Do Procedure Models Actually Guide Maturity Model Design? A Citation Analysis

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Abstract

More than a decade ago, guidelines for the development of maturity models were proposed in the form of procedure models. In theory, such procedure models provide scholars with guidance, but does the scientific community actually use them according to their intended purpose. This paper conducts a citation analysis and identifies an impressive number of citations. However, it is noteworthy that the publications are mainly cited for other reasons, such as the components or the general purposes of maturity models. The analysis also provides indications that many maturity models are developed without using a procedure model. Despite the fact that methodological rigor is considered a crucial criterion for publishing articles, maturity model designers might have concerns about using domain-specific procedure models. Future studies should address the reasons for this reluctance.

Keywords: Maturity model, Procedure model, Digitalization, Industry 4.0, Citation analysis.

1. Introduction

Ongoing digitalization and the related Industry 4.0 represent an area characterized by unpredictable dynamics that continuously change the status quo (Verhoef et al., 2021). This has a considerable impact on business processes, leading to a transformation in organizations (Bley, 2021; De Carolis et al., 2017b; Leyh et al., 2017; Schmidt et al., 2017). Maturity models can contribute to this organizational transformation and capability renewal by initiating and accompanying change processes (Colli et al., 2019; Mettler et al., 2010; Solli-Sæther & Gottschalk, 2010; Trautmann, 2021). They can be useful in determining the organization's current state, providing improvement measures, and conducting cross-organizational comparisons (Felch et al., 2019; Pöppelbuß & Röglinger, 2011). For years, maturity models, including those relating to digitalization and Industry 4.0, have received great attention in both academia and business practice (Bley, 2021; Gökşen & Gökşen, 2021; Pöppelbuß et al., 2011; Pöppelbuß & Röglinger, 2011; Wendler, 2012). Despite their importance, several researchers have criticized the arbitrary development process of maturity models focusing on digitalization and Industry 4.0 (e.g., Caiado et al., 2021; Nottbrock, 2021). This issue is by no means new; almost two decades ago, maturity models, in general, were already criticized for their quality, particularly the development process. Insufficient documentation (Becker et al., 2009; Pöppelbuß & Röglinger, 2011), a lack of scientific rigor (Maier et al., 2012; Rosemann & De Bruin, 2005; Solli-Sæther & Gottschalk, 2010), and "a certain arbitrariness" (Becker et al., 2009, p. 214) were criticisms raised at that time.

Considering that the literature back then provided insufficient guidance on how to design maturity models, de Bruin et al. (2005) proposed an initial procedure model in 2005. Subsequently, other procedure models, such as those by Becker et al. (2009), Maier et al. (2012), Mettler (2010), Solli-Sæther and Gottschalk (2010), or van Steenbergen et al. (2010), followed, suggesting similar steps necessary to develop a maturity model. The guidelines aim to support a purposeful design and ensure scientific rigor to publish more transparent and substantiated maturity models. They can be applied regardless of the research area addressed by the maturity model. The target audience for such models, apart from consultants and industry experts, is mainly researchers, as the use of adequate methods is required by common scientific principles and in peer-review processes (Bornmann et al., 2008). Despite these domain-specific procedure models, other generic research guiding methodologies exist. More than a decade ago, de Bruin et al. (2005) and Becker et al. (2009) pointed out that only future studies can measure the impact of procedure models on the maturity model community and whether the guidelines prove to be effective and useful. In addition to the renewed criticism regarding the development process of models addressing digitalization and Industry 4.0,

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Pereira and Serrano (2020, p. 162) recently stated that "[…] authors still do not adopt these methods". However, apart from this anecdotal evidence, no systematic analysis of procedure models' impact has been conducted. The paper at hand responds to this call for an evaluation. Thus, the research question is:

Are the procedure model publications actually used for their intended purpose, i.e., as guidance for maturity model design?

This paper contributes to the methodological aspects of maturity model research (cf. Pöppelbuß et al., 2011). The findings of the article create awareness of the fact that, thus far, these guidelines have rarely been used for developing maturity models. Several research streams arise from the obtained results, including (1) evaluating the suitability and (2) gathering data on the user-related requirements of procedure models and other research methodologies for maturity model development.

