was comprehensible, because the dissemination and success of maturity models emerged out of the software industry. The public sector and project management application domains were the second most dominant. Due to software normally being developed in projects, it was just a matter of time until the maturity concept was transferred to project management [e.g., A36, A85, and A169].

However, until today the development and application of maturity models was spread out to nearly any conceivable domain. Some examples of very specialized application domains are the separation of duties in ERP systems [A162], innovation activities [A24], mechanical design [A48], or consulting services [A201].

6.6. Research trends and publication forums (RQ9, RQ10)

To get an overview about trends in maturity model research, the articles in the study were analyzed by their year of publication. The earliest articles relevant for this study were published in 1993. The distribution of the 237 articles until 2010 is shown in Fig. 14. Between 1996 and 2002, the number of publications remained relatively stable from five to eight articles a year. Starting in 2003, a steady rise is noticeable, reaching its peak with 34 articles published in 2009. This shows that the topic of maturity models became more important to the research community during the last decade. Although the number of publications decreased in 2010, it is too early to state a downward trend yet.

A more detailed picture can be derived by distinguishing between the four identified topic areas (see Fig. 15). In analogy to the total numbers, every topic area shows an upward trend over time. In 2010 a sharp decrease in model application publications took place. This may explain the lower number of total publications in 2010 in comparison to 2009.

The most comprehensive topic area, model development, started to gain focus around the year 2000 and constituted the majority of published articles since 2004. Interestingly, the number of publications in model development and model application seemed to be contrary. When one of both topic areas showed a high number of publications, the other was low. This may be an indicator that main publication forums concentrated only on one of both topics within a definite time frame. The topic area of model validation showed a slight increasing trend, too. With a slight delay, this number also rose when model development articles rose, but it could never reach the amount of development articles. This showed that the necessary validation of maturity models had not been undertaken in the last few years (see Sections 6.4 and 7.3 for a further discussion). However, other research topics were taken more into consideration within the last 5 years. These topic areas included articles dealing with theoretical foundations or quality criteria of maturity models, among others [e.g., A18, A141, and A219].

As mentioned in Section 4.3.2, a specific procedure was used to exclude duplicate articles found in different data sources. Articles were kept in a special order regarding the databases where they were found. This was done to discover if one database delivered a sufficient amount of articles and to help future researchers with their data collection. The order and the resulting distribution of articles in the databases are shown in Fig. 16. For duplicates, the article from the database mentioned first was kept; the other was excluded.

The result indicated that nearly half of all articles can be found via the Business Source Complete database from EBSCOHost. Nevertheless, all other databases delivered nearly equal amounts of additional articles. Therefore, no database exists that covers the majority of publications within maturity model research and a predefinition of only a few or even one database may be misleading.

Finally, if duplicates were found via different search terms, the ones found by "maturity model" were kept. The rationale was to

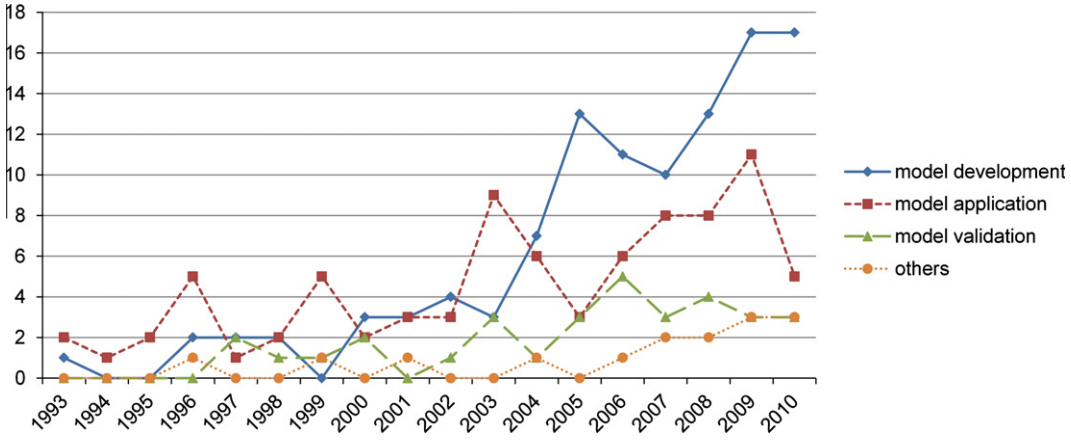

Fig. 15. Timeline of topic areas in maturity model research.