The remainder of the article is structured as follows: The next section provides a rationale for the relevance of research methodologies, particularly procedure models, and describes how to measure an article's impact on the scientific community. Subsequently, data collection and processing are described, followed by the presentation of the results. The paper concludes with its contribution to the field.

2. Motivational background

It is crucial to discuss whether research methodologies, such as procedure models, are needed in the first place (Section 2.1) before outlining how the impact of an article can be measured (Section 2.2).

2.1 Are procedure models really needed?

Choosing the appropriate research methodology is one of the most important decisions for scholars, as it affects the quality of their research and the chance of publication in high-quality outlets (Straub, 2009). Research methodology is understood to be a logically structured process consisting of a sequence of different steps that enable designing and conducting research (Crotty, 1998). Procedure models depict such a systematic process for the development of maturity models (Pereira & Serrano, 2020). The application and documentation of the research guiding methodology help scholars conduct more rigorous research that can be perceived as such by reviewers and editors (Rosemann & Vessey, 2008). In addition, the application and subsequent disclosure of the methodology increase the transparency of the research process, which, in turn, is a strong indicator of the reproducibility and replicability of the results (Aguinis et al., 2018; Campbell et al., 2014). Therefore, the use of appropriate methodologies and methods is included in the most common scientific principles (Canadian Institutes of Health Research, Natural Sciences and Engineering Research, Social Sciences and Humanities Research Council of Canada, 2016; Deutsche Forschungsgemeinschaft, 2019; National Academy of Sciences, 2009; UK Research Integrity Office, 2009) that are decisive criteria of peer-review processes. Consequently, the research methodology can be considered a mechanism for quality assurance in research.

When selecting the underlying research methodology, special attention should be given to its appropriateness, i.e., its suitability for the intended purpose (Walker, 1997). Since some research domains have their idiosyncrasies, it can be useful to develop domain-specific research methodologies (Davies et al., 1999; Denyer & Tranfield, 2009; Durach et al., 2017). The domain of maturity models is characterized by such idiosyncrasy as the fact that they prescribe a linear, predefined sequence of steps to reach an ideal end state (Becker et al., 2009; Fraser et al., 2002; Pöppelbuß & Röglinger, 2011). Maturity models constitute practical solutions for organizations. They enable companies to continuously improve their performance and increase their ability to remain competitive. Furthermore, maturity models contain dynamic elements to be able to adapt to new circumstances, e.g., new scientific findings or technological changes, and, thus, remain their model relevance (Becker et al., 2009; Maier et al., 2012; Mettler, 2010). These idiosyncrasies justify the engagement of various researchers, such as de Bruin et al. (2005) and Becker et al. (2009), with epistemological assumptions and the development of procedure models as a domain-specific methodology intended to support designers in creating solid and substantiated maturity models.

In general, research aims to propose a solution for a particular concern or problem (Creswell & Creswell, 2018; Kothari, 2004; 2003). Subsequent to artifact development, the focus is on evaluating whether the concern or problem was actually solved or at least improved by the artifact (Rosemann & Vessey, 2008). This ex post evaluation involves comparing the preset objective with the actual observed results of using the artifact. The alignment between the problem and artifact can, in turn, provide an impetus for subsequent iterations to improve the artifact. Although procedure models have been available for years and a retrospective consideration of the articles' impact has been called for (cf. Becker et al., 2009; De Bruin et al., 2005), such an analysis is still lacking. The paper at hand responds to this call for an evaluation. The

Table 1. Citations retrieved and selection process

	B09	D05	M12	S10	V10	Σ
Initially retrieved citations	77	378	135	50	68	708
Exclusion of						
Non-English citations	16	15	2	1	2	36
Non-academic citations	0	0	1	0	0	1
Duplicates within database	1	1	1	0	1	4
Self-citations	1	0	5	1	6	13
Non-accessible citations	3	6	3	1	0	13
Missing in-text citations	0	2	1	0	2	5
Finally selected citations	56	354	122	47	57	636

following section addresses how an article's impact can be measured.

2.2 Reflection on citation analyses

Citation analyses are frequently performed to measure a publication's impact on the scientific community (Bornmann, 2011; Lowry et al., 2007; Recker & Mendling, 2016). They are based on the number of times an article has been cited by other works (Lowry et al., 2007; Meho, 2007). In the long term, articles perceived as useful by the community are used and cited more often, while articles considered less useful are referenced more seldom (Lowry et al., 2007). Consequently, "[…] papers with more citations are considered significantly more influential than articles with fewer citations" (Nyam et al., 2020, p. 6).

Often, each citation of an article is considered to be of equal value (Mettler & Ballester, 2021; Rüdiger et al., 2021). In recent years, doubts about this view and the mere consideration of an article's citation count have been raised (e.g., Mettler & Ballester, 2021; Rüdiger et al., 2021). Instead, it is suggested that the citation type be considered in more detail. Various approaches have already been proposed in the literature (cf. Anderson & Lemken, 2020; Bornmann et al., 2020; Rüdiger et al., 2021; Zhang et al., 2013). As an example, the value of the citation can be determined by assessing the location, frequency, or even style of the citation in an article (Rüdiger et al., 2021; Zhang et al., 2013). Additionally, a citation context analysis can be performed (Anderson & Lemken, 2020; Bornmann et al., 2020), which involves extracting the content to which the citing author(s) refer. Thus, it can be concluded whether, for example, the referenced content refers to the main research focus of the cited article. Such detailed classification can improve conventional citation analysis (Rüdiger et al., 2021) and allow more precise conclusions to be drawn regarding the phenomenon of interest, i.e., an article's impact on the community.

To conduct the retrospective analysis of procedure model articles and understand how such models have shaped the academic discourse, the study at hand relies on a citation context analysis. The findings are presented in the following paragraph.

3. Citation context analysis of procedure model publications

Summarizing the current research streams in maturity model research, Patas et al. (2013) mentioned six procedure models released by the following authors: (1) Becker et al. (2009, B09), (2) de Bruin et al. (2005, D05), (3) Maier et al. (2012, M12), (4) Mettler (2010, M10), (5) Solli-Sæther and Gottschalk (2010, S10), and (6) van Steenbergen et al. (2010, V10). Using citation context analysis, the impact of these six articles on the maturity model community is determined. The process and results of the analysis are presented in the following sections.

3.1 Citation context analysis: method

Scopus or Web of Science databases are recommended for retrieving the citation data (Nunhes & Oliveira, 2020; Waltman, 2016). Since two of the six procedure model articles (D05, M10) are not listed in Web of Science and just one paper (M10) is not included in Scopus, the latter was used. A total of 708 citations (as of November 2021) were identified that reference one of the five remaining publications (see Table 1). Next, the search results were screened using six criteria. For example, citations not published in English were excluded from further consideration. In this way, the number of citations was reduced to 636, distributed among 517 individual articles from various areas, e.g., process and innovation management, service engineering, and e-collaboration (see

Appendix B). The majority of articles (421) cite one procedure model publication, while only 20 articles cite between three and five publications (see Table 2). The consideration of the citation count shows that D05 (354 citations) and M12 (122) have been cited most frequently, followed by V10 (57), B09 (56), and S10 (47) (see Table 1). To account for different publication dates and allow better comparability, the average citations per year are calculated (see Appendix A). Again, D05 (19.7 citations per year) and M12 (11.1) show the highest values. More than half of all citations, namely, 391, were gathered in the last five years (2017–2021). In 2020, in particular, citations increased considerably for all five articles (see Appendix A).

Table 2. Number of cited procedure model publications within the articles

Number of cited procedure models	Number of articles	Cumulative percentage
5	0	0.0 %
4	3	0.6 %
3	17	3.9 %
2	76	18.6 %
1	421	100.0 %