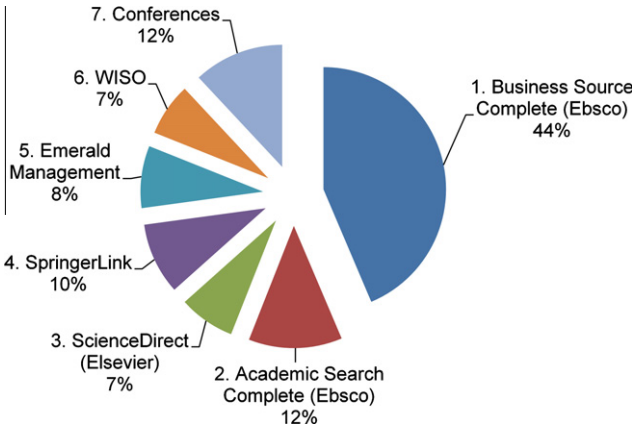

Fig. 16. Publication forums of maturity model research articles.

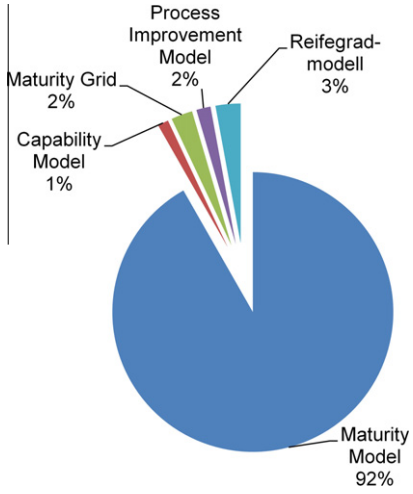

Fig. 17. Relevant search phrases for the mapping study.

get an impression of how many relevant articles could be found by this term as guidance for future researchers, too. The result is obvious. Fig. 17 shows that the search term "maturity model" delivered 92% of all relevant articles. The other terms contributed only to a small extent.

7. Discussion

7.1. Summary of study findings

The conducted study is the first systematic mapping study in the field of maturity model research (see Section 3.1). The research questions aimed at generating a comprehensive overview about research topics, application domains, and especially about the process of developing and validating maturity models. The answers to these questions deliver potential benefits for both research and practitioner communities. Researchers may use the study results as state-of-the-art research in maturity model research and as a reference and starting point for their own research projects. Simultaneously, the study may be a good starting point for practitioners, too. They can identify appropriate maturity models for their domain, or check if the maturity concept is relevant for them to deliver practically useful results.

To summarize the study findings, interest in maturity models has shown growing importance during the last two decades, which is shown by the rising amount of publications in this field (see Figs. 14 and 15). Furthermore, as Fig. 13 clearly reveals, the maturity concept is widely applicable across many domains, but still has its focus in software development and software engineering.

Looking at the objectives in maturity model research (see Section 6.1), most of the articles examined in the study deal with construction of maturity models (128) and empirical studies (130) about antecedents for their usage, applications, validations, or with the models as a measurement tool. As RQ1 revealed, theoretical reflections about the maturity concept are scarce. Looking especially at the development of maturity models (see Section 6.4), conceptual designs outweigh design-oriented model developments. This has significant consequences for validation. The study shows that many maturity models suffer a lack of a proper validation of their structure and applicability (see Fig. 9) and therefore of their usefulness. Additionally, when validation takes place, the study identifies a preference of qualitative validation methods in particular case studies, which build up nearly the half of all used validation methods (see Fig. 10).

Furthermore, standard (industrial) maturity models play a less important role in research. Fig. 12 shows that most of the used maturity models are developed by the researchers themselves. Well-known maturity models only occur occasionally. An exception is CMM(I), which is often used as the basis for new maturity models and in empirical studies (see Section 6.5).