In the following, the paper focuses on the context of those citations. The aim is to determine whether the five articles are cited for their main research focus, i.e., the procedure model for model development. First, the in-text citations were highlighted in each of the 517 articles. Special attention was given to the different citation styles, e.g., (last name of the author(s), year of publication) or [1], but also to spelling errors within the citations to include all in-text citations accordingly. A total of 1,805 in-text citations were identified. On average, each of the 517 articles has 3.5 in-text citations. Second, MAXQDA 2022 was used to analyze the in-text citations for their respective purpose to classify them into one of the following categories: citations placed for (C1) applying the procedure model for maturity model development, (C2) discussing/comparing the procedure model(s), or (C3) serving another purpose. C1 citations refer to a partial or full application of at least one procedure model for model design, whereas C2 citations refer to at least two models discussing their differences. C3 citations address a textual aspect beyond the procedure models, e.g., the relevance or definition of maturity models. Due to the interpretative nature of natural language, the classification of the in-text citations was not automatically performed based on certain preset rules. Instead, they were classified manually. For accurate classification, the assumption was followed: "[…] words likely to describe the use of the cited publication occur close to the citation, whereas words further away are less likely to describe the cited paper" (Rüdiger et al., 2021, p. 9785). Accordingly, in addition to the sentence in which the citation is located, the preceding and following sentences were considered (cf. Bornmann et al., 2020). When this did not lead to an unambiguous classification, the entire paragraph containing the citation was examined. Articles with more than one in-text citation were assigned to more than one category. For example, the article by Wißotzki and Koç (2013, p. 297) refers to the criticism stated by B09 (classified in C3): "The models have a poor theoretical basis and they are not well-documented". Furthermore, they apply B09's procedure model for their maturity model design (classified in C1): "The maturity model development process (MMDP) proposed in this paper is based on the maturity model development procedure of Becker et al. [29] and is illustrated in Figure 3" (Wißotzki & Koç, 2013, p. 300).

3.2 Citation context analysis: results

The classification results show that a minority of in-text citations, namely, 173 (9.6 %), are assigned to C1 and thus to the main research focus of the publications (see Table 3 and Appendix B). Only 109 articles apply at least one of the five procedure models to actually develop a maturity model. An illustrative example of classifying into C1 is "Steenbergen et al. (2010) provides guidelines for the development of maturity models, and recommends comparison with existing models, followed by an iterative procedure to define focus areas and capabilities, starting from literature, including expert input and possibly surveys in order to obtain a generally agreed model. This procedure is followed in the design of the PCMM" (Hermans et al., 2014, p. 1307). C2 accounts for 446 in-text citations (24.7 %), distributed among 181 articles. These publications include, for example, Wißotzki and Koç (2013) and García-Mireles et al. (2012), who compare the different procedure models, including B09 and D05, in tabular form. However, a total of 1,186 in-text citations (65.7 %) contained in 446 articles are assigned to C3 ('other purposes'). Thus, the citing articles do not reference the procedure model publications predominantly for their main research focus. The most frequent citation purposes that relate to C3 are the components of maturity models (234 in-text citations, e.g., Lahrmann & Marx, 2010), the general purposes of maturity models (185, e.g., Adrodegari & Saccani, 2020; De Carolis et al., 2017a), and criticism regarding maturity models (100, e.g., Frick et al., 2013; Proença & Borbinha, 2016).

Citations tracked shortly after releasing the procedure model publications are classified into either C2 or C3 (see Appendix C). Presumably, due to the time-intensive model development process, the first applications of procedure models (B09 and D05) were recorded in 2011. In recent years, a marginal decline in citations can be observed for C1. Meanwhile, C2 remained at a constant level, while citations in C3 increased considerably.

Table 3. Number of in-text citations by category

	B09	D05	M12	S10	V10	Σ
C1	32	101	23	8	9	173
C2	68	265	58	36	19	446
C3	81	655	267	84	99	1,186
Σ	*181*	*1,021*	*348*	*128*	*127*	*1,805*

A more detailed analysis of C1 shows that D05's procedure model was by far the most frequently used among the citing articles (75). This is followed in descending order by B09 (18), M12 (10), V10 (7), and S10 (6) (see Appendix D). A total of 103 of the 109 articles applied one procedure model for model design. Five articles (Antonsen & Madsen, 2021; Siedler et al., 2021; Smits & van Hillegersberg, 2014, 2015; Thordsen & Bick, 2020) use a combination of two procedure models, while one paper (Jin et al., 2014) combines three models.

Additionally, to assess the influence of the procedure model publications, the number of maturity models developed with a procedure model (109) needs to be compared with the number of models released to date. The results are positioned in the context of digitalization and Industry 4.0 as an area characterized by unpredictable dynamics that continuously change what can be considered the status quo (Verhoef et al., 2021). To successfully cope with this organizational transformation, maturity models focusing on digitalization and Industry 4.0 have emerged as useful tools (Bley et al., 2020). The comprehensive review by Caiado et al. (2021) identified a total of 24 models, of which only 5 (Asdecker & Felch, 2018, Rübel et al., 2018, Schumacher et al., 2016, Scremin et al., 2018, Weber et al., 2017; 20.8 %) rely on a procedure model for model design (see Table 4 and Appendix E).

The remaining 19 articles do not report using other generic frameworks, procedure models, or research methodologies that aid in developing artifacts, such as design science research, to create their maturity model. Instead, these papers focus on the various methods used to develop, evaluate or validate the model (see, for example, Bibby & Dehe, 2018; Oleśków-Szłapka & Stachowiak, 2019; Zheng & Ming, 2017). Only a few articles refer to particular principles, such as a comparison of existing maturity models (e.g., Akdil et al., 2018; Bibby & Dehe, 2018; Canetta et al., 2018; Gökalp et al., 2017), on which the procedure models are also built. However, a generic research methodology for model development is not made explicit. As already highlighted in section 2.1, disclosing the research methodology leads to a more rigorous and transparent research process (Aguinis et al., 2018; Campbell et al., 2014; Rosemann & Vessey, 2008). However, a reason for hiding may be that the chances of publication in higher quality outlets are simultaneously affected, as already noted by Alexander (1964, p. 8): "The use of logical structures to represent design problems […] brings with it the loss of innocence. A logical picture is easier to criticize than a vague picture since the assumptions it is based on are brought out into the open. Its increased precision gives us the chance to sharpen our conception of what the design process involves."

Table 4. Overview of applied research methodologies

	Maturity model by
Procedure model	Asdecker and Felch (2018), Rübel et al. (2018), Schumacher et al. (2016), Scremin et al. (2018), Weber et al. (2017)
Other research methodology	-
No explicit reference	Akdil et al. (2018), Bibby and Dehe (2018), Canetta et al. (2018), Castor et al. (2016), De Carolis et al. (2017a), Ganzarain and Errasti (2016), Gökalp et al. (2017), Jung et al. (2016), Katsma et al. (2011), Leineweber et al. (2018), Leyh et al. (2016), Lichtblau et al. (2015), Oleśków-Szłapka and Stachowiak (2019), Pessl (2017), PricewaterhouseCoopers (2018), Qin et al. (2016), Rockwell Automation (2014), Wang et al. (2016), Zheng and Ming (2017)

The finding on the application frequency of procedure models is further supported by Felch and Asdecker (2022), who concluded that out of 25 articles releasing a business process maturity model, only two refer to such procedure models. Various researchers, such as Pöppelbuß et al. (2011), Lasrado et al. (2016), and Pereira and Serrano (2020), emphasize that the

development of new models is often based on existing models instead of domain-specific methodologies. Altogether, the results indicate that the number of maturity models developed with a procedure model is considerably lower than the number of maturity models released thus far. Therefore, the impact of the procedure model publications on the scientific community can be considered moderate.

4. So what? Contributing to a research agenda

This research used citation context analysis to evaluate the impact of procedure models on the scientific community. It turns out that such models were often not cited for their intended purpose. To gain an understanding of how widespread the use in the model development actually is, digitalization and Industry 4.0 maturity models were analyzed. Two things became apparent: (1) Very few of these models referred to a scientifically recognized development methodology; and (2) in the rare case in which a methodology is applied, it is a procedure model. This rather surprising finding raises several new questions that form the basis of a research agenda. Due to the limited space, only the three most intriguing ones are addressed in the following.

First, the results of the study are considered in the context of digitalization and Industry 4.0. It would be interesting to know whether these findings are a peculiarity of this area or can be generalized. In addition, it raises the question of whether different generic frameworks or research methodologies are used in the other areas of which future digitalization or Industry 4.0 models could benefit. Thus, two important research leading questions are as follows:

- Which methodologies for maturity model development are used in other areas?
- Which parallels can be drawn with the results achieved thus far?