7.2. Comprehensive research framework

The first two research questions led to the four main topic areas: model development, model application, model validation, and meta-articles (see Section 6.2). These topic areas are suitable to describe all activities in maturity model research, because it was possible to classify every article into one of these topic areas. The first three build on each other and form a research cycle that ideally should be completed by every newly developed maturity model. The last topic area (meta-articles) includes foremost theoretical aspects about maturity models. The framework showing the relationship between the identified topic areas is illustrated in Fig. 18.

These three "steps" for maturity model research are carried out by most articles with a design-oriented research design [e.g., A32, A56, A172, and A210]. This is not surprising because the steps resemble those of design science research approaches (see Section 3.2). Unfortunately, all conceptually developed models in the study remained in the stage of model development, although 12 articles stated further planned validation (see Section 7.5 for a further discussion).

As emphasized in Section 2, the purpose of maturity models is to describe and determine the state of maturity of certain capabilities. From such a perspective, the suitability and usefulness of a maturity model without any application and validation is doubtful. However, validation and application do not need to be described in one and the same publication or by the same authors. Classic examples are articles dealing with the application or suitability of CMMI independent from its development [e.g., A81, A103, A122, and A221]. Also, two (nonstandard) maturity models in the study had development and validation described in separate articles [A20, A21, A130, and A131]. Consequently, the Design Science paradigm (see Section 3.2) delivers a useful contribution to the development of maturity models. The stated guidelines (see Table 1) offer a stringent perspective for researchers covering the three important elements of the framework above. While new maturity models are developed, they form an artifact (guideline 1) which ideally solves a relevant problem when used (guideline

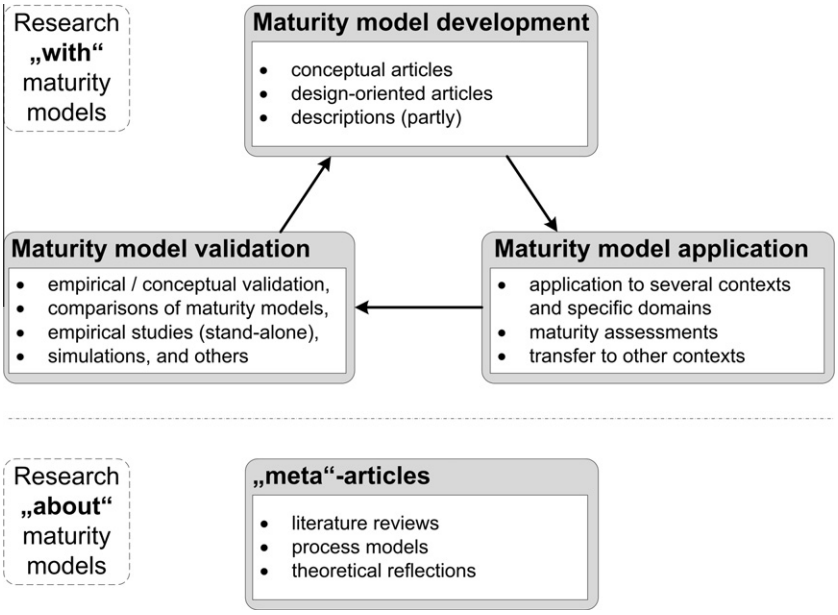

Fig. 18. Comprehensive research framework in maturity model research.

2). By applying and validating the models, researchers have to evaluate their design (guideline 3) and prove the contributions (guideline 4). Research Rigor (guideline 5) is assured by applying scientific methods during every step of the construction process. The illustration of the framework in form of a cycle shows that maturity model development is a process with iterations (guideline 6). Finally, publications out of this research process ensure the communication of the results (guideline 7).

Altogether, 48 articles in the study dealing with the construction of maturity models were based on a design-oriented approach. Nevertheless, there were still 69 articles based on a pure conceptual approach (see Fig. 6), covering only one aspect of the framework above. Hence, the ability of these models to fulfill their purpose is threatened and there is room to improve this kind of research (see Section 7.3 for a further discussion).

Moreover, as RQ9 revealed, "meta"-articles dealing with theoretical foundations of the maturity concept are scarce but have undergone a slight rise within the last 5 years (see Section 6.6). One year earlier, in 2004, Hansen et al. [A79] stated in their literature review that the field lacked theoretical contributions. This may be a positive sign that the research community has started to question and analyze why and under which circumstances maturity models can be successfully used. This may have a positive influence on validation possibilities for future research, as well.