Second, despite the idiosyncrasies of maturity models and the suggestion of domain-specific research methodologies, the study's insights reignite the discussion about the necessity of procedure models. It should be questioned whether domain-specific research methodologies are necessary in this case. Furthermore, the question arises whether other research methodologies have the potential to better serve the intended purpose, namely, the development of solid and rigorous digitalization and Industry 4.0 maturity models. This leads to the following research guiding questions:

- Are the current domain-specific approaches even necessary?
- Are there (better) alternatives to procedure models?

Third, the perspective of maturity model designers has been neglected thus far, despite being crucial for the dissemination and success of such guidelines. It would be interesting to know how the procedure models are perceived by the digitalization and Industry 4.0 community. To derive possible adjustments for the procedure models or other guiding research methodologies, or even to establish a new approach, it is necessary to shed light on the phases of an application (model selection, deployment preparation, model application). Three essential research guiding questions are, therefore:

- Are procedure models perceived at all by the developers of digitalization and Industry 4.0 models? And if so, how?
- Which criteria are considered to decide for or against applying a procedure model?
- Which problems are encountered during the preparation and application of procedure models?

The proposed research streams do not represent an exhaustive list. Rather, they highlight relevant aspects to unfold the potential of the dynamic, ever-growing area of digitalization and Industry 4.0 models.

5. Conclusion

The paper at hand evaluates the impact of procedure model articles published years ago and thus takes a critical view of the designed artifacts. The derived research agenda formulates specific research guiding questions to further address the initial problem of the arbitrary development process of digitalization and Industry 4.0 maturity models, thus advancing the area accordingly. The proposed research streams guide future efforts of researchers to specific priorities arising from identified opportunities and challenges.

What can fellow researchers take away from these findings? First, it may be worthwhile to apply a procedure model for model design, regardless of whether it is the best methodology. The comparison with the values of Felch and Asdecker (2020) shows that the average impact factors of articles that refer to a procedure model (C1, Reuters Index: 4.3, H Index: 65.1, SJR: 0.9) are higher, implying that these are published in higher-quality outlets. Second, it can be useful to develop domain- and area-specific procedure models that address the peculiarities of individual areas, including digitization and Industry 4.0. Similar approaches can be found in systematic literature reviews that are both generic (e.g., vom Brocke et al., 2009) and area specific (e.g., for SCM by Durach et al., 2017). Third, this paper contributes to the

discussion on the mere consideration of an article's citation count. The results reinforce the extension of conventional citation analysis by taking a closer look at the citation type, especially the citation context. Despite the promising potential of citation context analysis, this work is the first to apply the approach to the maturity model domain. Other scholars can adopt this approach to conduct in-depth evaluations of the intended use of other research methodologies, such as those applied in action or design science research.

A limitation of the paper is that just one database, namely, Scopus, was used to retrieve the citation data. Using multiple databases, e.g., combining the citation data of Scopus and Web of Science, would, at first glance, result in a more comprehensive overview. However, since not all five remaining articles are listed in both databases (see section 3.1), this approach would lead to a biased presentation of the results and, thus, does not constitute a more rigorous approach. For this reason, the paper at hand focused on the most comprehensive database, which contains a broad spectrum of journal and conference articles from almost all disciplines. In addition, other procedure models (e.g., Mettler, 2010) exist, but their impact on the community was not considered in this case. However, the approach described in the article can be adopted for other guidelines. Beyond that, it should be pointed out that citation (content) analysis is only one indicator to measure an article's impact. Future studies should also consider other indicators to further validate the article's results. Finally, it should be noted that due to a lack of standardized terminology, a potential selection bias might occur regarding the procedure models. To address this issue, the 24 maturity models were analyzed regarding any type of development methodology. In the absence of any other approach, the sample can be considered appropriate. Despite these limitations, the paper contributes to raising awareness about the limited application of procedure models, originally intended to eliminate criticism regarding the model development process and to increase their quality in the long term.

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7. Appendix

Due to page restrictions, the Appendix can be found using the link:
→ https://doi.org/10.6084/m9.figshare.21130169.v1