7.3. Implications for research

The discussion above already indicates that certain research gaps currently exist. First of all, the theoretical reflections of the maturity concept are mostly missing. Between 1993 and 2006, the number of publications in maturity model research rose from three to 23 articles per year. However, theoretically motivated articles remained at 1 article per year at the most during the same period. Although a slight rise is recognizable in the last years, theoretical reflections are still under-represented (see Section 6.6). Such research may contain underlying theories [e.g., A141, A219], quality criteria for maturity models [e.g., A18], and hindering or supporting circumstances for successful usage [e.g., A205, A206].

Also, as stated in Section 6.5, many articles used CMMI as basis for new maturity models by adapting its structure and content. Although this procedure is principally right, it is critical that the scientific suitability of the used maturity model for the intended research purpose often remains unexamined. Researchers have to address the question of whether or not (industrial) maturity models are suitable for research purposes with regard to scientific requirements [11].

The high number of new model developments (46%, see Fig. 5) leads to a closely connected issue. Authors intending to develop new maturity models should carefully check if there are other solutions available. This has already been stated in the process model by Becker et al. [A18]. This mapping study underlines the importance of that issue. On the one hand, authors developed new maturity models without a careful review of existing models, which may serve their purpose, too. On the other hand, authors sometimes referred to other models (mostly CMMI) and transfered their structure and content without checking if this makes sense for their intended purpose (see Section 6.5). Thus, in both cases, the authors of new maturity models first have to analyze if there are existing models and then carefully check their applicability. This is important to improve quality and relevance of new model developments and to avoid unnecessary development expenditure. Examples where this procedure is well described are [A8, A56, and A57], among others. This study may deliver a good starting point when looking for existing models.

The analysis of applied research methods and designs delivered a varied picture. Many research methods were used in different designs (see Section 6.3). However, there were still 24 articles without a recognizable research design and even 43 articles with no research method at all (see Fig. 6). Although the majority within these articles dealed with descriptions of maturity models, this issue is still critical, because the mapping study included only academic publications. Authors should pay attention to make use of rigorous methods (see Section 7.2) to increase the scientific and replicable nature of the outcome, whether it is a new maturity model, a comparison of existing models or others.

Looking at the developed maturity models, it turned out that the majority of them were based on a conceptual design (see Figs. 6 and 8). Although a conceptual development is often appropriate, demonstrating the usefulness of the developed model is inevitable. However, Fig. 7 illustrates that empirical or other demonstration

methods were rarely used within a conceptual design. In addition, none of the 56 conceptually developed maturity models was validated (see Fig. 9). For improvements in future research, the introduced comprehensive research framework (see Fig. 18) and the principles of design science (see Sections 3.2 and 7.2) are a useful contribution to guide researchers in their actions. The conscientiousness accompanied with such a procedure, is noticeable within the design-oriented articles included in the study. Every one of these articles had at least one scientific method applied (see Fig. 7) and included empirical content for application and/or validation purposes (see Fig. 6). Hence, future research should intend to apply and validate existing and further maturity models in order to assure their suitability and relevance, especially when practical application is the stated research purpose.

However, the question how to validate a maturity model appropriately is very difficult. The study revealed a clear focus on qualitative methods like case studies and interviews. One third of the validated models included quantitative surveys. A combination of both was only used with 3% of the models (see Fig. 10). The presented examples in Section 6.4 show that there is no "ideal" validation method. However, a combination of multiple methods in different research states seems recommendable. Such course of action ensures to include empirical data at early research stages, for instance by conducting piloting workshops or interviews, and therefore improve the suitability of the developed maturity model (see for instance [A130, A131, and A233]). Ongoing validation may take place while using the maturity models in real environments to test its applicability and search for improvements. Depending on the context both qualitative and quantitative methods are able to deliver useful results (see for instance [A20, A21, A172, and A184]). On the whole, qualitative methods are important to deeply understand the object of research, but a combination with quantitative approaches has the potential to deliver generalized insights.

7.4. Implications for practice

The answer to RQ8 stated that the maturity model concept was mainly used in software development and software engineering. Nevertheless, the study identified 17 additional application domains with at least three articles, as well as 30 further individual domains which are grouped into others (see Fig. 13). This shows a very broad and general applicability of the maturity concept. It is likely that practitioners may find an available maturity model for their problems and assignments, where this study serves as a possible starting point.

When applying maturity models, practitioners can fall back on well validated models. Due to the fact that the most used validation methods are case studies (see Fig. 10), they can compare the contexts with their own situation and therefore ensure the suitability of the chosen model.

However, practitioners must be aware that many of the identified maturity models lack sufficient validation (see Section 6.4). So, on the one hand, they have to pay attention to the individual context when using these models; but on the other hand, they can contribute to ongoing research by providing new cases for empirical validations.

7.5. Limitations

The conducted systematic mapping study suffers from some limitations. First, the selection process of articles for the study causes the exclusion of certain publication types. As stated in Section 4.2, the study aims at analyzing research activities especially. Therefore literature was included selectively by focusing on journals and international conferences. It is conceivable that research parts, for instance applications of developed models, are published in working papers or other forums. But in these cases it is assumed that this research is still in progress and will eventually be published in journals or conference proceedings. Furthermore, there exist conferences dealing with very specialized topics in maturity model research which were excluded, too. These restrictions support the research aim of the study but are still a threat to completeness.

The focus on research articles is also the reason for the relatively small proportion of standardized and industrial maturity models. It cannot be denied that such models have a huge influence in practice, but to include them directly would change the aims and scope of this study.

The comprehensive selection of included databases resulted in a huge set of potentially relevant articles. The number of articles finally analyzed (237) is still huge. It is assumed that this set is representative and sufficient for the study aim. Therefore, no backward search in the references of the included articles was conducted.

8. Conclusion and outlook

The presented mapping study analyzed the field of maturity model research. Out of 2019 initially found articles, 237, reaching from 1993 to 2010, were finally included in the study. The developed classification scheme allowed a systematic and reproducible mapping of the articles. It is the first comprehensive representation of the maturity model research field and builds a reference basis for further research activities. The study revealed an ongoing and rising interest in the maturity topic. Maturity models are not limited to the domain of software development, but are rather generally applicable.

The study analyzed the content of the included articles, research designs, and methods; it also took a closer look on maturity model development and validation, and examined current research trends. The analysis resulted in the identification of the state-of-the-art research and discovered important research gaps. Furthermore, implications were deduced to give advice for further research and usage of maturity models. In addition, it was possible to structure the field of maturity model research into four main topic areas that formed a comprehensive research framework, covering maturity model development, application, validation, and meta-articles.

Main implications for future research include a need for more work about theoretical issues, quality criteria, etc. (meta-articles) for the maturity model concept. Furthermore, researchers should carefully search for existing models before developing new ones on the one hand, and take care to examine the suitability of existing models for the intended purpose on the other hand. Another basic critique forms the relatively high number of conceptually developed maturity models without any validation at all. A comparison with design-oriented model developments showed a number of improvements to enhance the quality of new maturity models.

The discussion of results and the deduced implications revealed that the structure of the deduced research framework is closely connected to the design science paradigm. Therefore, the framework offered a stringent perspective on the development of maturity models, which could only be recognized in a portion of the analyzed literature. The framework ensures a systematic approach guiding research in the field of maturity models and enables the inclusion of empirical as well as conceptual elements. Researchers may orientate themselves towards the framework while planning the strategy, methods and steps for their projects.

Due to the limitations of the study, future research may complete the literature basis. The classification scheme can easily be

applied to new publications, other publication types, or specialized topics in maturity model research that were excluded in this study. Therefore, an ongoing update of the mapping is unproblematic. Such an update is worth striving for due to the possibility that "younger" maturity models are applied and validated at a later time than this study took place.

Furthermore, it would be interesting to systematically compare existing maturity models regarding structures, contents, underlying theories, assumptions, and processes. The results may be useful as quality indicators, which have to be prevalent when developing maturity models. Such a comparison may not necessarily be limited to research activities and may include industrial and standardized models, if manageable.

Appendix A. Complete list of all articles included in the mapping study

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Appendix B. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.infsof.2012.07.007.

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